Max Planck Institute
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Second Conference on Music and Eye-Tracking

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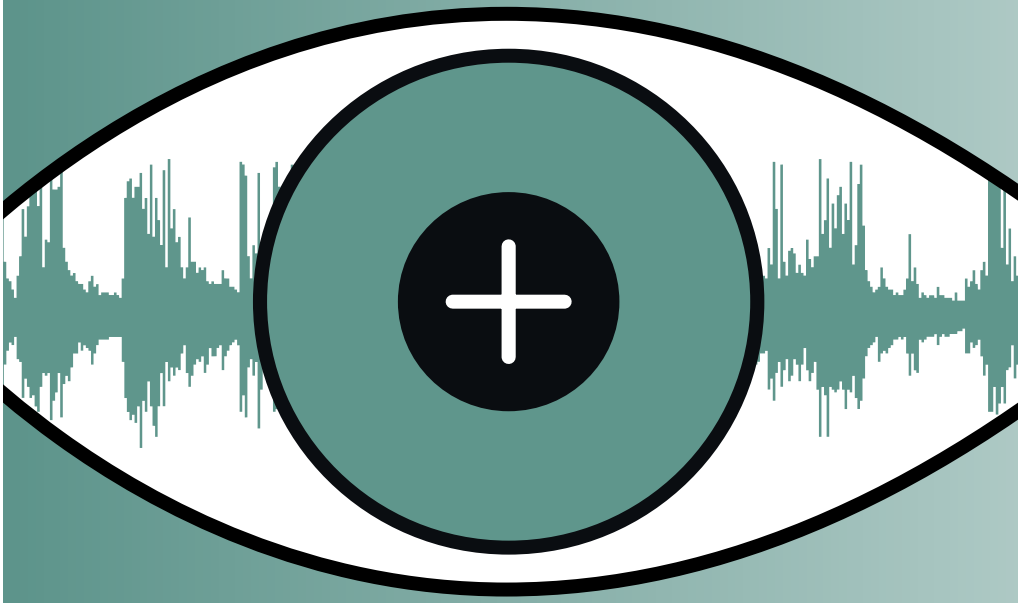
#musicET2022



July 7 & 8, 2022

Frankfurt, Germany

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Scientific Chairs:
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Lauren K. Fink, Max Planck Institute for Empirical Aesthetics

Virtualization Chair:
Shreshth Saxena, Max Planck Institute for Empirical Aesthetics

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Opening Keynote

The pupil response to auditory stimuli: relevant factors

***Dr. Adriana Zekveld**, Amsterdam UMC*

Among an array of measures used to assess effort and stress, pupillometry and cardiovascular measures are the most common ones. The pupil dilation response has been used as a proxy measure to study mental effort allocation since the seminal work of Kahneman and Beatty in the last century. Pupillometry has been applied in research to music processing to study auditory attention, engagement, salience, deviant detection, surprise, emotional processing and attractiveness. Pupillometry has also gained interest in the assessment of the mental effort required to process speech in difficult listening conditions. The pupil dilation response is sensitive to changes in intelligibility, the type of background sound (including music) and hearing acuity. Furthermore, the motivation and engagement of the listener influence the pupil response during speech perception. For example, social factors and monetary reward affect the pupil dilation. This presentation provides an overview of the application of pupillometry to assess speech perception. I will discuss the correspondence with its application in research on music processing, the feasibility and value of the method, as well as limitations and potential confounders. Furthermore, the relationship with cardiovascular measures will be discussed.

Day 1 Thursday 7 July 2022

Location: Artlab Foyer (except poster sessions) & online

12:00 Registration open

13:00 **Welcome**
(by Elke Lange & Lauren Fink)

13:15 **Keynote lecture**

Zekveld, Adriana.
The pupil response to auditory stimuli: relevant factors

14:15 Short break

14:30 **Pupil dilation response in context**
[Chair: Lauren Fink]

Widmann, Andreas. [IP: in-person]
Effects of luminance and arousal related baseline amplitude on the auditory phasic pupil dilation response

Vanzella, Patricia. [IP]
Pupillometry as tool to investigate absolute pitch ability

Ahmad, Nashra. [O: online]
Preference of consonant chords over dissonant chords, revealed through subjective ratings and pupil dilation responses

15:45 Break

Poster session 1
(see poster titles below)

16:15 Blitz 1
(Location: Artlab Foyer)

16:45 Live session 1
[Interviewer: Adriana Zekveld]
(Location: Library)

17:30 Break

18:00 **Reading & expertise**
[Chair: Rebecca Atkins]

Timoshenko, Maria. [IP]
Experienced choral conductors' score-reading strategies: Methodological triangulation with interviews, eye-tracking, and retrospective recall

Arco, Nicole. [O]
Music expertise effects on fixation locations and durations

Joris Perra / Véronique Drai-Zerbib. [IP]
Evolution of eye movements across five expertise levels during sight reading of music

19:30 Social dinner at "Gemahltes Haus"
(prior registration required)

We will leave / travel together from the institute

www.zumgemaltenhaus.de

Day 2 Friday 8 July 2022

Location: Artlab Foyer

09:00 Conference room opens

09:30 **Entrainment and dynamic processing**
[Chair: Andreas Widmann]

Wang, Youjia. [IP]
Auditory and visual cues in rhythmic entrainment of attention to singers

Spiech, Conner. [IP]
All aboard the groove (en)train(ment)!: Oscillatory brain and pupil activity varies with rhythmic complexity and groove ratings

Wu, Yiyang. [O]
Combining EEG and eye-tracking: The neural mechanisms underlying dynamic processing and learning of musical hierarchical structure

10:45 Break

11:15 **Subjective states**
[Chair: Laura Bishop]

Takeuchi, Anna. [O]
Sound-induced ASMR as investigated with pupillometry

Vidal, Marc. [O]
Measuring arousal with pupil dilation during experience of musical agency

Lange, Elke. [IP]
Eyeblinks as indices of subjective states during music listening: Methodological considerations

12:30 Lunch provided in room 416

13:30 **Learning & memory**
[Chair: Avi Mendelsohn]

Kurzom, Nawras. [IP]
Musial tension and declarative memory: between perception and physiology

Cara, Michel. [O]
Skill differences in learning a new piece for piano; eye-hand span, performance and eye movement measures

Fink, Lauren. [IP]
Consistency of eye movements across multiple memorized performances: A mobile eye-tracking pilot study

14:45 Break

15:15 **Singing and music performance**
[Chair: Jörg Mühlhans]

Atkins, Rebecca. [IP]
Musicians' gaze patterns on sight-singing tasks: An eye-tracking study

Guthridge, Lauren. [IP]
Using pupillometry to measure the effects of cognitive load on singers

Bishop, Laura. [IP]
Expertise modulates the relationship between musical demands and mental effort

16:30 Short break

16:45 **Panel discussion**

Poster session 2
(see poster titles below)

17:15 Blitz 2
(Location: Artlab Foyer)

17:45 Live session 2
[Interviewer: Véronique Drai-Zerbib]
& Farewell Reception (Location: Library)

Day 3 Saturday 9 July 2022

09:00 to 13:00 **Outing to Palmengarten**
(prior registration required)

We will meet at 9 a.m. and leave together from the institute.

www.palmengarten.de/en/gardens/palmengarten

Posters

Virtual presentations

Poster session 1:

Caitlin Smith.
New directions for note reading within the Suzuki method using eye-movement research

Elena Capelli.
Audio-visual integration abilities in infants at high-risk for autism, what is the relationship with communicative development?

Ivan Simurra.
Visualizing contemporary music using heatmaps analysis: A study combining music and the bouba-kiki effect

Krzysztof Basiński.
The effect of harmonicity on pupil dilation response in an auditory oddball task

Laura Hicken.
Music teacher expertise via visual attention and cognition

Lucas Lörch.
MidiAnalyze – a program for the analysis of musical performance accuracy

Poster session 2:

Margarethe Maierhofer-Lischka.
When music is looking back. Eye movements as musical tool in Carola Bauckholt's „Oh, I see"

Mattis Dalton.
Time perception in film is modulated by sensory modality and arousal (indexed by pupillometry)

Robin Heinsen.
Me, myself, and eyes: What gaze behavior reveals about thought processes and divided attention during active teaching vs. observing teaching

Yannis Mygdanis.
Implementing eye-tracking practices in music teaching-learning processes

Yasmin Cardoso.
Music intervention and the development of joint attention in toddlers: An eye-tracking study

In-person presentations

Poster session 1:

Mikael Hope.
Does actual movement modulate one's subjective feeling of groove while listening to musical rhythms with varying amounts of syncopation?

Laura Bishop.
Eyes and hearts of adepts and experts: Physiological rhythms in string quartets

Dijana Popovic.
… and I just can't hide it: Implicit and explicit assignment of gender stereotypes to musical instruments

Poster session 2:

Shreshth Saxena.
Tracking eye movements in online experiments using appearance-based deep learning methods

Matthias Seitz.
Tracking a vocal group: A pilot study on multiple and simultaneous eye-tracking

Judith Beck.
Rhythmic subvocalization: An eye-tracking study on silent poetry reading

Jimpei Hitsuwari.
The effects of emotional and cognitive changes on aesthetic evaluation of Haiku poetry: Perspectives from joystick and pupil diameter

Preference of consonant chords over dissonant chords, revealed through subjective ratings and pupil dilation responses

Authors: **Nashra Ahmad**[1]**; Krishna Miyapuram**[1]**; Pankaj Pandey**[1]**; Derek Lomas**[2]
[1] Indian Institute of Technology Gandhinagar, India; [2] Delft University of Technology, Netherlands
Corresponding author: **ahmad_nashra@iitgn.ac.in**

Perceptual preference of consonance and dissonance in music has been debated since the time of Pythagoras, with studies mostly concluding a preference of consonance over dissonance. Studies have provided ample neural evidence for different processing of consonance and dissonance, however, a preference of consonance is still challenged. Eye movement, especially pupil dilation responses (PDR), have provided insights into surprising events in music, arousal in music, subjectivity in music perception, etc. Hence, PDR can be a useful tool in assessing preference of consonance and dissonance. This study will assess this preference through subjective responses and PDR to consonant and dissonant chords when presented as dyads and triads.

Stimuli consisted of 24 dyad and triad musical chords each. Dyad consonants contained root and perfect fifth, and dissonant contained root and minor second. Triad consonants constituted root, major third and perfect fifth; and dissonants were root, minor second and major second. Stimuli were presented one after the other in pairs, such that they formed 4 conditions, consonant-dissonant (CD), dissonant-consonant (DC), consonant-consonant (CC), and dissonant-dissonant (DD). Twenty participants (13 females, 7 Males) from IITGN India, with a mean age of 23.3 (SD = 2.45), were instructed to listen to two stimuli, followed by giving their preference by pressing 1 (first stimuli), 2 (second stimuli), or nil (preferring both or no preference). Eye-tracking responses were collected using Tobii Eye tracker (300 Hz) while listening.

Behavioral responses suggest a significant difference between consonant and dissonant chords in both dyads and triads, with a preference for consonant chords in conditions CD and DC. Interestingly, participants significantly selected 'nil' for DD triads, however, there was no significant 'nil' response for CC conditions in both dyads and triads. PDR was significantly more for Stimulus 2 than for Stimulus 1, irrespective of the type of stimulus. There was no effect of dyad and triad combinations, however, PDR was observed to be slightly more for consonant chords in both dyads and triads. We also observed a negative correlation between hours of listening (daily) and pupil dilation to both consonant and dissonant chords.

Results suggest that participants preferred consonant chords, and failed to report no preference between two consonants. Observing more PDR for consonant chords supports previous studies on brain responses, and researches claiming an increased PDR to events that are liked and involve decision making (preference). We conclude that PDR can efficiently provide insights into musical interval processing and preference.

Music expertise effects on fixation locations and durations

Authors: **Nicole Arco**[1]**; Kinnera Maturi; Heather Sheridan**[1]
[1] University at Albany, State University of New York
Corresponding author: **narco@albany.edu**

According to chunking and template theories of expertise, experts learn how to group together individual features into larger meaningful patterns called "chunks". Here, we tested if expert musicians use "chunks" to process music scores by re-analyzing an eye tracking dataset from a music expertise study by Maturi & Sheridan (2020). In Maturi & Sheridan (2020)'s study, 30 experts and 30 non-musicians completed a music-related visual search task while their eye movements were monitored. Specifically, both the experts and non-musicians searched for a specific bar of music (i.e., the search template) within a larger music score (i.e., the search array). The experts showed higher accuracy and they also spent more time looking at relevant regions, compared to the non-musicians. We extended Maturi & Sheridan (2020) by re-analyzing their dataset to explore the landing locations of individual fixations within specific bars of music. To analyze landing locations, we divided each of the search template bars into four equal quartiles on the horizontal dimension. As evidence that experts were allocating more of their attention to the outer regions of the bar, the experts had a higher proportion of fixations and longer fixation durations than novices for the two outer quartiles (i.e., the quartiles at the beginning and end of the bar), but not for the two middle quartiles. Consistent with our results, in the domain of chess, de Groot and Gobet (1996) showed that skilled chess players are more likely than less skilled players to fixate near the edges of squares on a chessboard. One possible explanation for why music experts fixate closer to the edge of a bar of music is that they are using parafoveal processing to encode larger patterns (or chunks) that extend across multiple bars. Taken together, our findings suggest that there are qualitative differences in how experts and non-musicians allocate their attention while processing music scores, which is consistent with the assumptions of chunking and template theories.

Musicians' gaze patterns on sight-singing tasks: An eye-tracking study

Authors: **Rebecca Atkins**[1]**; Hui Tang**[1]
[1] University of Georgia, USA
Corresponding author: **rlatkins@uga.edu**

Sight-singing a musical passage requires the singer to utilize various cognitive tasks including but not limited to perceptual and memory processes, problem-solving skills, working memory processes, and the translation of visual and auditory stimuli to motor responses. In this exploratory study, we investigated musicians' gaze patterns when sight-singing new music utilizing procedures similar to an all-state choral audition or a university aural skills class in the

U.S. Eighteen college music majors practiced aloud an 8-measure melody for 30 seconds using their preferred sight-reading method, followed immediately by a performance trial. Each new melody (n = 4) became more difficult. Participants heard the tonic triad of the key followed by one-measure of metronome at = 60. We recorded their gaze patterns using a Tobii T120 eye tracker and was synchronized to the audio recording.

First, we counted total errors in the performance trial. We identified the timestamps for the onset of every note (Praat) and compared to the fixation timestamps on the performance trial (eye-voice span). We also determined fixation duration and counted the number of regressions, skips, look- ahead fixations, fixations before the metronome count-off, and total fixation count for each musical example for every participant.

A Pearson product correlation revealed significant moderate positive correlations between eye-voice span and the number of errors, skips, regressions, and total fixations. We noticed an increase in eye-voice span as examples became more difficult. Therefore, we compared the means between those who made 0–1 errors, 2–10 errors, and more than 11 errors for eye-voice span, regressions, and skips. The 0–1 error group had less regressions on all examples, and more skips except the most difficult example than the 2–10 and 11+ error groups. Eye-voice span was similar across the three groups except for the most difficult example, where participants with more errors looked farther ahead than those with fewer errors. The best sight-singers seemed to purposefully hold their gaze the full duration on long notes and not allow themselves to look too far ahead. These findings contradict some previous research showing an increased eye-voice / hand span for expert sight-readers compared to their novice counterparts. This difference may be a result of the synchronized sound to fixation analysis on more advanced eye tracking equipment. Further experimental research is needed to explore the eye-voice / hand span and error relationship.

The effect of harmonicity on pupil dilation response in an auditory oddball task

Authors: **Krzysztof Basiński**[1]**; Tomasz Domżalski**[1]**; Lauren Fink**[2]**; Dominika Szalewska**[1]
[1] Medical University of Gdańsk, Poland; [2] Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany
Corresponding authors: **lauren.fink@ae.mpg.de, tomdom@gumed.edu.pl, k.basinski@gumed.edu.pl**

Predictive coding accounts posit that perception relies on making predictions about incoming sensory stimuli and updating these predictions via prediction errors. This process is crucially dependent on precision weighting, namely that some prediction errors are more likely to influence future predictions than others. Precision is related to the information entropy of the stimulus. Here, we explore mechanisms of precision weighting in the auditory domain, by using complex sounds that differ in terms of harmonicity. Harmonic sounds are comprised of frequencies that are integer multiples of one fundamental frequency, while inharmonic sounds lack this property. Importantly, harmonic sounds have lower spectral entropy than inharmonic sounds, which we take as a proxy for information entropy. Therefore, under predictive coding,

any prediction errors associated with harmonic sounds should have higher precision. To test this hypothesis, participants will complete an auditory oddball task: listening to a series of synthesized complex tones of a set fundamental frequency (f0), with randomly occurring oddballs of higher f0. In the harmonic condition, the frequencies of sounds will be integer multiples of the f0. In the inharmonic conditions, the harmonic frequencies will be randomly perturbed (jittered), in order to introduce different levels of inharmonicity. We use the pupil dilation response as a proxy for prediction error and hypothesize that harmonic oddballs will yield a pupil dilation response larger in amplitude than inharmonic oddballs. Data collection for this study is currently under way and the results will be presented at the Music & Eye-Tracking Conference in Frankfurt.

Rhythmic subvocalization: An eye-tracking study on silent poetry reading

Authors: **Judith Beck**[1]**; Lars Konieczny**[1]

[1] University of Freiburg, Germany

Corresponding authors: **judith.beck@cognition.uni-freiburg.de, lars.konieczny@cognition.uni-freiburg.de**

Eye movements during silent reading share comparable, closely aligned patterns with speech (Gagl et al., 2021) and rhythmicity of auditory stimuli influence perception and predictive coding (Kotz, Ravignani, & Fitch, 2018). For speech, the concept of isochrony is dismissed (Fiveash et al., 2021; Patel, 2008). However, conventionally metered and rhymed poetry provides a special case for research on effects of temporally regularized rhythmicity on eye-movements. Our study (Beck & Konieczny, 2021) on MRRL (metrically regular, rhymed language) examined to what extend eye-movements reflect rhythmic subvocalization and how the processing is influenced by a visual presentation mode. Thirty-eight participants read eight German MRRL-stimuli, with one half presented in poem layout, where verse endings coincided with line breaks, and the other half in prose layout, where verse endings often appeared mid-line. Additionally, we introduced 3 types of anomalies to generate an inconsistent version of stimuli, i.e., a metrical anomaly, a rhyme anomaly, and a combination of both.

We predicted that the silent reading of MRRL results in generating auditive expectations based on a rhythmic "audible gestalt", induced by subvocalization of rhythmic patterns. Our results show a fairly robust pattern over several reading time measures. Readers seem to be sensitive to rhythmic gestalt-anomalies, but differently so in poem and prose layouts. Metrical anomalies in particular resulted in increased fixation and reading times in the poem layout, as well as in re-reading of local context. Rhyme anomalies elicited stronger effects in prose layout and triggered systematic re-reading of pre-rhymes. Moreover, we found a clear effect of number of syllables, further indicating subvocalized reading and strongly suggesting a close eye-to-(inner)-voice span. For presentation mode, the presence of anomalies had differential effects: participants initially read slower in poem layout when anomalies were present, but adapted to them in later trials, which they did not in prose layout. In general, the overall pattern of results suggests that eye-movements reflect, and are closely aligned with, the rhythmic subvocalization of

MRRL. Our findings corroborate other evidence of comparable implicit and explicit patterns of reading (Breen et al., 2019, Blohm et al., 2022) reflected in eye-movements, and extend it by adding a musically-rhythmic perspective with respect to MRRL- processing.

Expertise modulates the relationship between musical demands and mental effort

Authors: **Laura Bishop**[1,2]**; Bruno Laeng**[1,3]

[1] RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo, Norway, [2] Dept. ofMusicology, University of Oslo, Norway, [3] Dept. of Psychology, University of Oslo, Norway

Corresponding author: **l.e.bishop@imv.uio.no**

Music requires continuous fluctuations in mental effort as musicians' attention is variably engaged by different features of the music, the technical demands of playing their instrument, and monitoring each other's performance. This study investigates the relationship between musical demands and mental effort during string quartet performances, and tests how this relationship is affected by musical expertise.

Participating in the study were the Borealis String Quartet—an advanced student group in Norway— and the world-renowned Danish String Quartet (DSQ). Both quartets were requested to perform several times an excerpt from a String Quartet by Haydn, while pupillometry, audio, and motion capture data were collected. A modelling approach was then used to assess how changes in pupil size related to: 1) technical demands (including head and arm motion intensity and Borealis' ratings of technical difficulty); 2) harmonic complexity (including a score-based measure of tonal tension and Borealis' ratings of harmonic difficulty); and 3) expressive difficulty (Borealis' ratings of expressive difficulty). We also tested for coupling in pupil size changes between co-performers, within each quartet.

Analysis is still underway, but preliminary results suggest that mental effort, as indexed by pupil diameters, is evoked differently for the two quartets. Borealis' ratings of difficulty predicted their own pupil size, but not pupil sizes of the DSQ. For the DSQ, the pupil size of the 1st violinist was predicted most strongly by the pupil sizes of other players. Coupling was found between the two violinists, and between the 1st violinist and violist. For Borealis, there was no 'best predicted' player in terms of pupil size, and coupling was found only between the 2nd violinist and cellist.

These preliminary results show that mental effort was different for Borealis and the DSQ, likely reflecting differences in expertise. Coupling patterns for the DSQ were more in line with the performer roles that we would expect for a string quartet playing classical repertoire (i.e., the 1st violin leading). Ultimately, this experiment should help to explain how mutual attention and effective regulation of cognitive resources contribute to expert ensemble musicians' high-level performance.

Eyes and hearts of adepts and experts: Physiological rhythms in string quartets

Authors: **Laura Bishop**[1,2]**; Simon Høffding**[1,2]**; Wenbo Yi**[1,3]**; Bruno Laeng**[1,3]

[1] RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo, Norway, [2] Department of Musicology, University of Oslo, Norway, [3] Department of Psychology, University of Oslo, Norway

Corresponding authors: **l.e.bishop@imv.uio.no, wenbo.yi@psykologi.uio.no, bruno.laeng@psykologi.uio.no, simon.hoffding@imv.uio.no**

This talk discusses findings from two experiments concerning mental effort and musical absorption with an adept and an expert string quartet. The first experiment with the Borealis String Quartet, from the Norwegian Academy of Music, took place in the end of 2019 and the latter, a replication, with the renowned Danish String Quartet, took place in the fall of 2021. In both experiments, pupil size data were used as an index of mental effort and heart rate synchronization was used as an index of joint musical absorption.

We tested the hypothesis that more adverse conditions, which disrupted the quartets' normal mode of playing and relating to each other, would induce more dilated pupils (increased mental effort) and a decrease of heart rate synchronization (lower joint musical absorption).

The quartets recorded a total of six performances of the same material (an excerpt of a String Quartet by Haydn; see Bishop, et al., 2021). The first five were given under "rehearsal-like" conditions, so the musicians were in the lab with the experimenters, and no audience was present. The sixth performance was given in the same location under concert conditions with an audience. Pupillometry and heart activity data were collected in all performances.

Our preliminary findings for the Borealis Quartet suggest that the concert induced a larger pupil size than the other conditions. For the Danish String Quartet, pupil size was largest in an adverse condition that visually separated the 1st violinist from the other players. Heart rate synchronization was lower for the Borealis Quartet than for the Danish String Quartet.

In our talk, we will discuss how to best interpret these findings: Within the context of our experiments, what exactly are the experiential correlates of pupil dilation and heart rate synchronization? What is the relationship between the two measures, and what is the role of expertise in explaining the physiological differences between the two ensembles?

Bishop, L., González Sánchez, V., Laeng, B., Jensenius, A. R., and Høffding, S. (2021). Move like everyone is watching: Social context affects head motion and gaze in string quartet performance. Journal of New Music Research, 50(4), 392–412.

Audio-visual integration abilities in infants at high-risk for autism, what is the relationship with communicative development?

Authors: **Elena Capelli**[1]**; Elena Maria Riboldi**[1]**; Chiara Dondena**[1]**; Massimo Molteni**[1]**; Chiara Cantiani**[1]**; Valentina Riva**[1]

[1] Scientific Institute IRCCS E. Medea, Italy

Corresponding author: **elena.capelli@lanostrafamiglia.it**

Integrating information from visual and auditory modalities (Audio Visual Integration, AVI) is a key building block for higher-level skills, particularly language and communication. Individuals with autism spectrum disorder (ASD) perform poorly in these skills. However, few studies have examined neural and behavioral processing of AVI in infants at higher likelihood of autism (HL-ASD), i.e., siblings of children with a diagnosis of ASD. There is a growing interest in identifying reliable brain-based and behavioral predictors, which may constitute useful tools for early detection on at-risk cases. Advances in the identification of such early markers are crucial to provide timely intervention programs to be applied at very young ages.

The aims of the study are: (a) to explore whether and to what extent differences in AVI skills can differentiate HL-ASD from TD infants, applying eye-tracking and EEG / ERP techniques and, (b) to assess the association between early AVI abilities and clinical measures of infant communicative skills.

For these aims, in our ongoing longitudinal study following HL-ASD infants, we have implemented and already piloted an experimental protocol testing both speech / non-speech and social / non-social AVI skills. Recruitment is currently ongoing. We are planning to follow 2 groups (between the ages of 6 and 12 months): HL-ASD infants and typically developing infants (TD). AVI skills are measured using two approaches: (1) an eye-tracking (ET) preferential looking paradigm and (2) an integrated EEG / ET paradigm.

(1) The ET preferential looking paradigm is presented in 3 conditions: (a) social / speech condition (based on the McGurk effect); (b) social / non-speech condition (synchronous / asynchronous hands clapping), and (c) non-social / non-speech condition (synchronous / asynchronous drumming). Infants at 6, 9, and 12 months of age are taking part in the study, allowing for the observation of looking preference differences between groups, conditions, and ages and providing new insights into the role multisensory functions in early developmental trajectories of ASD.

(2) The integrated EEG-ET paradigm is recorded at 12 months of age in the two groups. Video stimuli of faces will be presented in congruent or incongruent conditions, arranged in a block design. EEG brain responses and looking behaviors are simultaneously recorded.

In addition, clinical measures of sensory, language and communicative development are available for all infants. The experimental paradigms will be presented and preliminary results for the ET experimental task will be reported.

Skill differences in learning a new piece for piano; eye-hand span, performance and eye movement measures

Author: **Michel Cara**[1]

[1] Pontificia Universidad Católica de Valparaíso, Chile

Corresponding author: **michcara2001@yahoo.com.mx**

This study examines short-term learning in music reading and the oculomotor behavior during four successive executions of a brief musical piece composed by Bartók, "Slovak Peasants' Dance". Pianists were able to practice for two minutes between each trial and were divided into two skill groups based on their tempo and accuracy scores. In order to study the link between working memory and anticipation capacities, pianists performed the second version of the Daneman and Carpenter (1980) reading span test and, for short-term spatial memory the Corsi-block tapping-test. The effect of musical structure was observed in 100% of the studied variables and practice effect in the following variables representing 54% of the cases: substitutions, tempo, number of fixations, number of glances at the keyboard (GAK), eye-hand span (EHS) and awareness span. Compared to the less expert group, we noted that expert pianists played faster and had fewer and shorter GAK. In addition, anticipation awareness linked to the GAK was studied. Across the trials, we observed that skilled pianist outperforms less skilled pianist in those sections where thematic development occurs, and those differences occurred mainly during the second trial. This reveals the implementation of different learning strategies and more effective planning process. The results of comparison to the previous data obtained with the same pianist's panel (Cara, 2018), suggest that the mobilization of visuospatial capacities of experts is related to the processing of music style features. We also found significant correlations between the reading span test and the number of GAK, stretching the link between working memory and music reading processing.

In our view, musicians use different strategies that vary according to their degree of expertise, reflected in oculomotor and anticipation behavior. These observations are consistent with the findings of Lim et al. (2019), who studied the link between music complexity and anticipation (see also Rayner & Pollatsek, 1997). Everything seems to indicate that a dynamic relationship is established between the different variables throughout the practice phase, where periods of instability alternate with periods of stability (see Aiba & Matsui, 2016); according to Timmers, Sadakata, and Desain (2012) this is an indicator of skill acquisition.

Music intervention and the development of joint attention in toddlers: An eye-tracking study

Authors: **Yasmin dos Anjos de Deus Cardoso**[1]**; Victor Hugo Silva**[1]**; Luisiana Passarini**[1]**; Pedro Oliveira Neto**[2]**; Andrea Almeida**[1]**; Rodrigo Magalotti**[1]**; Leticia Souza1; Mariana Sola**[1]**; Maria Teresa Carthery-Goulart**[1]**; Patricia Vanzella**[1]**; Katerina Lukasova**[1]

[1] Universidade Federal do ABC, Brazil, 2 University of Jyväskylä, Finland

Corresponding author: **yasmin.anjos@aluno.ufabc.edu.br**

Joint visual attention (JA) is the ability to use someone else's eye-gaze to indicate where attention should be directed. Previous studies show that JA is a good predictor of communicative abilities in babies. Furthermore, the scientific literature reports that musical involvement in childhood is associated with better performances in language tasks. The present study investigates JA and language development in babies involved in musical activities.

Ten toddlers (age 15,8±2,4 months old) participated in music sessions (twice/week) that consisted of singing, playing instruments, and moving with the music. Each baby was assessed before and after the intervention. Communicative development was assessed with the Bayley Scales of Infant and Toddler Development (Language Subscale, L-BSID-III). JA was evaluated using an eye-tracker (EyeLink 1000) on video sequences with an actor/actress and two identical toys placed in front in three conditions: Responding to JA (RJA); Initiating JA (IJA); and a Control Condition (Bicelli et al., 2017). The entire procedure took approximately four minutes, and the trials were pseudorandomized.

In the L-BSID-III, all the babies scored above the 49th percentile in pre and post-tests. Eye-tracking data were compared for gaze duration in the target toys' Area of Interest (AOI) and proportion of alternating fixations actor-toy and toy-actor. Repeated measures ANOVA compared condition (IJA x RJA) as within-factor and time (pre x post) as between-factor. Differences between conditions were found for the gaze on the target toy ($F[1,4] = 87.412$, $p < .001$, $\eta^2 = .484$) with shorter gaze time for RJA than for IJA. No interaction was found between condition and time, although there was a small increase in the gaze on the target in RJA post-intervention [M(pre) = 159 ms; M(post) = 339 ms], suggesting that the toddlers got involved more with the stationary toy indicated by the actor's gaze. The proportion of transition from actor to toy and toy to actor was approximately 3 to 1 and was similar for both conditions remaining unchanged by the intervention.

Our study reveals differences in toddlers' responses to JA, lending support to the posterior-to-anterior model of development (Billeci et al., 2017). Our findings also indicate adequate behavioral response to JA, according to other studies that report signs of RJA between 6 and 9 months of age and IJA at 9 months of age. Music intervention showed little effect on JA pattern.

Billeci, L. et al. (2017). An integrated EEG and eye-tracking approach for the study of responding and initiating joint attention in Autism Spectrum Disorders. Scientific Reports, 7, 13560.

Time perception in film is modulated by sensory modality and arousal (indexed by pupillometry)

Authors: **Mattis Appelqvist Dalton**[1]**; James Wilmott**[1]**; Mingjian He; Andrea M. Simmons**[1]

[1] Brown University, USA

Corresponding author: **mattis.dalton@gmail.com**

The subjective experience of time is not isomorphic to physical time, and indeed can be altered by internal and external factors. One of those factors is affect, and arousal is key in this process. Several scholars have asserted that the perception of time is also influenced by sensory modality, however, much of our understanding of how sensory modality influences perception of time is based on experiments in which non-naturalistic stimuli are presented in an artificial context. To date, there is very little research on time distortions in a multimodal context, such as in film, where auditory and visual cues are present simultaneously and can interact. In this paper, we ask how the added presence of the auditory modality (which always included music) to a visual scene influences subjective estimates of the duration of that scene. In addition, we predicted that arousal would modulate these duration estimates. Arousal was measured by pupillometry, an index of modulation in physiological arousal levels, paired with self-reports of subjective arousal. Finally, we assessed whether the strength of the modulating relationship between arousal (pupil size) and time estimation differed between modality conditions.

Consistency of eye movements across multiple memorized performances: A mobile eye-tracking pilot study

Authors: **Lauren Fink**[1]**; Shreshth, Saxena**[1]**, Elke B. Lange**[1]

[1] Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany

Corresponding author: **lauren.fink@ae.mpg.de**

The eyes can reveal information about musical processing and the neural mechanisms underlying musical engagement. While most eye-tracking research in musical contexts has focused on music reading, here we examine eye movements during memorized music performances. In particular, we ask 1) whether eye movements become a (subconsciously) rehearsed and stable aspect of the motor performance, and 2) whether the structure of the music is reflected in eye movement patterns. To answer these questions, we invited musicians to choose two pieces (between 30 secs and 3 min long) to play entirely from memory (no score). On four different days (separated by at least 12 hrs), they played the two pieces 3 times each, in the ArtLab of the Max Planck Institute for Empirical Aesthetics, resulting in 12 recordings of 2 pieces each, per musician. Ocular, world audiovisual, and head movement data were recorded at 200 Hz using Pupil Labs' Invisible glasses. At time of submission, data from 3 pianists have been collected. To answer whether eye movement patterns are unique and consistent within each piece, we compare intra-subject correlation coefficients and dynamic

warping costs within vs. between pieces. To answer whether regularities and anomalies in the ocular data relate to those in the music, we examine the Matrix Profiles of both time series. Analyses are on-going but so far promising, suggesting consistencies in eye movement data, within piece and musician.

Using pupillometry to measure the effects of cognitive load on singers

Authors: **Lauren Guthridge**[1]**; T Shune**[1]**; J Gilbert**[1]**; K Gautereaux**[1]**; J Ren**[1]**; I Howell**[1]

[1] New England Conservatory, Boston, USA

Corresponding author: **lauren.guthridge@necmusic.edu**

Introduction

Cognitive load studies pertaining to singers is under-explored. As a popular tool for assessing cognitive load, pupillometry measures how pupils dilate when one carries out a defined task [1]. This study investigates singers' cognitive load when singing vocal exercises of varying complexity. Consistent with existing findings in the literature that higher cognitive load involves larger pupil dilation [2], we hypothesize that tasks with higher complexity will induce larger pupil sizes compared to lower complexity tasks.

Methods

Subjects (n = 4, ongoing) are graduate students in voice pedagogy and performance programs aged 23–28, all with corrected vision. The study protocol consisted of three phases: five-point calibration, training, and experiment. Eye-tracking data collection was completed using the Gazepoint GP3 eye tracker controlled by PsychoPy (sampling rate: 60 Hz). The training phase was led by a proctor and explored the exercises in real-time with the subjects. The experiment phase had the subject sing the given exercise with a pre-recorded accompaniment track while looking at a blank screen. The pre-recorded, randomly ordered exercises varied with Exercise 3 being the most complex. Each exercise is repeated chromatically with ascending and descending intervals. After executing the singing tasks, participants ranked the exercises from least to most complex.

Results / Conclusions

Figure 1 shows average pupil size aggregated over time for each exercise. Figure 2 depicts average pupil size over time for each exercise. We collapsed pupil size data of the first 60 second time window and entered them into a linear regression model with pupil size as the dependent variable and the exercises as the independent variable. The mean pupil size of Exercise 2 significantly outranked that of Exercise 1 (beta = 1.564, SE = 0.044, $p < .001$), and the mean pupil size of Exercise 3 significantly outranked that of Exercise 2 (beta = 2.361, SE = 0.070, $p < .001$). Responses to the difficulty ranking questionnaire support the predicted means. A distinct change in pupil size can be seen in all three exercises in the first 20 seconds, with a sharp decline immediately following. These preliminary results may suggest pupillometry can serve as a reliable and efficient tool to measure cognitive load in singing.

Me, myself, and eyes: What gaze behavior reveals about thought processes and divided attention during active teaching vs. observing teaching

Author: **Robin Heinsen**[1]
[1] The University of Texas at Austin, USA
Corresponding author: **robinheinsen@utexas.edu**

As a way of investigating unconscious perceptual processes engaged during music teaching, I compared a teacher's attention allocation while teaching with the same teacher's attention allocation during self-observation. I devised a unique case-study approach in which I served as both the research participant and the experimenter. I wore eye-tracking glasses while teaching a brief lesson to two university music students learning trumpet. Approximately two weeks later, I watched a video of the lesson and tracked my gaze again.

My gaze behavior while teaching revealed a high level of automaticity, both with regard to my lesson sequencing and my allocation of attention. The strategic moment-to-moment shifts in attention between the two students took place entirely below my conscious awareness, yet post hoc analyses revealed well-timed attentional shifts that were related to momentary goals. Fixation durations and total dwell time were both greater for the student who experienced the most difficulty with the lesson tasks, and shorter for the more successful student, whom I nevertheless fixated frequently but for shorter durations to assess his level of engagement. While watching the video, absent the demands of behavioral interaction and momentary decision-making, I directed more sustained attention (longer dwell times) to both students than I had while teaching.

These results reveal important features of "teacher thinking" that are not directly observable or typically construed as conscious or intentional behavior. My allocation of attention was nevertheless strategic, albeit governed by processes to which I devoted no conscious attention while teaching. That this component of teaching practice does not involve volitional control suggests that teachers' descriptions of their thinking may not reveal to novices important elements of pedagogical expertise.

Music teacher expertise via visual attention and cognition

Authors: **Laura Hicken**[1]**; Robin Heinsen**[2]**; Lorelei Batislaong**[3]
[1] Towson University, USA, [2] The University of Texas at Austin, USA, [3] Baldwin Wallace University, USA
Corresponding authors: **robinheinsen@utexas.edu, lhicken@towson.edu, lbatisla@bw.edu**

Optimal allocation of attention is central to expert music teachers' abilities to create meaningful change in student performance. Experts consistently identify significant components of behavior and direct learners' attention to alter their thinking and behavior. Eye movements of music teachers with varying levels of expertise were analyzed in three experiments. We identified teachers' selection and prioritization of musical and behavioral goals and defined performance outcomes that guide teachers' moment-to-moment behavior during tasks.

In the first study, flute teachers observed videos of individuals playing musical instruments, juggling, batting a baseball, and dancing ballet. Consistent with previous research, experts fixated targets during the music performances that were relevant to the accomplishment of goals, and their fixations were longer than those of novices. Novices' fixations were shorter and less focused on relevant targets. When novices did fixate relevant targets, their fixations were of insufficient duration to gather information to inform goal-setting and feedback.

In the second study, undergraduate music education majors and middle-school band directors watched video excerpts from two rehearsals: one of their own students and classroom, and another with unfamiliar students in an unfamiliar classroom. Experts' gaze behavior varied depending on momentary goals, focusing most often and for the longest durations on elements that changed over time and fixating few uninformative locations. Novice gaze behavior was characterized by numerous fixations in places providing little actionable information (e.g., the wall of the room, tapping feet), and occasionally by extended fixations that may indicate novices' difficulty in interpreting what they were seeing.

The third study compared the gaze behavior of an experienced music teacher and an undergraduate music education major watching a video of an elementary general music class. Fixation patterns of both teachers suggested that the experienced teacher judiciously selected students for observation, as she fixated specific students longer and more often than did the novice teacher. The novice's gaze patterns showed no specificity in fixation frequencies or durations, possibly suggesting the novice did not discern between goal-related and goal-irrelevant student behavior.

These results reveal expert music teachers' clarity and intentionality in directing attention to the most informative aspects of their environment, suggesting aspects of attention allocation that inform pedagogical decision-making and facilitate the prioritization and accomplishment of proximal instructional goals. These differences between gaze behavior of experts and novices reflect not only differences in their allocation of attention, but also in their conceptualizations of the activities in which they engage.

The effects of emotional and cognitive changes on aesthetic evaluation of Haiku poetry: Perspectives from joystick and pupil diameter

Authors: **Jimpei Hitsuwari**[1]**; Michio Nomura**[1]
[1] Kyoto University, Japan
Corresponding author: **hitsuwari.jimpei@gmail.com**

In our previous studies, we found new findings such as that not negative but only positive emotions explain the aesthetic evaluation of haiku, and that ambiguity reduces the beauty of haiku. At the same time, considering the importance of negative emotions and ambiguity in art, it is necessary to examine more carefully the relationship between the emotional and cognitive change processes that occur during haiku appreciation and aesthetic evaluation. Therefore, this study examined the temporal effects of emotional and cognitive changes on the aesthetic evaluation of haiku from various perspectives by measuring the graded evaluation of each part of the haiku, the continuous reporting of emotions by joystick, and the changes in pupil diameter. 112 students participated in the experiment. First, participants rated each haiku at three time points-each after five seconds presentation of the top five, the middle seven, and the bottom five with a VAS rating on six main items: positive emotion, negative emotion, arousal, emotional ambiguity, cognitive ambiguity, and beauty. Second, a continuous grading using a joystick is performed on the same haiku. A two-dimensional plot of valence on X-axis and arousal on Y-axis is displayed on the screen, and participants report their own emotions for 20 seconds using joystick. During this time, the pupil diameter was also measured. Third, participants answered a questionnaire about personality traits. The results of four mixed-effects models with the third-stage beauty scores as the dependent variable and the participants and haiku as random effects showed that the increase in positive emotion, decrease in negative emotion, emotional ambiguity, and cognitive ambiguity from the first to third stage explained the beauty of the haiku. The plots of the joystick reports of emotions show that the positive emotion gradually increased for the positive haiku and the negative emotion gradually increased for the negative haiku, while the arousal gradually decreased in both haiku. The pupil diameter also tends to become smaller and smaller in both haiku types, which may reflect the low arousal transition. From the above, it is clear that, as in other art genres, negative emotions and the resolution of ambiguity are also related to the beauty of haiku. And the importance of changes in emotion and cognition in haiku appreciation was revealed, which could not be seen only by measuring emotion and cognition at a single point in time.

Does actual movement modulate one's subjective feeling of groove while listening to musical rhythms with varying amounts of syncopation?

Authors: **Mikael Hope**[1]**; Connor Spiech**[2]**; Georgios Sioros**[2]**; Bruno Laeng**[2,3]**; Anne Danielsen**[2,4]
[1] University of Oslo, Norway, [2] RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo, Norway, [3] Department of Psychology, University of Oslo, Norway, [4] Department of Musicology, University of Oslo, Norway
Corresponding author: **mikaehop@student.sv.uio.no**

"Groove" has been explained as the pleasurable compulsion to move along to musical rhythms (Madison, 2006), and has been shown to follow an inverted U-shaped curve with increasing levels of metric uncertainty (Witek et al., 2014). This metric uncertainty is the result of rhythmic features such as syncopation. According to this perspective, the highest level of perceived groove occurs with moderate levels of metric uncertainty and decreasing levels of groove for both higher and lower levels of metric uncertainty.

According to the predictive coding framework, the pleasurable compulsion to move to music results from prediction errors between the internal model of the beat and the perceived music (Koelsch, 2019). Through the process of active inference the brain can reduce prediction errors through movement. For the moderate levels of metric uncertainty, the prediction errors facilitate active inference, which drives the listener to move along to the beat in order to suppress prediction errors arising from syncopations in the music. This is not the case for lower or higher levels of rhythmic complexity as the lower end of the curve yields no reason for correction, and the higher end will not construct a sufficient internal model to guide movement. Therefore, moderate levels of syncopation are optimal for the feeling of groove, as it gives sufficient amounts of prediction errors to facilitate active inference, but not so much that it obscures the internal meter on which to base one's movement. Furthermore, larger pupil sizes have been associated with higher groove ratings (Spiech et al., 2021) If this is the case, we should see a selective increase in groove, along with greater pupil dilations when people are actually moving compared to when they're instructed not to, at least in the presence of moderate syncopation where it can be used to correct prediction errors.

Our preliminary analyses show no interaction between movement and rhythmic complexity on pupil responses or feelings of groove. This challenges a popular theory in music cognition, which might need a more nuanced approach to fully explain the perception of groove.

Musial tension and declarative memory: between perception and physiology

Authors: **Nawras Kurzom**[1,2]**; Ilaria Lorenzi**[1,2,3,4]**; Avi Mendelsohn**[1,2]

[1] Sagol Department of Neurobiology, University of Haifa, Israel, [2] The Institute of Information Processing and Decision Making (IIPDM), University of Haifa, Israel, [3] Institute of Neuroscience, Department of Biology, University of Pisa, Italy, [4] Institute of Neuroscience, National Research Council, Pisa, Italy

Corresponding author: **nawras_i12@yahoo.com**

Music comprises a complex, yet intuitive language, which can induce various emotions and states. A unique form of emotion that can be elicited through harmonic progression is musical tension. The main aim of the current studies was to examine the effect that musical tension exerts on the formation of declarative memory. Here I present two studies where we used manipulations in musical harmony in order to evoke tension: first by evoking tension within natural music pieces (by delaying the release of harmonic progressions from dominant to tonic chords), and the second by using isolated single complex chords with various degrees of dissonance/roughness. Each experiment included an encoding phase, wherein participants studied stimuli (words and/or images) with different conditions of background music or single chords. Memory for the studied stimuli was tested one day later using recognition tasks. Musical tension was validated through subjective reports of tension, as well as physiological measurements of skin conductance response (SCR) and eye-tracking measures to assess pupillary responses to the chords. In addition, music information retrieval (MIR) was used to quantify the musical properties associated with tension and its release. We observed a trade-off effect between post-experiment tension perception and memory, such that individuals who perceived musical tension as such displayed reduced memory performance for images encoded during musical tension, whereas tense music benefited memory for those with lower musical tension perception. The relationship between pupillary responses to chords and memory is still under investigation (currently in the piloting phase). Understanding the interrelations between musical components, physiological responses, and cognitive faculties may provide insights into the basic features of memory formation.

Exploring eye-blinking during musical listening: A methods account

Authors: **Elke B. Lange**[1]**; Lauren Fink**[1]

[1] Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany

Corresponding author: **elke.lange@ae.mpg.de**

Eye-blink activity can be modulated by a variety of factors, some related to individual differences in physiology, others to changes of states and demands. In this paper, we report data from three experiments (n = 30/35/29), exploring blink activity (recorded from EL 1000, SR research) in

relation to subjective experiences during music listening and to acoustic features. Participants' task was to listen to 56 excerpts from a broad range of musical styles, trying to immerse themselves into the music. We report a sophisticated outlier analyses for the blink data and its importance for mean-based analyses (i.e., ANOVAs), but not for trial-based analyses (i.e., mixed effect models). We discuss different ways to fit mixed models. In addition, we explore blink rates across time and discuss several methods to do so. We find two consistent effects: 1) increased blinking during music vs. silence, 2) decreased blinking during music trials in which participants report feeling highly immersed. However, we failed to find statistical evidence to explain (1) and further studies are necessary to do so. We conclude that exploring blinking activity is fruitful for researchers mainly interested in gaze, as it comes at no extra measurement cost in video-based eye-tracking, and can reveal interesting effects.

MidiAnalyze – a program for the analysis of musical performance accuracy

Author: **Lucas Lörch**[1]
[1] Universität Mannheim, Germany
Corresponding author: **lloerch@mail.uni-mannheim.de**

There is initial evidence that eye movements during the instrumental performance of notated melodies are associated with performance accuracy. Thus, the assessment of instrumental performance accuracy can be crucial in the context of eye movement research. Nevertheless, tools and methods for this assessment are limited. Past studies have largely relied on counting performance errors by hand, an approach that is only feasible for small data sets. Therefore, I developed a software package for the analysis of musical performance MIDI (musical instrument digital interface) data. It can be applied without any programming skills and provides binary accuracy measures on the level of individual notes.

After installing the MidiAnalyze package, researchers load the MIDI files that hold the musical stimuli and those that hold the instrumental performances collected during an experiment. The program then assigns each instrumental performance file to the file of the respective stimulus based on the file names. To assess the accuracy of the performances, the program iterates through all the notes of a performance and compares their onset, pitch, and duration with the musical stimulus. The program generates a spreadsheet with a binary (correct / incorrect) accuracy measure for each note and a proportional accuracy measure for the whole melody. In addition, several measures that describe the performance, such as the number of performed notes, are assessed. The spreadsheet can then be used in the analysis of eye movements.

The MidiAnalyzer is an open-source, fast, and easy to-use tool for the analysis of instrumental performances. As accuracy is provided on the level of individual notes, the performance accuracy within specific AOIs can be easily calculated. A drawback of the software, however, is that it provides only binary measures

of accuracy. For an incorrectly performed note, it is unclear how far its pitch or onset differed from the correct note. Moreover, the program currently has no graphical user interface. Pre-build functions have to be executed in the Python code editor. Although the user only has to define single variables within these functions, i.e., does not actually have to program anything, this might be challenging for users without any programming experience. Consequently, I plan to implement continuous accuracy measures and a graphical user interface in the next version of the program. This would further support the workflow of researchers in the field of eye movements during music reading.

When music is looking back. Eye movements as musical tool in Carola Bauckholt's „Oh, I see"

Author: **Margarethe Maierhofer-Lischka**[1]
[1] Universität Salzburg, Austria
Corresponding author: **margarethe@mur.at**

Recent studies show that eye movement in chamber music performance is not only a crucial tool for musicians to establish timing and feelings of togetherness (Kawase, 2009, Vandemoortele et al., 2017) but it also is part of the interaction happening between performers and audience (Kawase & Obata, 2016). Yet, eye movements during music concerts rarely are a consciously choreographed, musicalized act. „Oh, I see" by German composer Carola Bauckholt is a piece for chamber music trio plus two extra performers and video projections. Employing a chamber musical setting, it highlights the performance as a spectacle in a double sense: besides classical instruments, the piece features two giant balloons that are turned into a twofold video projection screen. Appearing and acting like virtual eyes, these „eyeballs" obtain a pivotal role in the development of the piece and its dramaturgy, making „Oh, I see" an ironic play with the musicians' and the audience's gaze in music performance, challenging bodily and cultural patterns of musical interaction and voyeurism.

In my case study I integrate and transfer findings from studies in the field of musical eye-tracking into a wider context of musical performance studies, creating an interdisciplinary methodology that describes musical experiences both through aesthetical, intra-musical discourses as through their related cultural contexts and through the empirical study of bodily behavior in performance. My study shows that gazing as a musical phenomenon stimulates and/or interacts with auditory attention in the context of a performance (de la Motte-Haber, 2013; Utz, 2008, 2010). Thus, it can become a tool composers use to create irritation, coherence and enjoyment. I intend my study to be a contribution towards analyzing audiovisual processes in performance from a perspective of empirically founded aesthetics.

Implementing eye-tracking practices in music teaching-learning processes

Author: **Yannis Mygdanis**[1]
[1] European University Cyprus, Cyprus
Corresponding author: **yannis.mygdanis@icloud.com**

An increasing interest in involving eye-tracking methodologies to various musical processes –perception, cognition, and engagement– is observed in recent years, especially in music reading and music- making (Fink et al., 2018). In the last decade, eye-tracking tools have been developed focusing on musical expression for people with disabilities (Hornof, 2014). However, much less research has highlighted the role in music education and students' engagement with music. Eye-tracking practices can provide extended multimodal ways of learning (Jarodzka et al., 2017) and in music lessons can lead to new music experiences, in-depth knowledge, and creativity development.

Synth4kids consists of an original interactive educational application created by the author with an orientation to music lessons for students aged 5 to 8. It combines elements from the traditional music-pedagogical methods–Dalcroze Eurhythmics, Kodály Method, Orff Schulwerk– along with emerging technologies in education– ubiquitous computing, IoT, augmented reality, QR codes, camera tracking etc.–providing new and extended ways of music-making–performing, producing, arrangement–, and teaching-learning (Mygdanis, 2021). The most prominent feature incorporated in the last version are eye-tracking capabilities via web-camera.

This presentation emphasizes the practical application of Synth4kids' eye-tracking function in two music classes in Greece and Cyprus, with students aged 6 to 7. Educational interventions took place simultaneously, with eye-tracking practices as the primary methodological tool. Music-pedagogical activities focused on cooperative and inquiry-based music teaching-learning, interdisciplinarity, and game-based learning. The ultimate aim was to investigate how eye-tracking practices in such ages can lead to meaningful music comprehension of abstract musical-theoretical terms, as well as creativity development. Results of the current research may shed light on the ways that eye-tracking techniques can enhance music teaching-learning processes at young ages, contributing to the formation of a musical-technological educational context with new orientations.

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Evolution of eye movements across five expertise levels during sight reading of music

Authors: **Joris Perra**[1]**; Bénédicte Poulin-Charronat**[1]**; Thierry Baccino**[2]**; Patrick Bard; Philippe Lalitte; Véronique Drai-Zerbib**[1]

[1] Laboratoire d'Étude de l'Apprentissage et du Développement, France, [2] LUTIN, Paris VIII, France

Corresponding author: **joris.perra@gmail.com**

Sight-reading of music is a task in which the musician must perform a score during the first reading or with very little preparation (Wolf, 1976). It is a widely studied task in the music reading literature as it generates issues that involve a high level of cognitive processing.

The challenge facing the musician during sight-reading is to perform despite a conflict between, on the one hand, the need for time to decode the visual information and prepare a motor response, and on the other hand, a limited time determined by the rhythmic constraints to perform the score.

Eye movements variables are known to discriminate individuals according to their ability and difficulty to process visual information. Therefore, studying musicians' eye movements during a sightreading task enables to discriminate musicians according to their level of expertise and to evaluate their ability to cope with the complexity generated under the temporal constraint linked to the production.

In this experiment, 68 musicians from 5 conservatory levels had to sight-read 34 excerpts of different level of complexity while their eye movements were recorded. Musical score consisted of both classical tonal of Western music and contemporary repertoire and eye-movements data were recorded using the SR Research Eyelink 2000 Hz system.

The main results show that the study of eye movements makes it possible to discriminate the level of expertise of musicians, even those whose conservatory level are close. Furthermore, this experiment shows that complexity is a significant factor in the evolution of eye movements and should be taken further into account to explain the differences in eye movements between performers.

… and I just can't hide it: Implicit and explicit assignment of gender stereotypes to musical instruments

Author: **Dijana Popovic**[1]**; Felix Klooss**[1]**; Jörg Mühlhans**[1]

[1] MediaLab, University of Vienna, Austria

Corresponding authors: **joerg.muehlhans@univie.ac.at, dijana.popovic@univie.ac.at, felix.klooss@univie.ac.at**

Background

Stereotypes appear as a combination of (social) categories with associated attributes (Ashmore & Del Boca, 1979, p. 225). Musical instruments are inherently genderless and yet subjects rated e.g., harp, flute, piccolo, etc. as feminine, while tuba, double bass, trumpet, etc. turned out to be particularly masculine (Griswold & Chroback, 1981, p. 59). Questionnaires were used to elicit these (explicit) stereotypes, which are prone to bias by social desirability or may result in impaired validity due to lack of awareness of one's own stereotypes (Spinner, Cameron & Ferguson, 2020, p. 18). To measure the strength and direction of association between target and attribute categories the Implicit Association Test (IAT) is used. The measurement is based on the fact that incongruent concepts and attributes in the incompatible task lead to a longer processing time and thereby longer reaction time. This is interpreted as the result of higher task difficulty (Greenwald, McGhee & Schwartz, 1998). Implicit measures can be extended by eye-tracking, which allows inferences to be made about workload and arousal. While blink rate and fixation duration tend to decrease with increasing workload, pupil dilation increases (Holmqvist et al., 2011, p. 393).

Hypotheses

H1: The longer the reaction time, the more incompatible are the targets with the attribute.
H2: A longer reaction time leads to pupil dilations.
H3: A longer reaction time leads to a higher blink rate.

Methods

Forty subjects are recruited to take part in the laboratory study where participants complete an IAT. The target concepts are pictures of different musical instruments and the attribute stimuli are built on the concepts 'feminine' and 'masculine'. While subjects perform the IAT, eye-tracking data are collected using an EyeLink® 1000 Plus (SR Research). To compare the implicit (IAT, eye-tracking) and explicit measurement methods, the explicit associations are additionally collected via questionnaires. Furthermore, the familiarity with the respective instruments, the musical preference and musical expertise are surveyed.

Results

As the experiment is currently being conducted, no conclusions can be made yet. The results will be presented at the conference.

Tracking eye movements in online experiments using appearance-based deep-learning methods

Authors: **Shreshth, Saxena**[1]**; Elke B. Lange**[1]**; Lauren Fink**[1]
[1] Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany
Corresponding author: **shreshth.saxena@ae.mpg.de**

Webcam eye-tracking enables eye-tracking studies to be conducted outside of the lab, sample diverse populations online and reduce cost of data collection. Traditionally, real-time regression based methods are applied to predict gaze position from low-resolution webcam eye images, however, they are prone to gaze drift, head movements and environment noise. Recent deep learning based methods have greatly improved accuracy and robustness of gaze prediction, however, their application is still restricted to offline setups, due to the computation requirements and difficulty of estimating physical calibration parameters (e.g., camera intrinsics and user-camera distance) in online experimentation. Here, we propose appropriate calibration procedures and apply state-of-the art deep learning methods to data collected in an online experiment consisting of a battery of five eye-tracking tasks. We compare performance of different calibration strategies and perform a comprehensive evaluation of the models on measures, such as fixation accuracy, precision, smooth pursuit onset and angle, attended zone classification, saliency mapping, etc. Our results demonstrate a mean fixation error of 2.4 visual degrees for the best performing model which is a significant improvement over previous results from online eye-tracking studies (4.17° from Webgazer.Js).

Tracking a vocal group: A pilot study on multiple and simultaneous Eye-Tracking

Authors: **Matthias Seitz**[1]**; Ulrich Frick; Miles Tallon; Karina Gotthardt; Katrin Rakoczy; Daniel Mark Eberhard**[2]
[1] Hochschule Döpfer, Germany, [2] Katholische Universität Eichstätt-Ingolstadt, Germany
Corresponding authors: **mail@matthiasseitz.de, daniel.eberhard@ku.de**

Background
The proposed study focuses on ensemble singing in the masterclass setting and measures its study endpoints using modern methods like Ambulatory Assessment and Eye-Tracking. Although Eye-Tracking has certainly and repeatedly been used in music didactics so far, its use has mainly focused on the study of reading sheet music. To our knowledge, yet no studies have been published that had used Eye-Tracking in musical ensembles scrutinizing gaze behavior in a three-dimensional space. Nor have ambulatory assessment procedures been used to investigate listeners' learning engagement and attentional distribution in the masterclass setting. Therefore, the feasibility has to be tested in a pilot study enrolling a limited number of cases.

Method

The design is based on the general principle of masterclasses encompassing three actor groups: (1) active singers, (2) conductor, and (3) observing singers. All study participants will be equipped with tablets displaying sheet music and questions. During the measurement period, the active singers are guided in singing together according to a semi-standardized rehearsal plan confronting them with musical and didactic sample passages. Questions about the acute perception of the learning situation are displayed in predefined time intervals on the tablets. Scan paths (fixation points) will be categorized in five areas of interest: a) sheet music on the tablet, b) other singers, c) instructor, d) audience, e) other. Based on fixation durations, attention distribution and specific patterns thereof can reveal specific learning situations. By recording each singer, performance quality and interaction effects between singers may be identified. The data will be recorded using SMI BeGazeTM and Pupil Capture software and analyzed by innovative statistical methods (Hidden Markov Chains).

Objectives

This pilot study focuses on:

- Technical feasibility of mobile Eye-Tracking glasses to simultaneously measure the gaze behavior of several people in different roles
- Displaying musical notation on tablets with occasional insertion of questions
- Comparison of gaze behavior and attention in active vs. observing singers, as well as its dependence on musical parameters and the instructor´s intervention during the master class.

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www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2019/01/2232_bekanntmachung

Visualizing contemporary music using heatmaps analysis: A study combining music and the bouba-kiki effect

Authors: **Ivan Simurra**[1]**; Patricia Vanzella**[1]**; João R. Sato**[2]

[1] Universidade Federal do Acre, Brazil, 2 Universidade Federal do ABC, Brazil

Corresponding author: **ieysimurra@gmail.com**

Consistent associations between shapes and sounds have been described in the scientific literature. Nonsense words such as Bouba and Kiki, for example, are systematically associated with round and pointed-angular figures, respectively (Ramachandran and Hubbard, 2001). Associating sound with visual forms is also common while people listen to music and it seems that the timbre of the musical material mediates this cross-modal phenomenon (Adeli et al, 2014). Eye-tracking is a promising tool to investigate associations between musical sounds and visual stimuli. Through the analysis of heatmaps and fixations in areas of interest, in this ongoing study we investigate how modern music relates to specific visual forms.

Eleven 5-second sound stimuli in different timbres were recorded using overlapping instruments and non-standard composition techniques. Visual stimuli consisted of four visual shapes used in a previous study (Simurra, Sato, & Vanzella, 2020). A VT3 eye-tracking device from MangoldVision was used for data collection at a sampling rate of 60 Hz. Eight volunteers (mean age: 31.37 years, SD = 5.37, musicians and non-musicians) orally indicated the shape alternative that, in their opinion, best represented each sound they were hearing. The order of presentation of the auditory stimuli was randomized. The experimental session lasted approximately 45 minutes.

Our partial results suggest that certain acoustic features of the sound stimuli are associated with specific visual features, mainly concerning the types of angles at line intersections. On smooth sounds, fixations were greater in rounded shapes than in angular forms. In contrast, for jagged sounds, fixations concentrated on the edged boundaries of specific visual forms. A larger number of participants is necessary to confirm these findings.

This study is potentially useful for interdisciplinary research in timbre perception, cognition, eye-tracker, and modern music. The objective of the investigation at this stage focuses on the assessment of eye fixation as a good index to retrieve an individual's engagement in an artistic and multimodal experience.

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New directions for note reading within the Suzuki method using eye-movement research

Author: **Caitlin Smith**
Corresponding author: **caitlinsmithviolin@gmail.com**

The Suzuki Method of teaching musical instruments to children emerged in post-World War II Japan. Shinichi Suzuki was an amateur-violinist-turned-professional-music-educator who based his method on the idea that all Japanese children learn to speak Japanese with little difficulty. He called his system "The Mother Tongue Method." Key principles to teaching a child a musical instrument via the Suzuki Method include starting very young (preferably before the age of 5) and daily listening for multiple hours to the core repertoire. Reading notes on a page is delayed until the child can play in tune with beautiful tone. Then, as the child matures,

both in terms of technical ability and age, a Suzuki teacher adds note-reading components (International Suzuki Association, 2020).

The Suzuki Method is one of the world's most widely used music pedagogies (Kendall, 6). It has produced countless accomplished musicians—but it frequently produces musicians whose ability to learn by ear and memorize far outstrips their note-reading and sight-reading abilities. In fact, this inconsistency in musical ability is one of the most common stereotypes of and objections to the Suzuki Method (Barber, 1993).

This paper is a preliminary, data-driven analysis of how the existing literature and emerging directions on eye-tracking movement in music can contribute to closing the gap between teaching playing by ear and reading notes within the Suzuki Method.

Specific research findings explored include crucial differences between language and music, symbol relationships, musical stimuli, fixation durations and frequencies, Eye-Time Span, Early Attraction and Distant Attraction, and others. As the Suzuki Method is now used worldwide, this paper's evaluation of suggested future endeavors has vast potential interest and practical significance.

All aboard the groove (en)train(ment)!: Oscillatory brain and pupil activity varies with rhythmic complexity and groove ratings

Authors: **Connor Spiech**[1]**; Georgios Sioros**[1]**; Anne Danielsen**[1]**; Bruno Laeng**[1]**; Tor Endestad**[1]
[1] RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo, Norway
Corresponding author: **connor.spiech@psykologi.uio.no**

The pleasurable urge to move to music (often referred to as "groove") exhibits an inverted U-like relationship with rhythmic complexity. According to the Predictive Coding of Music (PCM) model, moderate levels of complexity spur movement to reduce sensory prediction errors and more accurately represent the metric structure in a process called active inference (Koelsch, Vuust, & Friston, 2019; Vander Elst, Vuust, & Kringelbach, 2022). When rhythmic complexity is too high and our sensory precision commensurately drops, a metric model to guide movement cannot be constructed. When rhythmic complexity is too low, movement isn't necessary to suppress the few prediction errors that arise. Here, we search for correlates of these patterns directly using EEG to measure sensory precision (via oscillatory approaches like steady-state evoked potentials) and pupillometry (specifically the rate the pupil size changes over time). Prior EEG work has demonstrated weaker entrained responses at beat frequencies to a syncopated (i.e., more complex) rhythm than an unsyncopated one (Nozaradan, Peretz, & Keller, 2016), but whether this persists into the upper extremes of complexity remains unclear. Pupillometry, on the other hand, seems to map onto groove – Bowling, Graf Ancochea, Hove, & Fitch (2019) found greater pupil dilations for groovy (compared to less groovy) and syncopated (compared to straight) rhythms, and work from our own lab found more sustained pupil

dilations for moderately complex drumbeats rated groovier (compared to less groovy high and low complexity drumbeats) (Spiech, Sioros, Endestad, Danielsen, & Laeng, under review). These studies, however, did not measure precision. Thus, we aim to extend past EEG research to a wider range of complexity and tie it to replicated pupillometry findings. Participants rated three drumbeats of varying complexity in terms of evoked urge to move, pleasure, and arousal. Preliminary results seem to show decreasing spectral power at beat frequencies with increasing complexity and more sustained pupil dilations for the groovier, moderately complex drumbeat, lending tentative support to the PCM model. Ongoing analyses to strengthen this evidence include correlating brain activity to stimuli structure and comparing event-related potentials for on- and off-beat events in different predictive contexts.

Sound-induced ASMR as investigated with pupillometry

Authors: **Anna Takeuchi**[1]**; Gerard Remijn**[1]
[1] Kyushu University, Japan

The Autonomous Sensory Meridian Response (ASMR) is the experience of feeling "tingling" sensations and feelings of relaxation and calmness in response to certain visual or auditory stimuli. Here we investigated the effects of sound-induced ASMR experiences on pupil dilation, using an eye- tracking device. First, we conducted a questionnaire (n = 43) in which the respondents were asked about their ASMR experience in response to a variety of auditory stimuli. Based on their answers, we selected 10 stimuli that would typically induce ASMR and 10 control stimuli. Each stimulus was then randomly presented for 20s, in which we measured the participant's pupil diameter (n = 30, right eye) by means of an eye tracker. Following this, the participant evaluated each stimulus on a 9-point rating scale on a) whether it induced ASMR, b) their preference for the stimulus, c) whether it induced feelings of relaxation, and d) whether it induced feelings of pleasantness.

The pupillometry results showed that the pupil diameter during the auditory ASMR stimuli (M = 5.24 mm, SD = 0.98) was significantly larger ($p < .05$) than during the control stimuli (M = 5.07 mm, SD = 0.96). In addition, the ASMR stimuli received significantly higher rating values than the control stimuli for all four evaluation items. Interestingly, though, a significant positive correlation ($r = 0.75$, $p < .001$) was observed only between the mean ASMR rating and the mean pupil diameter for each stimulus, but not between pupil diameter and the ratings for the other three items (pleasantness, preference, relaxation). The results thus clearly show that the experience of sound-induced ASMR is reflected in the listener's pupil diameter, which becomes larger when the ASMR sensation increases.

So far, many sound-pupillometry studies have focused on listening effort and the employment of attentional resources. Assuming that sound-induced ASMR comprises both cognitive and affective processing, future research with these and a wider variety of stimuli may help to better understand the physiological underpinnings of sound-induced pupil dilation.

Experienced choral conductors' score-reading strategies: Methodological triangulation with interviews, eye-tracking, and retrospective recall

Authors: **Maria Timoshenko**[1]**; Erkki Huovinen**[1]**; Marcus Nyström**[2]

[1] Royal College of Music in Stockholm, Department of Music Education, Stockholm, Sweden,

[2] Lund University Humanities Lab, Lund, Sweden

Corresponding author: **maria.timoshenko@kmh.se**

In curricula for choral conducting in higher music education, the overall perception of score design and outlining a conducting strategy are often seen as critical skills (Durrant, 1998; Kaufman & Flanders, 2020). Regarding score reading skills, there is rich pedagogical literature to draw upon (e.g., Battisti & Garofalo, 2000; Durrant, 2017; Varvarigou, 2016). Such skills could be effectively taught by explaining how expert conductors themselves relate to music processing (e.g., Durrant, 2003; Varvarigou, 2016). However, how experts' visual and cognitive strategies unfold over time as they read a choral score is largely unknown. Experts might be unaware of some aspects of the knowledge behind their superior performance (Sheridan et al., 2020), and they might even lose conscious control over some already-internalized processing approaches (Reingold & Sheridan, 2011; Samuels & Flor, 1997). The present study addresses expert choral conductors' general conceptions of score-reading strategies and their approaches to concrete silent-reading tasks.

Four experienced Swedish choral conductors participated in two studies. The first study investigated conductors' thoughts about their silent reading strategies, including pedagogical considerations. The semi-structured interviews were analyzed inductively, using a thematic analysis approach. We identified four broad themes to silent score reading based on the interviews. In the second eye-tracking study, the same conductors silently viewed 15 contemporary choral score excerpts for 30 seconds. For a deeper understanding of the practices in a silent-reading situation, this study also incorporated retrospective verbal reports, allowing both quantitative (gaze patterns) and qualitative information (retrospective verbal reports) regarding their silent score-reading processes. When viewing the score, conductors tended to shift between horizontal eye movements similar to those during text reading and vertical eye movements focusing on specific aspects of the choral score. According to participants' verbal descriptions, a holistic overview of the score appeared to be critical. For tentative accounts of the conductors' individual reading styles, we attempted to connect their characteristic eye-movement features with their cognitive interests, as revealed in verbal descriptions.

We conclude that methodological triangulation using interviews, eye tracking, and verbal reporting could provide a deeper understanding of silent score reading. Moreover, insights into experts' reading approaches could contribute to the choice of score reading procedures in choral pedagogy.

Pupillometry as tool to investigate absolute pitch ability

Authors: **Patricia Vanzella**[1]**; Guilherme Alves Delmolin Oliveira**[1]**; Thenille Braun Janzen**[1]**; Francisco J. Fraga**[1]**; João R. Sato**[1]

[1] Universidade Federal do ABC, Brazil

Corresponding author: **pmvanzella@gmail.com**

Absolute Pitch (AP) is the ability to identify and/or produce pitches without reference. Behavioral research suggests that accuracy of pitch identification is affected by the timbre of the stimulus- e.g., piano tones are easier to identify than sung tones. Based on the evidence that pupillary responses are a reliable indicator of the extent of central nervous system processing allocated to a task, we used pupillometry to investigate whether pitch labelling in different timbres (piano and voice) would require different amounts of cognitive resource allocation in AP possessors. To test this, we measured accuracy, response time, and pupillary responses of musicians with AP during a pitch-labelling test. Participants were 18 AP musicians (11 women, age M = 23 years, SD = 4.8) with an average of 9.8 years of formal music training (SD = 4.5). They were asked to verbally label tones in different timbres as fast and as accurately as possible. The task consisted of the presentation of a 1-second tone with a 5-second inter-stimulus interval, totaling 72 trials divided into 12 blocks (six per timbre). The tones presented included all pitches of the chromatic scale between A3 and Gsharp5. The response time was measured as the elapsed time between the onset of the stimulus and the onset of the participant's vocal response using a Voice Activity Detection algorithm while accuracy was measured by auditory recognition of each trial response. Pupil diameter was measured at a60 Hz sampling rate with an eye tracker (Mobile Eye-5 ASL).

Behavioral results revealed a significantly longer response time for vocal tones compared to piano tones. However, there was no difference in accuracy when comparing pitch identification in piano and vocal tones. Pupillary responses were significantly different across timbre conditions, with larger pupil dilation for vocal tones than piano tones. There was also an effect of key color on pupil dilation, with greater dilation for sung tones that corresponded to black keys.

These finings expand the current knowledge regarding how pitches in different timbres are processed by musicians with AP and add weight to the accumulating evidence that human voice has particular significance for human listeners. Evidence suggests that the human voice carries different levels of linguistic and paralinguistic information (e.g., identity and affective cues). Therefore, it may be that higher cognitive resources are needed to decode non-referential information (pitch chroma) from vocal stimuli when the task involves mappings with linguistic information (note names), warranting further research.

Measuring arousal with pupil dilation during experience of musical agency

Authors: **Marc Vidal**[1,2]**; Kelsey E. Onderdijk**[1]**; Ana Aguilera**[2]**; Tom Fritz**[3]**; Joren Six**[1]**; Pieter-Jan Maes**[1]**; Marc Leman**[1]

[1] Ghent University, Belgium, [2] University of Granada, Spain,

[3] Max Planck Institute for Human Cognitive and Brain Sciences, Germany

Corresponding authors: **marc.vidalbadia@ugent.be, kelsey.onderdijk@ugent.be**

In this study, the relationship between arousal (i.e., as measured through pupil dilation) and musical agency is investigated. However, as arousal and movement are intimately related, controlling for movement is warranted. Recent findings in rodents suggest slow pupil fluctuations during locomotion are an index of sustained activity in cholinergic axons, and as such slow pupil fluctuations might be of interest to investigate arousal induced through agency in humans, while controlling for the influence of mere bodily motion. Here, sixteen participants with musical training were recruited to perform vocal tasks under different movement conditions, which in various degrees engaged the agency experience of the performer. Our results suggest that ancillary movements during vocal performance modulate the slow drift of pupil diameter while affecting spontaneous pupil activity in higher frequency bands. Results further provide evidence of a complex dissociation in the acquired pupil data between movement and higher cognitive processes. A novel functional semiparametric methodology was applied to avoid confounding effects of responses to ocular events, as these are more likely to occur during complex motor tasks.

Auditory and visual cues in rhythmic entrainment of attentionto singers

Authors: **Youjia Wang**[1]**; Michael Burchesky**[2]**; Miriam Lense**[2]

[1] University of Illinois at Chicago College of Medicine, USA, [2] Vanderbilt University Medical Center, USA

Corresponding author: **ywang634@uic.edu**

Rhythm and timing play an important role in social interactions. Predictable rhythmic behaviors–such as those provided during speech and singing–serve to entrain attention to socially adaptive information beginning in infancy. When infants as young as two months of age view audio/visual (a/v) stimuli of infant directed singing, they increase gaze to the eyes of the singer, a fundamental marker of social engagement, during the strong rhythmic beats of the singing (Lense & Jones, 2017). However, it is unknown what cues contribute to this entrainment. During the course of a typical interaction, rhythm is specified cross-modally: for example, people use coordinated rhythmic speech, gestures, facial expressions, and movements. During singing, visual cues co-occur with auditory structure, and both infants and adults use visual cues to attend to and recognize singers (Trehub et al., 2013, 2015).

In the current study, we aim to replicate infant patterns of entrainment in an adult sample. We additionally manipulate the availability of auditory and visual information to parse the contributions of these cues. Adults (n = 25) watched videos of solo singing performances while eye-tracking data was collected. By measuring participant fixations to the eyes and mouth of the singer, we examined if entrainment was modulated based on the rhythmic structure in original a/v stimuli, visual-only stimuli (audio removed), and auditory-preserved visually degraded stimuli (via visual blurring and visual noise). Peri-stimulus time histograms revealed that adults' attention was rhythmically time-locked with increased attention to the eyes of the singer during the strong beats of singing, as is seen in infancy. Comparisons of entrainment across original and manipulated versions showed rhythmically time-locked increases in eye-looking of similar magnitude across all conditions. Additionally, the silent condition showed a significant decrease in the total amount of eye-looking accompanied by an increase in the amount of mouth-looking as compared to original condition (original: 62.5% fixation to eyes and 27.7% fixation to mouth; silent: 49.4% fixation to eyes and 43.4% fixation to mouth; p = .004). Yet, in the absence of auditory cues, adults were still able to use rhythmic visual cues in order to maintain beat-based entrainment of gaze to the eyes. These results suggest that social rhythmic entrainment when viewing singing is a robust and persistent behavior. Future studies will further probe multi-sensory rhythmic timing cues and the salience of their contributions to social visual entrainment during singing interactions.

Effects of luminance and arousal related baseline amplitude on the auditory phasic pupil dilation response

Authors: **Andreas Widmann**[1]**; Wolfgang Einhäuser**[2]**; Nicole Wetzel**[3]**; Phillip Alday**[4]

[1] University of Leipzig and Leibniz-Institute for Neurobiology, Madgeburg, Germany, [2] University of Technology Chemnitz, Germany, [3] Leibniz Institute of Neurobiology, Magdeburg, Germany, [4] Beacon Biosignals, USA

Corresponding author: **widmann@uni-leipzig.de**

Pupil diameter not only changes with the light level but the pupil also dilates in relation to arousal or cognitive processes, also referred to as psychosensory pupil dilation response. Little is known on the relation of luminance and arousal related baseline pupil diameter on the amplitude and shape of the auditory phasic pupil dilation response (PDR).

Here, we systematically examined this relation in an experiment presenting 24 participants with an auditory oddball paradigm including rare to-be-detected target and rare task irrelevant novel sounds among frequent standard sounds. We manipulated stimulus luminance in six blocked conditions between 0.3 and 100 cd/m2 resulting in linearly spaced baseline pupil diameters between 3.5 to 6.5 mm. The data were analyzed by means of temporal principal component analysis to separate the contributions of iris sphincter muscle relaxation due to parasympathetic inhibition and iris dilator muscle constriction due to sympathetic nervous system activation to the observed phasic pupil dilation response. Using means of linked linear mixed models, we separated the luminance

related changes from possibly arousal related spontaneous trial-by-trial fluctuations of baseline pupil diameter.

The early parasympathetic inhibition related component of the PDR increased linearly with increasing luminance (i.e., decreasing baseline pupil diameter). The late sympathetic activation related component of the PDR showed an inverse u-shaped relationship with small PDR amplitudes at low and high luminance levels (i.e., small and large baseline pupil diameters) but large PDR amplitudes at medium luminance levels. For the spontaneous, non-luminance related fluctuations we observed decreasing amplitudes of both PDR components with increasing baseline pupil diameter. Importantly, this decrease was stronger for task irrelevant novel sounds compared to task relevant target sounds. This suggests that the novelty induced arousal increase is larger at low baseline arousal levels and smaller at high baseline arousal levels while the target related enhancement is independent of baseline arousal level.

We discuss possible explanations for the observed results in terms of the dynamics and mechanical properties of the pupillary system. Our results imply that divisive baseline correction should be discouraged in pupillometry as the underlying assumption—the response amplitude is proportional to baseline amplitude—does not hold. Rather we observed the opposite—decreasing amplitudes of the PDR with increasing baseline or a non-linear relationship depending on latency. We propose regression-based baseline correction as a feasible alternative. To compare pupil dilation response amplitudes across studies or conditions, the precise control and report of the light level is mandatory.

Combining EEG and eye-tracking: The neural mechanisms underlying dynamic processing and learning of musical hierarchical structure

Authors: **Yiyang Wu**[1]**; Xiangbin Teng**[2]**; Yi Du**[1]

[1] Institute of Psychology, Chinese Academy of Sciences, China, [2] Freie Universität Berlin, Germany

Corresponding author: **duyi@psych.ac.cn**

Same as speech perception, music processing is affected by musical syntax. Previous studies in music neuroscience have shown that to what degree can listeners learn the musical syntax depends on their perception of musical hierarchical structures, and is modulated by their musical experience and allocation of attention. However, how does the brain track dynamic music information, especially the neural mechanisms of segmenting music pieces into meaningful units and establishing high-level musical structures online remain unclear. In this study, we aimed to examine (i) whether cortical oscillations can track high-level hierarchical musical structures (e.g., phrase), and (ii) what roles are played by ocular activities during musical processing.

We presented 10 Bach chorales each for 3 times consecutively to 29 non-musicians undergoing electroencephalogram (EEG) recording. Eye-tracking data were recorded via an EyeLink

Portable Duo eye tracker. The acoustic cues indicating phrasal structures were removed. Phrasal structures were disrupted by locally or globally reversing the harmonic progression to yield two reversal conditions in comparison with the original condition.

Results found that low-frequency neural oscillations, that entrained to the musical beat (1.417 Hz) and note (2.834 Hz), showed a significant decrease with repetitions. A similar pattern was observed for musical envelope reconstruction accuracy under all conditions except the local reversal condition. Using 2nd-order FFT, we derived the modulation spectrum of EEG power and discovered that the phrase tracking at 0.177 Hz was modulated by phrasal structure manipulation as the modulation magnitude was significantly stronger in the original and local reversal conditions than the global reversal condition. Phase precession index of the EEG power was also quantified to investigate the predictive process of musical phrase segmentation. Although the phases at phrasal boundaries were gradually accelerating when listening to original pieces at the first time, repetitions did not facilitate phrase learning, indicating that the prediction of musical phrase requires prior knowledge of classical music. Additionally, eye-tracking data showed that blinking activity was synchronized to the beat frequency, and even peaked at phrase boundaries in the original condition at the first time of listening. Cosine similarity between each participant's blinking activity and the average of the remaining participants increased with repetitions, revealing that subjects may implicitly develop a common pattern in processing musical hierarchies.

Our findings provide novel evidence that the brain parses musical hierarchical structure online via low-frequency neural oscillations, and the ocular activity plays a supporting role in it.