The Eyes as a Window to Auditory Processing and Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

This symposium touches on key issues in systems and cognitive neuroscience and audiology and should therefore be of interest to the broad ARO community. We expect to attract those who are already using pupillometry in their work, and those who might be interested to add it to their

toolkit.

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

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Etienne	Gaudrain	Lyon Neuroscience Research Center, CNRS UMR5292, Inserm U1028, UCBL, UJM, Lyon, France
Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry has recently emerged as a potential tool for estimating the mental effort associated with listening in adverse conditions. However, the absence of associations in the literature between the task-evoked pupil response (TEPR) and perceived effort cast some doubt over this interpretation. We present findings from two experiments showing that changes over time in TEPR during a taxing speech recognition task are associated with subjective tiredness, but not effort, ratings. These findings suggest that pupillometry is sensitive not just to varying levels of acoustic or attentional demand, but also to changes in perceived tiredness from listening that unfold over time.

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Alexandre	Marois	Thales Research and Technology Canada

Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Kang	Sun	Eriksholm Research Centre
Sébastien	Santurette	Oticon A/S
Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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First Name	Last Name	Affiliation
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Marianny	Pernia	University of Pittsburgh
Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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First Name	Last Name	Affiliation
Stephen *	David *	Oregon Health & Science University

Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

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Submitter Maria Chait

Affiliation UCL Ear Institute

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SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

consistent with monitoring for environmental change probability. The implications of these findings to our understanding of how the brain monitors for environmental statistics will be discussed.

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Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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Submitter Thomas Koelewijn

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry has recently emerged as a potential tool for estimating the mental effort associated with listening in adverse conditions. However, the absence of associations in the literature between the task-evoked pupil response (TEPR) and perceived effort cast some doubt over this interpretation. We present findings from two experiments showing that changes over time in TEPR during a taxing speech recognition task are associated with subjective tiredness, but not effort, ratings. These findings suggest that pupillometry is sensitive not just to varying levels of acoustic or attentional demand, but also to changes in perceived tiredness from listening that unfold over time.

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First Name	Last Name	Affiliation
Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Francois *	Vachon *	Université Laval
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Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

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Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Marianny	Pernia	University of Pittsburgh
Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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* Presenting Author

First Name	Last Name	Affiliation
Stephen *	David *	Oregon Health & Science University

Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

consistent with monitoring for environmental change probability. The implications of these findings to our understanding of how the brain monitors for environmental statistics will be discussed.

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* Presenting Author

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Maria *	Chait *	UCL Ear Institute
Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

This symposium touches on key issues in systems and cognitive neuroscience and audiology and should therefore be of interest to the broad ARO community. We expect to attract those who are already using pupillometry in their work, and those who might be interested to add it to their

toolkit.

** this is a re-submission (with some modification; 2 new presenters) of a symposium previously scheduled to take place during ARO2022. Unfortunately, we had to withdraw due to covid-induced impact on the availability of a large proportion of the original presenters.

Presenter Diversity Gender diversity: 3 women/5 men presenters. Consistent with field base rate.

Geographical diversity: 2 presenters from the UK, 2 from the EU (Netherlands and Denmark), 3 from the USA (2 East coast, 1 West coast), 1 from Canada. 3 of the presenters have not previously attended ARO.

Career status: Presenters cover the range from mid-career (MC, SD, FV) to early career (SK, TK, DW, SS, RM).

Research institution: 6 of the presenters work in universities (MC, SD, FV, TK, SS, RM), 1 of the presenters works in a medical research facility (SK, Walter Reed National Medical Center), 1 of the presenters works in an industry research institute (DW; Eriksholm, Oticon).

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Speech perception in multiple-talker listening conditions can be challenging and effortful especially in people with hearing impairment. Perceiving differences in voice cues like fundamental frequency (F0) and vocal-tract length (VTL) can help listeners segregate competing talkers, which improves speech understanding. Research showed that cochlear implant (CI) hearing and vocoding (simulating CI-hearing) reduce sensitivity to F0 and VTL voice cues, potentially contributing to difficulties in understanding speech in adverse listening conditions. Pupillometry has shown to be an objective measure for cognitive processing load in adverse listening conditions, also referred to as listening effort. Using a variety of listening tasks, studies have shown different types of speech degradation, by using different types of maskers (e.g., noise vs. speech) or vocoding, to affect the pupil dilation response. It is relatively unknown how voice perception processes, that make use of voice cue information, affect listening effort in adverse (e.g., vocoded and/or masked by speech) listening situations. This presentation will focus on the effect of voice discriminability on listening effort. In the presented studies, F0 and VTL voice cues were systematically manipulated while participants performed voice cue discrimination tasks (CVC-triplets) or speech-on-speech listening tasks (sentences), while stimuli were either clear or vocoded. The impact of voice training and vocoding on listening effort during voice cue discrimination and speech-on-speech listening was investigated by means of pupillometry. Our main hypothesis was that improvement in voice cue discrimination would lower listening effort. Together with performance outcomes, conventional Peak Pupil Dilation outcomes as well as more advanced time-based GAMM analysis outcomes will be discussed. These outcomes provide insight on the impact that voice discriminability and voice familiarity have on listening effort in normal and CI-listening.

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Etienne	Gaudrain	Lyon Neuroscience Research Center, CNRS UMR5292, Inserm U1028, UCBL, UJM, Lyon, France
Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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First Name	Last Name	Affiliation
Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Francois *	Vachon *	Université Laval
Alexandre	Marois	Thales Research and Technology Canada

Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Sébastien	Santurette	Oticon A/S
Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Marianny	Pernia	University of Pittsburgh
Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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First Name	Last Name	Affiliation
Stephen *	David *	Oregon Health & Science University

Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

consistent with monitoring for environmental change probability. The implications of these findings to our understanding of how the brain monitors for environmental statistics will be discussed.

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Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

This symposium touches on key issues in systems and cognitive neuroscience and audiology and should therefore be of interest to the broad ARO community. We expect to attract those who are already using pupillometry in their work, and those who might be interested to add it to their

toolkit.

** this is a re-submission (with some modification; 2 new presenters) of a symposium previously scheduled to take place during ARO2022. Unfortunately, we had to withdraw due to covid-induced impact on the availability of a large proportion of the original presenters.

Presenter Diversity Gender diversity: 3 women/5 men presenters. Consistent with field base rate.

Geographical diversity: 2 presenters from the UK, 2 from the EU (Netherlands and Denmark), 3 from the USA (2 East coast, 1 West coast), 1 from Canada. 3 of the presenters have not previously attended ARO.

Career status: Presenters cover the range from mid-career (MC, SD, FV) to early career (SK, TK, DW, SS, RM).

Research institution: 6 of the presenters work in universities (MC, SD, FV, TK, SS, RM), 1 of the presenters works in a medical research facility (SK, Walter Reed National Medical Center), 1 of the presenters works in an industry research institute (DW; Eriksholm, Oticon).

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Speech perception in multiple-talker listening conditions can be challenging and effortful especially in people with hearing impairment. Perceiving differences in voice cues like fundamental frequency (F0) and vocal-tract length (VTL) can help listeners segregate competing talkers, which improves speech understanding. Research showed that cochlear implant (CI) hearing and vocoding (simulating CI-hearing) reduce sensitivity to F0 and VTL voice cues, potentially contributing to difficulties in understanding speech in adverse listening conditions. Pupillometry has shown to be an objective measure for cognitive processing load in adverse listening conditions, also referred to as listening effort. Using a variety of listening tasks, studies have shown different types of speech degradation, by using different types of maskers (e.g., noise vs. speech) or vocoding, to affect the pupil dilation response. It is relatively unknown how voice perception processes, that make use of voice cue information, affect listening effort in adverse (e.g., vocoded and/or masked by speech) listening situations. This presentation will focus on the effect of voice discriminability on listening effort. In the presented studies, F0 and VTL voice cues were systematically manipulated while participants performed voice cue discrimination tasks (CVC-triplets) or speech-on-speech listening tasks (sentences), while stimuli were either clear or vocoded. The impact of voice training and vocoding on listening effort during voice cue discrimination and speech-on-speech listening was investigated by means of pupillometry. Our main hypothesis was that improvement in voice cue discrimination would lower listening effort. Together with performance outcomes, conventional Peak Pupil Dilation outcomes as well as more advanced time-based GAMM analysis outcomes will be discussed. These outcomes provide insight on the impact that voice discriminability and voice familiarity have on listening effort in normal and CI-listening.

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Ada	Biçer	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands
Etienne	Gaudrain	Lyon Neuroscience Research Center, CNRS UMR5292, Inserm U1028, UCBL, UJM, Lyon, France
Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry has recently emerged as a potential tool for estimating the mental effort associated with listening in adverse conditions. However, the absence of associations in the literature between the task-evoked pupil response (TEPR) and perceived effort cast some doubt over this interpretation. We present findings from two experiments showing that changes over time in TEPR during a taxing speech recognition task are associated with subjective tiredness, but not effort, ratings. These findings suggest that pupillometry is sensitive not just to varying levels of acoustic or attentional demand, but also to changes in perceived tiredness from listening that unfold over time.

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

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Sébastien	Santurette	Oticon A/S
Niels	Pontoppidan	Eriksholm Research Centre
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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

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First Name	Last Name	Affiliation
Stephen *	David *	Oregon Health & Science University

Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

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* Presenting Author

First Name	Last Name	Affiliation
Maria *	Chait *	UCL Ear Institute
Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Speech perception in multiple-talker listening conditions can be challenging and effortful especially in people with hearing impairment. Perceiving differences in voice cues like fundamental frequency (F0) and vocal-tract length (VTL) can help listeners segregate competing talkers, which improves speech understanding. Research showed that cochlear implant (CI) hearing and vocoding (simulating CI-hearing) reduce sensitivity to F0 and VTL voice cues, potentially contributing to difficulties in understanding speech in adverse listening conditions. Pupillometry has shown to be an objective measure for cognitive processing load in adverse listening conditions, also referred to as listening effort. Using a variety of listening tasks, studies have shown different types of speech degradation, by using different types of maskers (e.g., noise vs. speech) or vocoding, to affect the pupil dilation response. It is relatively unknown how voice perception processes, that make use of voice cue information, affect listening effort in adverse (e.g., vocoded and/or masked by speech) listening situations. This presentation will focus on the effect of voice discriminability on listening effort. In the presented studies, F0 and VTL voice cues were systematically manipulated while participants performed voice cue discrimination tasks (CVC-triplets) or speech-on-speech listening tasks (sentences), while stimuli were either clear or vocoded. The impact of voice training and vocoding on listening effort during voice cue discrimination and speech-on-speech listening was investigated by means of pupillometry. Our main hypothesis was that improvement in voice cue discrimination would lower listening effort. Together with performance outcomes, conventional Peak Pupil Dilation outcomes as well as more advanced time-based GAMM analysis outcomes will be discussed. These outcomes provide insight on the impact that voice discriminability and voice familiarity have on listening effort in normal and CI-listening.

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Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry has recently emerged as a potential tool for estimating the mental effort associated with listening in adverse conditions. However, the absence of associations in the literature between the task-evoked pupil response (TEPR) and perceived effort cast some doubt over this interpretation. We present findings from two experiments showing that changes over time in TEPR during a taxing speech recognition task are associated with subjective tiredness, but not effort, ratings. These findings suggest that pupillometry is sensitive not just to varying levels of acoustic or attentional demand, but also to changes in perceived tiredness from listening that unfold over time.

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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First Name	Last Name	Affiliation
Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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* Presenting Author

First Name	Last Name	Affiliation
Francois *	Vachon *	Université Laval
Alexandre	Marois	Thales Research and Technology Canada

Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Dorothea *	Wendt *	Eriksholm Research Centre
Kang	Sun	Eriksholm Research Centre
Sébastien	Santurette	Oticon A/S
Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Pilar	Montes-Lourido	University of Pittsburgh
Marianny	Pernia	University of Pittsburgh
Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Sustained pupil responses track the statistics of rapidly unfolding sounds.

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Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Speech perception in multiple-talker listening conditions can be challenging and effortful especially in people with hearing impairment. Perceiving differences in voice cues like fundamental frequency (F0) and vocal-tract length (VTL) can help listeners segregate competing talkers, which improves speech understanding. Research showed that cochlear implant (CI) hearing and vocoding (simulating CI-hearing) reduce sensitivity to F0 and VTL voice cues, potentially contributing to difficulties in understanding speech in adverse listening conditions. Pupillometry has shown to be an objective measure for cognitive processing load in adverse listening conditions, also referred to as listening effort. Using a variety of listening tasks, studies have shown different types of speech degradation, by using different types of maskers (e.g., noise vs. speech) or vocoding, to affect the pupil dilation response. It is relatively unknown how voice perception processes, that make use of voice cue information, affect listening effort in adverse (e.g., vocoded and/or masked by speech) listening situations. This presentation will focus on the effect of voice discriminability on listening effort. In the presented studies, F0 and VTL voice cues were systematically manipulated while participants performed voice cue discrimination tasks (CVC-triplets) or speech-on-speech listening tasks (sentences), while stimuli were either clear or vocoded. The impact of voice training and vocoding on listening effort during voice cue discrimination and speech-on-speech listening was investigated by means of pupillometry. Our main hypothesis was that improvement in voice cue discrimination would lower listening effort. Together with performance outcomes, conventional Peak Pupil Dilation outcomes as well as more advanced time-based GAMM analysis outcomes will be discussed. These outcomes provide insight on the impact that voice discriminability and voice familiarity have on listening effort in normal and CI-listening.

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Etienne	Gaudrain	Lyon Neuroscience Research Center, CNRS UMR5292, Inserm U1028, UCBL, UJM, Lyon, France
Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

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Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Kang	Sun	Eriksholm Research Centre
Sébastien	Santurette	Oticon A/S
Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Marianny	Pernia	University of Pittsburgh
Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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First Name	Last Name	Affiliation
Stephen *	David *	Oregon Health & Science University

Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

consistent with monitoring for environmental change probability. The implications of these findings to our understanding of how the brain monitors for environmental statistics will be discussed.

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Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

This symposium touches on key issues in systems and cognitive neuroscience and audiology and should therefore be of interest to the broad ARO community. We expect to attract those who are already using pupillometry in their work, and those who might be interested to add it to their

toolkit.

** this is a re-submission (with some modification; 2 new presenters) of a symposium previously scheduled to take place during ARO2022. Unfortunately, we had to withdraw due to covid-induced impact on the availability of a large proportion of the original presenters.

Presenter Diversity Gender diversity: 3 women/5 men presenters. Consistent with field base rate.

Geographical diversity: 2 presenters from the UK, 2 from the EU (Netherlands and Denmark), 3 from the USA (2 East coast, 1 West coast), 1 from Canada. 3 of the presenters have not previously attended ARO.

Career status: Presenters cover the range from mid-career (MC, SD, FV) to early career (SK, TK, DW, SS, RM).

Research institution: 6 of the presenters work in universities (MC, SD, FV, TK, SS, RM), 1 of the presenters works in a medical research facility (SK, Walter Reed National Medical Center), 1 of the presenters works in an industry research institute (DW; Eriksholm, Oticon).

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

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Etienne	Gaudrain	Lyon Neuroscience Research Center, CNRS UMR5292, Inserm U1028, UCBL, UJM, Lyon, France
Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

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SUBMISSION DETAILS

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

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SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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* Presenting Author

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Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Alexandre	Marois	Thales Research and Technology Canada

Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

consistent with monitoring for environmental change probability. The implications of these findings to our understanding of how the brain monitors for environmental statistics will be discussed.

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Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

This symposium touches on key issues in systems and cognitive neuroscience and audiology and should therefore be of interest to the broad ARO community. We expect to attract those who are already using pupillometry in their work, and those who might be interested to add it to their

toolkit.

** this is a re-submission (with some modification; 2 new presenters) of a symposium previously scheduled to take place during ARO2022. Unfortunately, we had to withdraw due to covid-induced impact on the availability of a large proportion of the original presenters.

Presenter Diversity Gender diversity: 3 women/5 men presenters. Consistent with field base rate.

Geographical diversity: 2 presenters from the UK, 2 from the EU (Netherlands and Denmark), 3 from the USA (2 East coast, 1 West coast), 1 from Canada. 3 of the presenters have not previously attended ARO.

Career status: Presenters cover the range from mid-career (MC, SD, FV) to early career (SK, TK, DW, SS, RM).

Research institution: 6 of the presenters work in universities (MC, SD, FV, TK, SS, RM), 1 of the presenters works in a medical research facility (SK, Walter Reed National Medical Center), 1 of the presenters works in an industry research institute (DW; Eriksholm, Oticon).

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Speech perception in multiple-talker listening conditions can be challenging and effortful especially in people with hearing impairment. Perceiving differences in voice cues like fundamental frequency (F0) and vocal-tract length (VTL) can help listeners segregate competing talkers, which improves speech understanding. Research showed that cochlear implant (CI) hearing and vocoding (simulating CI-hearing) reduce sensitivity to F0 and VTL voice cues, potentially contributing to difficulties in understanding speech in adverse listening conditions. Pupillometry has shown to be an objective measure for cognitive processing load in adverse listening conditions, also referred to as listening effort. Using a variety of listening tasks, studies have shown different types of speech degradation, by using different types of maskers (e.g., noise vs. speech) or vocoding, to affect the pupil dilation response. It is relatively unknown how voice perception processes, that make use of voice cue information, affect listening effort in adverse (e.g., vocoded and/or masked by speech) listening situations. This presentation will focus on the effect of voice discriminability on listening effort. In the presented studies, F0 and VTL voice cues were systematically manipulated while participants performed voice cue discrimination tasks (CVC-triplets) or speech-on-speech listening tasks (sentences), while stimuli were either clear or vocoded. The impact of voice training and vocoding on listening effort during voice cue discrimination and speech-on-speech listening was investigated by means of pupillometry. Our main hypothesis was that improvement in voice cue discrimination would lower listening effort. Together with performance outcomes, conventional Peak Pupil Dilation outcomes as well as more advanced time-based GAMM analysis outcomes will be discussed. These outcomes provide insight on the impact that voice discriminability and voice familiarity have on listening effort in normal and CI-listening.

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Etienne	Gaudrain	Lyon Neuroscience Research Center, CNRS UMR5292, Inserm U1028, UCBL, UJM, Lyon, France
Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry has recently emerged as a potential tool for estimating the mental effort associated with listening in adverse conditions. However, the absence of associations in the literature between the task-evoked pupil response (TEPR) and perceived effort cast some doubt over this interpretation. We present findings from two experiments showing that changes over time in TEPR during a taxing speech recognition task are associated with subjective tiredness, but not effort, ratings. These findings suggest that pupillometry is sensitive not just to varying levels of acoustic or attentional demand, but also to changes in perceived tiredness from listening that unfold over time.

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

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SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry shows great promise as a non-invasive method of measuring auditory thresholds in animal models. Previous studies have largely used simple stimuli such as pure tones. Here, in a guinea pig animal model, we used pupillometry in the context of an auditory oddball paradigm to estimate detection and discrimination thresholds to stimuli spanning a range of complexities (tones, vocalizations and tone clouds), across different stimulus contingencies (acoustic changes and categorical changes), and with or without reinforcement. To do so, we first obtained pupil dilation responses to a range of oddball stimuli that parametrically differed from standard stimuli. We then used growth curve analysis to fit these responses and evaluate whether oddball responses significantly differed from standard stimuli. Using this technique, we could obtain pupillometric discrimination thresholds across the wide variety of stimuli described above, which allowed us to characterize basic features of auditory detection and discrimination in guinea pigs. We further ascertained that pupillometric categorization-in-noise thresholds broadly agreed with thresholds obtained using operant behavioral training, underscoring the robustness of using the pupil dilation response as a metric of auditory detection and discrimination. In ongoing work, we are using pupillometry to probe some complex auditory deficits in a noise-induced temporary threshold shift model. These results lay the foundation for using pupillometry as a reliable method for comparing broad similarities between human and animal auditory processing.

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Manaswini	Kar	University of Pittsburgh
Isha	Kumbam	University of Pittsburgh
Madelyn	McAndrew	University of Pittsburgh
Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Correlated variability within neural populations, sometimes called noise correlation, substantially impacts the accuracy with which information about sensory stimuli can be extracted from neural activity. Previous studies have shown that changes in behavioral state, reflecting phenomena such as attention and/or arousal, can change correlated variability. However, the degree to which these changes impact neural encoding of sensory information remains poorly understood, particularly in the auditory system. To study this problem, we used linear arrays to record populations of single neurons in ferret auditory cortex while monitoring arousal via pupillometry. Spontaneous increases in arousal tended to decrease the overall degree of correlation. However, the decreased correlation did not consistently improve the accuracy of neural coding. Instead, changes in correlation occurred in a low-dimensional population subspace, and the alignment this space with sound-evoked responses determined its effect on sensory coding. These results establish a clear link between behavioral state and correlated neuronal variability. However, the changes appear to reflect processes that are not simply related to the accuracy of sensory coding.

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Stephen *	David *	Oregon Health & Science University

Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

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Maria *	Chait *	UCL Ear Institute
Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

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Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Session Description Over the last decade, Pupillometry (the measurement of pupil responsiveness and size) has attracted considerable attention in hearing research - both in the context of basic investigation into hearing function, and as a non-invasive, cheap and portable means for assessing listening challenges in patient populations.

Capitalizing on the well-known link between pupil responses and the brain networks that control vigilance and arousal, 'classic' work has focused on using pupil measures to quantify listening effort. However, recent developments in technology and understanding of the neural circuitry that controls pupil responses have prompted the expansion of pupillometry to multiple different domains of hearing research.

This symposium will highlight the range of questions that are currently being pursued with this technology. It will include work in both human and animal models, from 'low-level' effects of arousal on neural responses in auditory cortex to 'global' effects linked to perception and attention.

Presentations will span the domains of listening effort, learning, distractability and auditory scene analysis. We will discuss the relation between pupil-linked arousal and neural excitability as measured via electrophysiology in animal models; how pupil dilation responses can be used as a metric of auditory detection, discrimination and distraction in animals and humans; how tracking pupil dynamics reveals listeners' sensitivity to the statistical structure of rapidly unfolding auditory signals; and how pupil responses provide unique insight into the factors that affect listening effort, speech communication and learning.

This symposium touches on key issues in systems and cognitive neuroscience and audiology and should therefore be of interest to the broad ARO community. We expect to attract those who are already using pupillometry in their work, and those who might be interested to add it to their

toolkit.

** this is a re-submission (with some modification; 2 new presenters) of a symposium previously scheduled to take place during ARO2022. Unfortunately, we had to withdraw due to covid-induced impact on the availability of a large proportion of the original presenters.

Presenter Diversity Gender diversity: 3 women/5 men presenters. Consistent with field base rate.

Geographical diversity: 2 presenters from the UK, 2 from the EU (Netherlands and Denmark), 3 from the USA (2 East coast, 1 West coast), 1 from Canada. 3 of the presenters have not previously attended ARO.

Career status: Presenters cover the range from mid-career (MC, SD, FV) to early career (SK, TK, DW, SS, RM).

Research institution: 6 of the presenters work in universities (MC, SD, FV, TK, SS, RM), 1 of the presenters works in a medical research facility (SK, Walter Reed National Medical Center), 1 of the presenters works in an industry research institute (DW; Eriksholm, Oticon).

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Signature Maria Chait

The Eyes as a Window to Auditory Processing and Perception

What Can Pupillometry Tell Us about Voice Perception

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Thomas Koelewijn

Affiliation Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Speech perception in multiple-talker listening conditions can be challenging and effortful especially in people with hearing impairment. Perceiving differences in voice cues like fundamental frequency (F0) and vocal-tract length (VTL) can help listeners segregate competing talkers, which improves speech understanding. Research showed that cochlear implant (CI) hearing and vocoding (simulating CI-hearing) reduce sensitivity to F0 and VTL voice cues, potentially contributing to difficulties in understanding speech in adverse listening conditions. Pupillometry has shown to be an objective measure for cognitive processing load in adverse listening conditions, also referred to as listening effort. Using a variety of listening tasks, studies have shown different types of speech degradation, by using different types of maskers (e.g., noise vs. speech) or vocoding, to affect the pupil dilation response. It is relatively unknown how voice perception processes, that make use of voice cue information, affect listening effort in adverse (e.g., vocoded and/or masked by speech) listening situations. This presentation will focus on the effect of voice discriminability on listening effort. In the presented studies, F0 and VTL voice cues were systematically manipulated while participants performed voice cue discrimination tasks (CVC-triplets) or speech-on-speech listening tasks (sentences), while stimuli were either clear or vocoded. The impact of voice training and vocoding on listening effort during voice cue discrimination and speech-on-speech listening was investigated by means of pupillometry. Our main hypothesis was that improvement in voice cue discrimination would lower listening effort. Together with performance outcomes, conventional Peak Pupil Dilation outcomes as well as more advanced time-based GAMM analysis outcomes will be discussed. These outcomes provide insight on the impact that voice discriminability and voice familiarity have on listening effort in normal and CI-listening.

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Deniz	Başkent	Department of Otorhinolaryngology/Head and Neck Surgery, University Medical Center Groningen, University of Groningen, Netherlands

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Signature Thomas Koelewijn

The Eyes as a Window to Auditory Processing and Perception

Pupil Dynamics Underlying the Subjective Experiences of Effort and Tiredness from Listening

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Ronan McGarrigle

Affiliation University of Bradford

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Pupillometry has recently emerged as a potential tool for estimating the mental effort associated with listening in adverse conditions. However, the absence of associations in the literature between the task-evoked pupil response (TEPR) and perceived effort cast some doubt over this interpretation. We present findings from two experiments showing that changes over time in TEPR during a taxing speech recognition task are associated with subjective tiredness, but not effort, ratings. These findings suggest that pupillometry is sensitive not just to varying levels of acoustic or attentional demand, but also to changes in perceived tiredness from listening that unfold over time.

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Ronan *	McGarrigle *	University of Bradford

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Signature RMG

The Eyes as a Window to Auditory Processing and Perception

Interactions between Pre-Stimulus and Stimulus-Evoked Pupil Dilation Indices of Listening Engagement

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stefanie Kuchinsky

Affiliation Walter Reed National Military Medical Center

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Understanding speech in adverse conditions often requires substantial effort not only to listen to auditory stimuli. Listeners must also prepare and maintain the mental processes necessary to carry out listening task goals within and across trials, often termed a “task set.” With greater time-on-task, it can become particularly challenging to sustain task-set and stimulus-evoked mental processes, potentially leading to poorer performance and fatigue.

Changes in pupil dilation within pre-stimulus (baseline) and stimulus-evoked (time-locked to stimulus onset) epochs have been used to index the mental resources engaged by task-set preparation and stimulus processing, respectively, due to their close relationship with tonic and phasic activity in the locus coeruleus norepinephrine (LC-NE) system. Studies of listening effort have historically focused on the latter: examining the engagement of cognitive resources for processing an auditory stimulus. However, studies have also observed that pre-stimulus pupil size (PSPS) is sensitive to the difficulty of preparing for an upcoming listening trial and can be impacted by time spent performing a task.

In this talk, I will describe two studies with younger, normal-hearing listeners that investigated interactions between baseline PSPS and the stimulus-evoked pupil response within and across listening trials of varying lengths. In a study of Mandarin lexical tone learning, we observed significant reductions in pupil size across the trials of the experiment (indicative of word learning). Trials on which PSPS was larger were associated with even smaller word-evoked pupil responses. In a separate study that involved listening to 60-second stories, story-evoked pupil responses decreased over time within each story and across repetitions of each story within a block. PSPS reflected expectations about the upcoming signal-to-noise ratio (SNR) difficulty, which was observed to mediate SNR effects during the subsequent story-evoked pupil response.

Together, these studies demonstrate the importance of characterizing listening engagement across moment-to-moment and trial-by-trial changes in the processes that support speech processing and task-set maintenance.

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Stefanie *	Kuchinsky *	Walter Reed National Military Medical Center

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Signature Stefanie E. Kuchinsky

The Eyes as a Window to Auditory Processing and Perception

Eyes Have ears: Using Pupillometry to Index Attentional Capture by Irrelevant Sound

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Francois Vachon

Affiliation Université Laval

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The presence of task-irrelevant sound is known to impede cognitive functioning. For instance, the occurrence of unexpected irregularities in the auditory background tends to capture attention, hence disrupting performance. There is growing evidence that violations of acoustic regularities can also trigger a pupil dilation response (PDR). Here, we propose a systematic assessment of the PDR as a potential psychophysiological proxy for this form of distraction. Our strategy consisted in examining whether the PDR and attention capture share the same functional properties. Through a series of studies, we established that the PDR mimics an orienting response: the PDR showed a habituation/dishabituation pattern, was influenced by the size of the deviation but was not reliant on acoustic novelty, and was amenable to top-down cognitive control. Taken together, these findings indicate that the PDR to deviant sounds is a valid biomarker of attentional capture in the auditory domain.

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Alexandre	Marois	Thales Research and Technology Canada

Alessandro	Pozzi	Université Laval

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Signature François Vachon

The Eyes as a Window to Auditory Processing and Perception

Evoked Pupil Response to Investigate the Effect of Salient Distractors on Attentional Effort Allocation

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Dorothea Wendt

Affiliation Eriksholm Research Centre

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract Listeners with normal hearing can direct their attention towards a particular talker of interested and are usually able to ignore another talkers, which is referred to as top-down – or intentional attention. However, bottom-up or automatic attentional processes might capture the attentional focus through salient interruptions. The potential strength of a sound to capture attention is referred to as auditory saliency. In particular people with hearing impairment frequently report environmental sounds to be disturbing and annoying especially when they are of a transient type. This talk will present findings of ongoing investigations about the impact of salient sounds (distractors) on the attentional resource allocation during speech understanding. Specifically, we were interested in the impact of hearing impairment as well as the timing of a distractor (i.e., when distractors is presented before, while or after the target speech) on attentional resource allocation using pupillometry. We hypothesized that the distractibility can be measured from the distractor-evoked pupil response, which suggests a disruption of intentional attention and the effort to restore attention to the target. It is hypothesized that hearing impairment increases this distractibility and that the timing of the distractors affects the degree of distractibility as indicated by the evoked-pupil response. The presented results will help to better understand the impact of distractors on attentional effort during speech processing. This may help to develop experimental paradigms that go beyond the question of how well a target stimulus can be attended, by asking how well a distracting stimulus can be ignored.

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Kang	Sun	Eriksholm Research Centre
Sébastien	Santurette	Oticon A/S
Niels	Pontoppidan	Eriksholm Research Centre
Lorenz	Fiedler	Eriksholm Research Centre

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Signature Dorothea Wendt

The Eyes as a Window to Auditory Processing and Perception

Pupillometry as a Reliable Metric of Auditory Detection and Discrimination in Animal Models

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Srivatsun Sadagopan

Affiliation University of Pittsburgh

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

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Srivatsun *	Sadagopan *	University of Pittsburgh

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Signature Srivatsun Sadagopan

The Eyes as a Window to Auditory Processing and Perception

Impact of Pupil-Indexed Arousal on Correlated Variability and Sound Representation in Neural Populations

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Stephen David

Affiliation Oregon Health & Science University

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

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Charles	Heller	Max Planck Institute for Biological Cybernetics
Leah	Schwartz	Oregon Health & Science University

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Signature Stephen David

The Eyes as a Window to Auditory Processing and Perception

Sustained pupil responses track the statistics of rapidly unfolding sounds.

Submission ID 3003149

Submission Type Symposia

Topic Other

Status Submitted

Submitter Maria Chait

Affiliation UCL Ear Institute

Participant(s) Maria Chait (Chair), Stephen David (Presenter), Francois Vachon (Presenter), Stefanie Kuchinsky (Presenter), Ronan McGarrigle (Presenter), Srivatsun Sadagopan (Presenter), Maria Chait (Presenter), Dorothea Wendt (Presenter), Thomas Koelewijn (Presenter)

SUBMISSION DETAILS

Individual Abstract The auditory system continuously analyses rapidly unfolding probabilistic information, even when this information is not immediately relevant to behaviour. Accumulating work has demonstrated that sensitivity to auditory regularities plays an important role in auditory scene analysis, speech perception and attention. What sound statistics does the auditory system automatically monitor?

Non-luminance mediated changes in pupil size index changes in instantaneous arousal. It has been suggested that these responses reflect the amount of processing resources drawn by a given task or stimulus and that stimulus uncertainty (which is associated with a draw on processing capacity) can therefore be manifested in pupillary dynamics.

I will present a series of studies in which we investigate pupil responses to statistically shaped auditory signals. Naïve participants performed an incidental task that did not require monitoring sequence structure. The stimulus sequences were rapid, preventing conscious tracking of sequence statistics thus allowing us to focus on the automatic tracking of different types of regularities, and transitions between them. We ask (1) how the fast-paced and automatic mechanisms that detect changes in statistics within rapid sensory signals interface with pupil-linked arousal, (2) how pupil responses compare to other aspects of brain dynamics (EEG measures).

We demonstrate that, broadly, pupil responses show reduced sustained amplitude for predictable relative to unpredictable auditory patterns, consistent with the notion that regularity facilitates processing by reducing processing demands. However the specific pattern of pupil size modulation (pupil size decrease, relative to unstructured sequences) as a function of sequence statistics suggests a difference between EEG and pupillometry. EEG responses track the precision (predictability) of unfolding sequences. In contrast, the pattern of pupil responses is more

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Alice	Milne	UCL Ear Institute
Ben	Skerritt-Davis	Johns Hopkins University
Mounya	Elhilali	Johns Hopkins University
Sijia	Zhao	UCL Ear Institute

In-Person Participation I intend to participate in the MidWinter Meeting in-person for the entirety of the scheduled meeting.

Video Consent & Release of Rights I have read and agree to the above terms and conditions. My presentation can be recorded and available post the conclusion of the MidWinter Meeting for 2 weeks or 14 days.

Signature Maria Chait