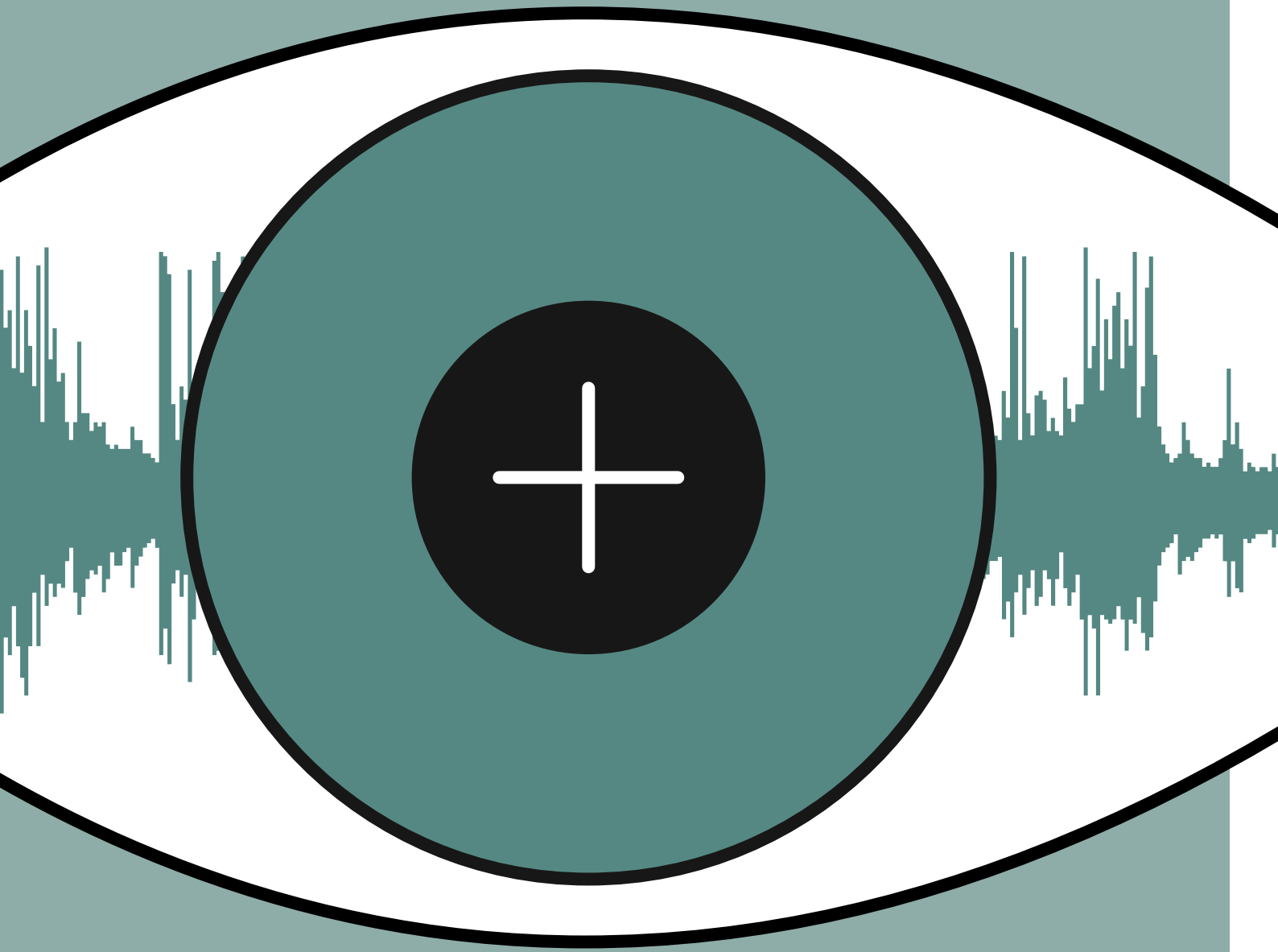
Conference on Music & Eye-Tracking

August 17th-18th, 2017

Max Planck Institute
for Empirical Aesthetics



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Conference Team

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OPENING KEYNOTE:

The eye pupil as a mirror to music's soul

Dr. Bruno Laeng, University of Oslo, Norway

"Music chills" are intense aesthetic/emotional responses to music. A defining characteristic is a set of bodily changes that occur at precise moments during music listening. The experience seems to be common, though there are strong individual differences both in their frequency and in their specific bodily expressions. Given that the bodily experiences are typical of activity of the autonomic nervous system, in particular sympathetic activity during states of intense attentional focus, we have studied in detail the pupillary response during listening and chills-inducing music. This pupil response offers a window into the phenomenon and may help also identifying some of the neural systems that underlie the experience. It remains unclear what are the musical features as well as associated non-musical factors that are responsible for the experience of music chills, also because the phenomenon is highly idiosyncratic and listeners differ greatly with respect to what kind of music and which of its elements elicit "chills".

Laeng, B., Eidet, L. M., Sulutvedt, U., & Panksepp, J. (2016). Music Chills: The eye pupil as a mirror to music's soul. *Consciousness and Cognition, 44*, 161-178.

DAY 1 Thursday, August 17th, 2017

12:30 **Registration desk open**

14:00 **Welcome & Opening Keynote**
Welcome: Lauren Fink & Elke Lange

The eye pupil as a mirror to music's soul
Bruno Laeng

Session 1: Pupillometry & Attention
Session Chair: Bruno Laeng,
University of Oslo, Norway

15:00 **Pupil dilation indexes the metrical hierarchy of unattended rhythmic violations**
Atser Damsma & Hedderik van Rijn

15:30 **Predicting attention to auditory rhythms using a linear oscillator model and pupillometry**
Lauren Fink, Brian Hurley, Joy Geng, Petr Janata

16:00 **What does pupil tell about musical processing?**
Hsin-I Liao, Makoto Yoneya, Makio Kashino, Shigeto Furukawa

16:30 **BREAK**
Coffee and cookies are provided

Session 2: Gaze & Instrumental Performance
Session Chair: Birgitta Burger,
University of Jyväskylä, Finland

17:00 **Eye-Hand synchronisation and interpersonal interaction in xylophone performance: A comparison between African and Western percussionists**
Fabrice Marandola

17:30 **Perceptual acuity and music teaching: Tracking teacher gaze**
Travis Marcum, Robert Duke

Poster Session and ArtLab tours
With light snacks and apertif

18:00 **Begin of Poster Session and ArtLab Tours**

19:00 End of Poster Session

19:20 End of Artlab Tours

ArtLab-Tours
led by Alexander Lindau (meet at ArtLab at any of the following four start times):

Tour 1: 18:00 – 18:20

Tour 2: 18:20 – 18:40

Tour 3: 18:40 – 19:00

Tour 4: 19:00 – 19:20 (priority for presenters of posters)

Posters
(organized by first author surname)

Arndt, Christin; Schlemmer, Kathrin; & Elke van der Meer:
Music in our minds: A pupillometric study of music processing.

Boehme, Almut:
The relevance of eye-tracking for the sight-reading of music and the development of digital technologies for the visually impaired musician.

Clendinning, Jane Piper; Hart, Sara; Rogers, Nancy; & Colleen Ganley:
Links between music theory and mathematics: Visual processing and strategies.

Hammerschmidt, David; Wöllner, Clemens; Albrecht, Henning; & Jesper Hohagen:
Music and slow motion: A study of eye movements in film and video clips.

Indraccolo, Allegra; Meloni, Roberta; Rizza, Aurora; Brunetti, Riccardo; & Marta Olivetti-Belardinelli:
The influence of musical style on pupil dilation during music perception and recognition: A pilot study.

Kreysa, Helene; Altmann, Carolin S.; Schneider, Dana; Zäske, Romi; & Stefan R. Schweinberger:
Explicit and implicit judgments of voice attractiveness and trustworthiness: Two pupillometry studies.

Lange, Elke; Pieczykolan, Aleksandra; Trukenbrod, Hans; & Lynn Huestegge:
The rhythm of cognition – Effects of an external auditory pacemaker on oculomotor control in exemplary cognitive tasks (reading and visual search)

Lörch, Lucas; Fehringer, Benedict; & Stefan Münzer:
Reading music. How tonality and notation influence music reading experts' eye movements, pupil dilation and performance in a pattern-matching task.

Rodziewicz, Agata; Krejtz, Izabela; & Katarzyna Kosmowska:
Similarities between text and music reading.

Simurra, Ivan Eiji; & João Ricardo Sato:
Analysis of pupil diameter during the listening of orchestral timbres: A case study.

Skaansar, Jo Fougner; Danielsen, Anne; & Bruno Laeng:
Pupil response reflects processing of musical micro- and polyrhythm. A study of musicians versus non-musicians.

Tang Poy, Colleen; & Matthew Woolhouse:
The effect of dance synchrony on perceived levels of attractiveness: A pupillary dilation study.

Timoshenko, Maria; Björk, Cecilia; & Fritjof Sahlström:
From unknown musical score to mature performance. A mixed-methods study of the learning process in a student choir.

DAY 2 Friday, August 18th, 2017

Session 3: Working Memory & Attention

Session Chair: Hsin-I Liao,
NTT Communication Science Laboratories, Japan

10:00 **Auditory attention, prediction, and surprise as reflected by eye movements and pupil dilation**
Andreas Widmann, Nicole Wetzel, Erich Schröger

10:30 **Dissociating the role of music predictability and liking in motor sequence learning**
Roberta Bianco, Ben Gold, Aaron Johnson, Virginia Penhune

11:00 **Physiological signatures of musical memory in frontotemporal dementia**
Elia Benhamou, Harri Sivasathiaseelan

11:30 **BREAK**
Coffee and cookies are provided

Session 4: Sight-Reading

Session Chair: Thierry Baccino,
University of Paris VIII, France

12:00 **The interplay of rhythm symbols, melodic patterns and expertise during music reading: A review of eye-movement studies in 1994-2017**
Marjaana Puurtinen

12:30 **Expert musical reading is supported by activation of harmony rules during cross-modal integration**
Véronique Drai-Zerbib, Thierry Baccino

13:00 **Statistical modelling of eye movements during simple sight-reading**
Anna-Kaisa Ylitalo, Aila Särkkä, Marjaana Puurtinen, Erkki Huovinen

13:30 **LUNCH**
Sandwiches and finger food are provided on the fourth floor, Rooms: 417-419 and 412-413

Session 5: Performance & Motion Capture

Session Chair: Fabrice Marandola,
McGill University, Canada

14:30 **Synchronizing eye tracking and optical motion capture: How to bring them together**
Birgitta Burger, Anna Puupponen, Tommi Jantunen

15:00 **Gaze behaviour in musical trios: methodological issues and analytical claims**
Sarah Vandemoortele, Kurt Feyaerts, Mark Reybrouck, Geert De Bièvre, Geert Brône, Thomas De Baets

15:30 **Mapping visual attention of ensemble musicians during performance of „temporally-ambiguous" music**
Laura Bishop, Werner Goebl

16:00 **BREAK**
Coffee and cookies are provided

Session 6: Audiovisual Scenes & Film

Session Chair: Jörg Fachner,
Anglia Ruskin University, UK

16:30 **Do auditory rhythms influence eye movement statistics?**
Michael Plöchl, Jonas Obleser

17:00 **Scene perception while listening to music: The eye-tracking study**
Marek Franěk, Roman Mlejnek, Denis Šefara, Jan Petružálek

17:30 **Film sound design: Do "sound stems" influence gaze?**
Jonathan P. Batten, Tim J. Smith

18:00 **Panel Discussion**

Discussion to wrap up the conference topic on what eye movements, pupil dilation, and blinking activity tell us about musical processing

Panelists: Thierry Baccino, Birgitta Burger, Jörg Fachner, Bruno Laeng, Hsin-I Liao, Fabrice Marandola

Moderators: Lauren Fink & Elke Lange

19:00 **End**

19:45 **SOCIAL DINNER**
at Restaurant "Zur Sonne"

On-site Exhibitors

(17. & 18. August, location: Library, Ground Floor)

Tobii Pro (Carsten Gondorf)

Okazo Lab: EventIDE – a modern software platform for designing behavioural experiments and eye-tracking studies (Ilia Korjoukov and Maria Molodova)

SOCIAL DINNER:

Zur Sonne in Frankfurt-Bornheim

HOW TO GET THERE:

From the MPI-EA take the underground from Grüneburgweg (lines U1, U2, U3, U8, U9 – direction Südbahnhof) to Hauptwache.

At Hauptwache change to U4 (direction Enkheim or Seckbacher Landstraße). Get off at Bornheim Mitte.

Go in the driving direction of the underground, take the front exit and continue walking in this direction as soon as you are on the street.

Now you walk north on Berger Straße for about 15 minutes. First you cross Saalburgstraße. Then you have to cross Fünffingerplätzchen ("Fivefinger-square"). Cross the square until you find yourself back in Berger Straße. Continue walking on Berger Straße until you arrive at No. 312 on the right side.

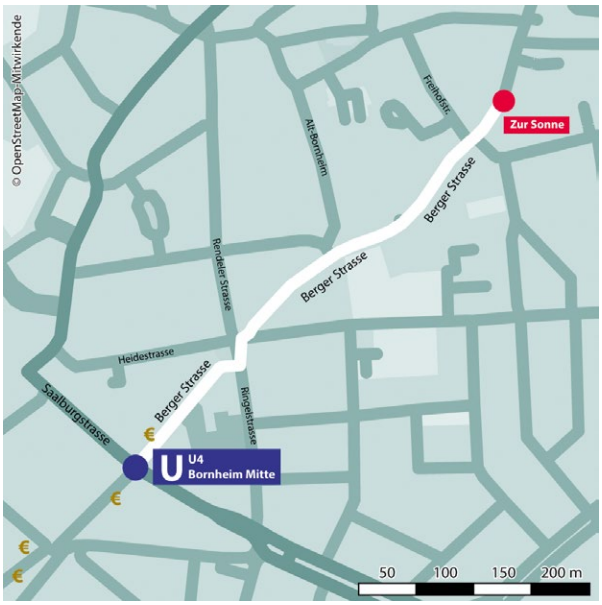
BANKS:

Please note that the restaurant does not offer EC-Card payment, only cash. You can find banks around the Bornheim Mitte station, e.g. in Wiesenstraße. Just walk down Berger Straße (against the driving direction of the underground) towards the little clock tower.

THE RESTAURANT:

"Zur Sonne" is a typical traditional Restaurant that exists since 1768. It offers a lot of Frankfurts own specialties such as *Grie Soß* (green herbs-sauce), *Handkäs'* (marinated sour milk cheese), *Äppler* (Applewine) or *Mispelchen* (digestif with Calvados and Medlar) as well as diverse meat-dishes and also vegetarian dishes with reasonable pricing.

It offers a big beer-garden to enjoy the setting sun and we have reserved 5 Tables there. However, if it is too cold, we will switch to inside, with a room reserved for us only.



Find more information at:

www.zursonne-frankfurt.de

Abstracts of Presentations

Arndt, Christin[1]; Schlemmer, Kathrin[2]; & Elke van der Meer[1,3]:

Music in our minds: A pupillometric study of music processing

[1]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [2]Department of Musicology, Katholische Universität Eichstätt-Ingolstadt, Germany, [3]Berlin School of Mind and Brain, Germany

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The present study investigated the processing of music with pupillometrics. 25 musicians and 25 non-musicians participated in this experiment and were asked to solve the Audiation task (Gordon, 1989). Behavioral measures to examine speed and accuracy of processing as well as the pupil peak dilation as a measure of resource allocation were collected. In addition, phonological and visual-spatial working memory capacity and crystallized and fluid intelligence were assessed. Musicians solved the Audiation task faster and more accurately than non-musicians. Musicians also outperformed non-musicians in the phonological working memory capacity, as well as in crystallized intelligence. Further and most importantly, musicians exhibited greater task-related pupil peak dilations. Behavioral evidence indicates a general enhancement of both phonological working memory and crystallized intelligence in musicians. The pupillometric findings indicate that musicians compared to non-musicians allocate more cognitive resources while performing musical tasks. Results correspond to findings for experts vs. non-experts in the mathematical domain (Bornemann et al., 2010) and emphasize the important contribution of resource allocation in expertise.

Bornemann, B., Foth, M., Horn, J., Ries, J., Warmuth, E., Wartenburger, I., & van der Meer, E. (2010). Mathematical cognition – Individual differences in resource allocation. The International Journal of Mathematics Education, 42(6), 555-567.

Gordon, E. (1989). Advanced Measures of Music Audiation (AMMA), GIA Publications.

Batten, Jonathan P.; & Smith, Tim J.:

Film sound design: Do "sound stems" influence gaze?

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Modern film production is a highly-refined craft in which the production team believe they employ techniques that can guide the viewers' attention around a scene, influence emotion, and convey the narrative. A common practice in sound design is to divide the sound into three distinct "stems": music, sound effects (SFX) and dialogue. The music is added to reinforce the pacing of action and add emotion. The SFX which are both of the scene (diegetic), for example foley sounds, and not (non-diegetic) are intended to foreground sonified objects, guiding the viewer's gaze to audiovisual objects. The final stem is dialogue (both diegetic and narration), which when attributed to a visible character is expected to orient gaze to that speaker. Empirical testing of these separate sound-stems and how they influence viewers' gaze is limited, with most research commonly comparing a final mix of the film sound to silence.

We eye-tracked 48 participants who free-viewed two 'found' experiments, firstly a 50 second clip from the animated film How to Train Your Dragon (DeBlois & Sanders, 2010), presented either with an isolated sound stem (music, SFX and dialogue) or a silent condition (12 participants were randomly assigned each condition). Secondly an exemplar of diegetic sound design by Walter Murch, the opening 2 minutes 54 seconds of The Conversation (Francis Ford Coppola, 1974) a continuous slow-moving shot of a busy market square, which was accompanied by diegetic sound without dialogue (for half of the participants) and a silent condition. Participants free-viewed the clips expecting a memory test and completed a self-report measure of arousal and excitement which asked how the clip made them feel. Eye movement differences between the groups were compared, in addition to pupillary variance and self-report measures.

The gaze within and between the conditions for both clips was generally localised to the screen centre and clustered around points of high motion and faces, a behaviour coined 'attentional synchrony' (Smith & Mital, 2013), irrespective of the sound condition. Interestingly, whilst the How to Train Your Dragon self-report measures indicate significant differences in arousal and enjoyment between the music and silent conditions the normalised pupillary variance (a measure of arousal) was not significantly different between the groups, rather they uniformly varied (across all conditions) in response to changes in luminance. In neither clip did the addition of sound to an object significantly alter the probability of fixating it, and only in one instance in The Conversation, with a non-centred dog barking did the sound significantly reduce the time to fixate it. This generally invariant film viewing behaviour is further evidence for the tyranny of film hypothesis (Loschky, Larson, Magliano & Smith, 2015), which argues that cinematic compositional techniques such as central framing, depth of field and editing ensure systematic viewing patterns and limit the opportunities for individual differences. Future work is required to generate scenes with isolatable sound stems that could capture and influence eye movement without such compositional constraints.

Loschky, L. C., Larson, A. M., Magliano, J. P., & Smith, T. J. (2015). What Would Jaws Do? The Tyranny of Film and the Relationship between Gaze and Higher-Level Narrative Film Comprehension. PLoS ONE, 10(11), e0142474–23.

Smith, T. J., & Mital, P. K. (2013). Attentional synchrony and the influence of viewing task on gaze behavior in static and dynamic scenes. Journal of Vision, 13(8), 16–16.

Benhamou, Elia; & Harri Sivasathiaseelan:

Physiological signatures of musical memory in frontotemporal dementia

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Background: Music is a useful probe of information processing mechanisms in major dementias. To date, however, most work in patients with dementia has addressed music recognition using neuropsychological tests. Here, we employed a novel paradigm combining a behavioural task with pupillometry, in order to assess autonomic correlates of musical semantic memory and musical deviance processing in patients representing syndromes of frontotemporal dementia (FTD).

Methods: We studied patients with semantic dementia and progressive nonfluent aphasia in relation to healthy older individuals. We designed a novel musical battery to assess detection of notes with key-preserving deviant pitch in familiar melodies (derived from a local database for healthy older British individuals). Performance on this task (which depends on musical semantic knowledge) was compared with detection of timbral deviants (a behavioural measure of acoustic change processing) and elementary pitch interval processing. We also presented a control set of familiar and unfamiliar melodies without embedded deviants. Pupillometry was obtained during presentation of all melodies, in order to assess autonomic responses to musical deviance and to musical familiarity per se.

Results: Relative to healthy controls, patients had behavioural deficits of pitch deviant detection and more variable deficits of timbral deviant detection. Pupil responses to timbral deviance were similar in all participant groups. However, pupil responses to melodic deviance were significantly reduced in the patient groups. In addition, pupil responses to unfamiliar melodies were greater than responses to familiar melodies both in healthy individuals and in semantic dementia, whereas this differential pupillary response was significantly reduced in progressive nonfluent aphasia.

Conclusions: Our findings suggest that dementia syndromes show separable profiles of physiological reactivity to musical familiarity and deviance. These profiles may reflect differential involvement of neural algorithms that match incoming musical information against stored 'templates' (musical predictive coding and error detection). Further work is needed to establish the validity of music as a gateway to these fundamental neural computational processes in larger cohorts of patients with dementia and with structural and functional neuroanatomical correlation.

Fletcher, P. D., Nicholas, J. M., Downey, L. E., Golden, H. L., Clark, C. N., Pires, C., … Warren, J. D. (2016). A physiological signature of sound meaning in dementia. Cortex, 77, 13–23.

Golden, H. L., Clark, C. N., Nicholas, J. M., Cohen, M. H., Slattery, C. F., Paterson, R. W., … Warren, J. D. (2016). Music Perception in Dementia. Journal of Alzheimer's Disease, 1–18.

Bianco, Roberta[1]; Gold, Ben[2]; Johnson, Aaron[1]; & Virginia Penhune[1,3]:

Dissociating the role of music predictability and liking in motor sequence learning

[1]Department of Psychology, Concordia University, Montreal, QC, Canada, [2]Montreal Neurological Institute, McGill University, Montreal, QC, Canada, [3]International Laboratory for Brain, Music and Sound Research (BRAMS), University of Montreal, Montreal, QC, Canada

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In this study we examine two questions: which aspects of melodic structure induce change in pupillary response as an indicator of preference formation (Graham, Lee, & Gingras, 2015) and how preferences and predictability effects interact on audio-to-motor transfer of melodic representation during piano learning (Lahav, Saltzman, & Schlaug, 2007).

To this aim, we manipulate the contexts of simple melodies in terms of (i) tonal predictability (the extent of non-scale pitches, high/low information content, see Pearce & Wiggins, 2006) and (ii) higher-level organization of notes, or contour (repeated/non repeated intervallic patterns). These factors and motoric variables (movement transitions, fingers used to play) are kept constant for the ending notes that participants will learn to play on the piano. During the listening session, pupil dilation and self-report liking ratings are measured for each melody. In the following practice session, participants listen to the melodic contexts and complete them by playing the relative set of ending notes on a midi piano. We hypothesise that tonal predictability and contour of musical contexts may differently contribute to preference formation, and this should be reflected by differences in sustained pupil dilation. Crucially, if the effects of preferences on motor sequence learning can be dissociated from the predictability properties of upcoming events, then we would expect enhanced motor learning rate and performance accuracy not only for predictable sequences, but also for those sequences that are less predictable, yet are reported as liked.

The outcome of this study will be relevant to uncovering under which conditions sequential movement organization benefits from predictions invoked by the musical context, and/or subjective preference derived by certain degrees of music unpredictability.

Graham, D. J., Lee, Y., & Gingras, B. (2015). The Eye is Listening : Music-Induced Arousal and Individual Differences Predict Pupillary Responses. Front Hum Neurosci, 9(November), 1–12.

Lahav, A., Saltzman, E., & Schlaug, G. (2007). Action representation of sound: audiomotor recognition network while listening to newly acquired actions. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 27(2), 308–14.

Pearce, M. T., & Wiggins, G. a. (2006). Expectation in melody: the influence of context and learning. Music Perception, 23(45), 377–405.

Bishop, Laura[1]; & Werner Goebl[2]:

Mapping visual attention of ensemble musicians during performance of "temporally-ambiguous" music

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During performance, musicians are in constant motion. Their movements serve (sometimes simultaneously) sound-producing, communicative, and self-regulatory functions. For audience members, the opportunity to see a performer's movements can affect their perceptions of coordination, expression, and performance quality. For ensemble musicians, the opportunity to see each other can facilitate temporal coordination, particularly in conditions where different performers might have different interpretations of the timing. Researchers have already investigated the conditions that encourage the use of visual communication among ensemble performers, and attempted to pinpoint how information like beat position is communicated via body gestures. Still unclear is where musicians focus their visual attention when looking towards a co-performer (e.g., at the face vs. at the instrument), and in what other ways visual communication might benefit performance (e.g., by bolstering feelings of engagement and confirming joint understanding). The current experiment tests the hypothesis that visual communication between ensemble members both 1) facilitates coordination by clarifying intended timing (particularly when an „unpredictable" piece structure causes performers to be uncertain about each other's interpretation) and 2) enables confirmation of joint attention and understanding.

Eye gaze (using mobile eye tracking glasses), motion capture, and audio/MIDI recordings are collected as piano and clarinet duos perform an unfamiliar piece. The piece, written specifically for this study, includes passages in free meter, alternations between specified meters, and periods of contrasting accent patterns in primo and secondo parts. The primo and secondo parts are not difficult to play individually, but the structure of the piece makes it difficult for a duo to coordinate. Experiment sessions are conducted like a structured rehearsal. Three complete performances (with two-way visual contact between musicians) are recorded at the start, middle, and end of the session, followed by an additional performance, during which musicians' views of each other are obscured.

Eye gaze vectors are then mathematically remapped to the motion capture space, so that we can identify when performers are looking towards each other. Data collection is still ongoing, but we expect an analysis of eye gaze patterns to show that performers look towards each other mostly during periods of high musical unpredictability (e.g., during the section with free meter). The time musicians spend looking towards each other should decline across successive performances, showing that reliance on visual communication decreases as the performers settle on a shared interpretation and become certain of each other's intentions. At the same time, the occurrence of co-performer-directed glances should become more predictable, as they (and certain body gestures) become a part of the practiced performance action sequence. In line with prior research on gestural communication (i.e., sign language), we also expect performers to focus their gaze mostly on each other's faces, rather than on peripheral body movements. Such a finding would support our hypothesis that performers visually monitor each other's attention and seek confirmation of joint understanding. Overall, our results should clarify the contribution visual communication makes to successful musical duo interaction.

Boehme, Almut:

The relevance of eye-tracking for the sight-reading of music and the development of digital technologies for the visually-impaired musician

Independent Researcher, UK

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Orchestral and choral musicians are often required to be advanced sight-readers. The act of sight-reading music puts extra-ordinary demands on the human eye which becomes very apparent when comparing the outcomes of the human eye reading music with digital devices that are already available today to help visually-impaired musicians sight-read adapted scores.

This paper presents examples of different situations and solutions that aim at enabling visually-impaired musicians retain their sight-reading skills. State of the art technologies such as optical music recognition, alternative music formats and digital music stands will be discussed and their uses in real music situations examined. Furthermore aspects of eye tracking and their relevance to the development of asstive technologies for the sight-reading visually-impaired musician will be considered.

Comparing research in eye-tracking in the context of sight-reading with current technologies for visually-impaired musicians it appears that the main problem is that the human buffering sequence of eye movement during the sight-reading process outstrips current technology where the buffering takes too long to be viable for sight-reading.

Developers of assistive technologies for the reading of music scores do not fully recognise the needs of the sight-reading musician at advanced level as much research and development has been carried out in educational contexts where the speed required for advanced sight-reading is not essential. For example, digital music stand technologies work with moving from one page to the next using ped-

als, usually in e-reader fashion where the page goes blank for a split second or they allow tabbing from one bar to another. The sight-reading visually-impaired musician requires a digital music stand where the music scrolls continually in ‚TV autocue' fashion, where the speed can be controlled as the speed of the music changes. The speed aspect moving through the score is currently a problem which may be solved if the buffer of digital technologies can be advanced enough to compare to that of the human eye.

A positive outcome of this paper would be inter-disciplinary research and development between Music Eye Tracking and Eye Movement researchers and assistive technologies developers to find solutions for the sight-reading visually-impaired musician.

Madell, J. & Hébert , S. (2008). Eye Movements and Music Reading: Where Do We Look Next? Music Perception: An Interdisciplinary Journal, 26 (2), 157-170.

Rayner, K. & Pollatsek, a. (1997). Eye Movements, the Eye-Hand Span, and the Perceptual Span during Sight-Reading of Music. Current Directions in Psychological Science, 6, (2), 49-53.

Burger, Birgitta[1]; Puupponen, Anna[2]; & Tommi Jantunen[3]:

Synchronizing eye tracking and optical motion capture: How to bring them together

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Both eye tracking and motion capture technologies are nowadays widely used in music research, although usually separately. However, the combination of measuring both eye and body movements simultaneously would offer great potential for investigating action-perception links and cross-model interaction in musical behavior, especially in communicative and joint actions, such as making music or dancing together.

In a pilot attempt, we combined an Ergoneers Dikablis head mounted eye tracker (http://www.ergoneers.com/eye-tracking/dikablis-glasses/) with a Qualisys Oqus optical motion capture system (http://www.qualisys.com/cameras/oqus/). In order to synchronize the recordings of both devices, Qualisys offers a plug-in solution, which, however, is rather costly and technically somewhat challenging requiring two computers and a wireless network connection in-between them. Furthermore, a more generalizable solution for synching both technologies would be favorable, since there are several manufacturers of both eye tracker and motion capture devices available without ready-made synchronization solutions.

In order to be able to easily and reliably synch the devices, we developed a semi-automatic approach. In the beginning of each recording, the participant – equipped with eye-tracker and motion caption markers – is advised to quickly nod (i.e. move their head down- and upwards) while keeping their eyes open and fixed to a point in space (i.e. a target on the wall). This results in sharp vertical displacement of both the eye and head marker data that can be detected and aligned using computational methods.

In case of clean data (i.e. participants kept their eyes open and fixed), the data of eye tracker and motion capture could be computationally processed and accurately synchronized using a peak-picking algorithm that reliably detected the vertical displacement of the eye and head movement in the beginning of the recording. However, if participants were unable to keep their eyes open during the nod, the blink of the participants had to be manually processed by predicting and adding the pupil movement first. After this manual adjustment, it was possible to adequately synchronize the eye tracker data to the motion capture data using the above-mentioned method.

This method produces accurate synchronization results in case of clean data, but requires additional manual work in case the nodding procedure has not been performed correctly. However, if these challenges can be overcome – either by instructing the participants very carefully and making sure they can comply with the task or by manually adjusting the pupil movement by filling the blink afterwards – this method provides an attractive alternative to costly plug-ins as well as offers a solution in case ready-made synching solutions are not available.

Chan, Grace; & Neal Peres Da Costa:

Two hands, two feet and both eyes: Incorporating eye-tracking technologies into virtual pipe organ performance.

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Playing the pipe organ physically consumes all four human limbs in activating complex sound modulating interfaces: multiple keyboards, pedals, stops, pistons, swell boxes. Unification of these tasks by a skilled organist is akin to a moving meditation that harmonizes physical action, perception and cognition to make music.

The advent of high quality real organ sample-sets powered by a computer, played on MIDI keyboards with touch screen organ stop controls, has allowed organists to experience ultra-realistic sonic representations of historically significant organs in locations that are remote from the original instrument1. Virtual reality becomes a conduit to organ learning, teaching and performance.

The Historical Performance Unit, Sydney Conservatorium of Music, University of Sydney, has been investigating the use of commercially available eye-tracking technology to interact with this novel touch screen interface on our virtual pipe or-

gan2. This allows the organist to change organ registrations with eye fixation or finger touch. This is particularly interesting when applied to the art of organ improvisation where the musician is creating music in the moment without preplanned registration changes that can be accomplished by a traditional piston system3. With eye-tracking technology, the organist can continue to make music with both hands and feet while adjusting registrations with their gaze. Without eye-tracking technology, organists would have to stop playing with one or both hands to change organ registrations. Eye tracking applications have the potential to push the boundaries of organ performance by harnessing a previously unavailable body-instrument interaction4.

Milan Digital Audio (2017) Hauptwerk Virtual Pipe Organ. Retrieved from https://www.hauptwerk.com

Tobii AB (2017) Tobii Eye Tracking. Retrieved from https://tobiigaming.com

Organist Mr Olivier Latry improvises on a submitted theme at the University of Notre Dame, USA. https://www.youtube.com/watch?v=dxMkmOEkcBA

De Souza, J. (2017) Music at Hand: Instruments, Bodies and Cognition, Oxford Studies in Music Theory. Oxford University Press, Oxford, England, UK

Clendinning, Jane Piper[1]; Hart, Sara[2]; Rogers, Nancy[1]; & Colleen Ganley[2]:

Links between music theory and mathematics: Visual processing and strategies

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Widespread beliefs in links between mathematics and music date back to the Ancient Greeks. Although researchers have reported positive correlations between mathematical and musical abilities, scholarly literature provides little insight into the specific nature of these connections. In particular, there is scant empirical study of the association between abilities in mathematics and music theory. The Mathematics and Music Theory Multidisciplinary Project brings together faculty from two fields—psychology and music—to examine this phenomenon. To date, our research has included study of seven years of data comparing student performance in music theory and mathematics that provided statistical confirmation that a connection between mathematics and music theory warranted further investigation; development and implementation of a screening tool that predicts incoming students likely to experience unusual difficulty with core music theory courses; interviews with selected students regarding their strategies for engaging music theory tasks; and administration of the screener to students from five other universities around the United States.

Our research demonstrates significant correlations between music theory performance and abilities to identify visual patterns (including geometric shapes, successions of letters, and notes on a musical staff) and the ability to recognize representations of rotated three-dimensional objects. We are now investigating these effective predictive tasks using eye tracking to reveal systematic differences in approach between subjects of varying abilities and experience. Using regions of interest, we examine whether experts (doctoral students and faculty in a prominent college of music) and novices (undergraduate students who can read music with varying music theory experience) attend differently to high-information notes compared to notes that are less important to the task.

For instance, we have demonstrated that the ability to quickly distinguish musical triads from other structures is a good predictor of future performance in music theory classes. We present notes aligned vertically on a single musical staff in various registral configurations, some exceeding an octave, and ask participants whether the notes conform to a triadic structure. In identifying a non-triad, we anticipate an expert may immediately focus on the pitch that makes a triadic structure impossible, whereas a novice may look equally at all three notes or show no particular pattern of attention. When triads are widely spaced, we anticipate that experts may look at the location of a "missing" note then look for that note in another octave or visually "move" a note, whereas novices may be less likely to exhibit this systematic strategy.

Given that we have revealed specific visual-spatial skills that correlate with music theory ability, we are also interested in whether the ways that people visually process music theory tasks are similar to the ways they process other tasks also requiring pattern recognition, such as logic tasks, spatial tasks, and math tasks. We hope that eye tracking will provide evidence of systematic cognitive patterns shared by both. This latest component of the Math and Music Theory Multidisciplinary Project is underway, with subjects to be tested in April and June 2017, and results to present at the August conference.

Damsma, Atser; & Hedderik van Rijn:

Pupil dilation indexes the metrical hierarchy of unattended rhythmic violations

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When we listen to music, we perceive regularities that drive our expectations. This is reflected in beat perception, in which a listener infers a regular pulse from a rhythm. However, it is still an open question whether attention to the music is necessary to establish the perception of a hierarchy of stronger and weaker beats, or meter. In addition, to what extent beat perception is dependent on musical expertise is still unknown. We addressed these questions by measuring the pupillary response to omissions at different metrical positions in drum rhythms, while participants attended to another task. We found that the omission of the most salient first beat elicited a larger pupil dilation than the omis-

sion of the less salient second beat. These results show that participants perceived stronger and weaker beats without explicit attention to the music, suggesting that hierarchical beat perception is an automatic process that requires minimal attentional resources. In addition, we found that this perception of meter was independent of musical expertise. Finally, our results show that pupil dilation reflects surprise without explicit attention, demonstrating that the pupil is an accessible index to unattentive processing.

Drai-Zerbib, Véronique[1]; & Thierry Baccino[2]:

Expert musical reading is supported by activation of harmony rules during cross-modal integration

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Multisensory integration of musical information is an important process in music reading. Integrate many sensory inputs (visual, auditory, motor) into a coherent pathway emerges during development of musical skill. We hypothesize that more skilled musicians can retrieve information across auditory and visual modalities, activating harmony rules as retrieval cues. The aim of the present research is to investigate this issue using the eye-tracking technique. Musicians (experts and non-experts) were asked to detect as fast as possible a modified note between listening and reading phases. Randomized fragments of classical music were sequentially versus simultaneously displayed in cross-modal presentation on a computer. The note was modified in the same tone mode or in a violation tone mode. Results from ocular measures and modified note detection accuracy validated the hypothesis of expert memory using harmony rules as retrieval cues. However, sequential presentation was more difficult than simultaneous one: number of fixations and gaze duration were shorter when fragments were displayed simultaneously compared to sequentially. Experts made significantly less fixations than Non-Experts when they listened and read the fragments simultaneously but this difference between expert and non-experts was no longer significant when it came sequentially. Results are discussed in terms of amodal processing in expert memory (Ericsson & Kintsch, 1995; Drai-Zerbib & Baccino, 2014).

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Drai-Zerbib, V., & Baccino, T. (2014). The effect of expertise in music reading: cross-modal competence. Journal of Eye Movement Research, 5(6), 1-10.

Fink, Lauren K.[1,2]; Geng, Joy J.[1,2,3]; Hurley, Brian K.[1,3]; & Petr Janata[1,2,3]:

Predicting attention to auditory rhythms using a linear oscillator model and pupillometry

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Multiple studies have shown facilitation of auditory and visual responses when targets of either modality are presented simultaneously with a salient beat in musical time. Most of these studies assume their stimuli follow a hierarchical music-theoretic model of time ('strong' and 'weak' beats), though often music is found pleasurable by virtue of violations of this hierarchy. Here we assess the potential of a stimulus-driven linear oscillator model (Tomic & Janata, 2008) to predict dynamic attention to complex musical rhythms, beyond 'strong' and 'weak' beats. In addition to calculating participants' perceptual thresholds for detecting deviants at time points of varying predicted salience, we measured pupil size as an index of attentional state. In our task, participants listened to continuously looping rhythmic patterns and responded anytime they heard a change in volume (200ms deviant; increments/decrements by block). An adaptive thresholding algorithm adjusted the intensity of each deviant at multiple temporal positions throughout each pattern. Interestingly, the pupil dilated to both increment and decrement deviants and was a reliable index for distinguishing detected vs. undetected deviants. A significant negative correlation was found between model-predicted temporal salience and perceptual threshold, highlighting our model's ability to predict dynamic attention.

Franěk, Marek[1]; Mlejnek, Roman[2]; Šefara, Denis[1]; & Jan Petružálek[1]:

Scene perception while listening to music: The eye-tracking study

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Music can be listened to with a large number of everyday activities. One of these activities may be listening when walking in an outdoor environment. Music can in some extent mask surrounding visual information while travelling or walking in an outdoor environment. To make a step further in order to deeply understand the described processes we need to know more about visual cognitive processing of outdoor scenes while listening to music. The eye-tracking methodology can provide a new insight to these processes. Recent investigations Schäfer and Fachner, 2015, Maróti et al., 2017) suggest that music reduces eye movement activity. The present study was designed to investigate effect of two different types of music compared to non-music condition on eye movements while perceiving various nature and urban outdoor scenes. The participants were asked to observe twelve photographs of urban scenes and twelve photographs of nature scenes. The photographs were presented in a random order. The eye movements were recorded using Tobii X2-60 eye tracker. In music conditions, the participants simultaneously listened to music. The first type of music was a fast piece of music (187 bpm), which motivates to bodily movement (for the definition of motivational music, see Karageorghis, Terry, and Lane, 1999), the second type of music was a slow piece of music (69 bpm). The both musical excerpts have been used in our previous study (Franěk, van Noorden, and Režný, 2014) and it was found that they have influenced tempo of a pedestrians walk. A number of eye fixations and their durations were measured and analyzed. ANOVA calculated for mean number of eye fixations indicated a statistically significant effect of the music condition and a statistically significant effect of the type of outdoor scene. There were no significant interactions. The same results were found for mean eye fixation durations. The results revealed that the mean number of fixations was significantly higher in no-music condition than in the both music conditions. The mean fixation durations were significantly shorter in no-music condition than in the both music conditions. In addition, the mean number of fixations was significantly higher for urban scenes than for nature scenes. The mean fixation durations were significantly shorter for urban scenes than for nature scenes. The results confirmed the prediction that that music listening while perceiving visual information reduces eye movement activity. However, we did not find differences in eye movements between fast and slow music condition. While Maróti et al. (2017) reported that fast drum grooves modulated the rate of eye movements, we did not confirm this finding in the present study. In addition, we found differences in eye movements between both types of outdoor scenes. It is consistent with the recent finding from environmental psychology. It is assumed that our visual system more fluently processes certain aspects of the visual structure of natural scenes compared to urban scenes. Our data showed that listening to different types of music did not influence the described effect of different visual properties of outdoor scenes.

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Karageorghis, C. I., Terry, P. C., & Lane, A. M. (1999). Development and validation of an instrument to assess the motivational qualities of music in exercise and sport: The Brunel Music Rating Inventory. Journal of Sports Sciences, 17, 713-724.

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Hammerschmidt, David; Wöllner, Clemens; Albrecht, Henning; & Jesper Hohagen:

Music and slow motion: A study of eye movements in film and video clips

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Background: Slow motion scenes in audio-visual media are a widely used technic that strongly affects their viewers. These scenes are typically combined with particular expressive music for various functions across film and video genres (Brockmann, 2013; Rogers, 2013). In everyday life, highly emotional experiences seem to cause time to pass more slowly, shedding light on psychological dimensions of time perception that shape perception and attention. Fixation data and pupillary responses provide insights into these experiences (Gingras et al., 2015; Schäfer & Fachner, 2015). In a series of studies, we investigate the role of attentional processes, cross-modal interactions, emotional responses and subjectively perceived durations of slow motion scenes in popular media genres. In this paper, we focus on the effects on eye movements.

Aims: The current study investigated highly expressive slow motion scenes compared to the same scenes in real time. We analysed the influence of slow motion on eye movements, time perception, and emotional experiences with regard to the interaction of auditory and visual information. We hypothesise that slow motion footage has an impact on attentional processes and subjectively perceived intensities. These processes may be shaped by music in a considerable manner, which effect eye movements.

Method: Forty-four participants watched original slow motion excerpts of three different media genres. Scenes from film, dance and sport (durations 16 – 40 sec.) were presented in an original (slow motion) as well as in an accelerated

version (real time) using a multimodal repeated-measure design. In order to analyse multimodal interactions, each clip was presented with and without music (modalities: v, a, av). Participants' eye movements were recorded with a SMI REDn system as well as physiological correlates (GSR, BVP, RSP). After each stimulus presentation, participants judged perceived duration, valence and arousal.

Results: First results indicate a difference in number of fixations ($p < .001$) for slow motion scenes ($M = 75.81$, $SD = 18.21$) compared to real time ($M = 70.84$, $SD = 16.67$) in the dance excerpts. No difference in average fixation duration could be found for the factor tempo ($p > .05$). Further statistical analyses will be carried out on number of fixations, mean fixation durations and pupil dilations for the factors tempo (slow motion, real time), modality (v, av) and genre (film, dance, sport). In a final step, eye-tracking results will be compared to participants' judgments and physiological correlates.

Conclusions: We expect that our results will provide insights into stretched time and music on multimodal perception, attention and emotion in a controlled experimental setup. Analysing fixations and pupil diameters of participants allows studying their attentional focus and arousal.

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Indraccolo, Allegra[1]; Meloni, Roberta[2]; Rizza, Aurora[3]; Brunetti, Riccardo[1]; & Marta Olivetti-Belardinelli[2]:

The influence of musical style on pupil dilation during music perception and recognition: A pilot study

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The influences of music on listeners' cognitive processes and emotions are modulated by the stimulus musical style. Previous studies classifying all musical genres according to the presence/absence of the categories Tonality and Salience found different effects in perception and memory at the behavioural and cerebral levels.

This study aims at investigating possible changes in pupillary responses during perception and recognition of four categories of unknown musical stimuli, equally divided in the 4 categories based on Tonality and Salience and presented in random order. In the study phase 20 music experts and 20 naïve participants listened to half of the stimuli. Afterwards subjects were presented with a test list containing 48 stimuli (24 old melodies and 24 new ones) and they had to respond whether each melody: was in the study list ("Remember" response denoting episodic memory according to Tulving's model); evoked a sense of familiarity ("Know" response, arousing from semantic memory, according to Tulving); or was not recognized at all. The results are discussed in light of a multicomponent model of music communication, by focusing our attention on the stylistic specificity of musical excerpts and the expertise of listeners.

Gingras B, Marin MM, Puig-Waldmüller E, Fitch WT (2015) The eye is listening: music- induced arousal and individual differences predict pupillary responses. Front Hum Neurosci doi: 10.3389/fnhum.2015.00619

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Kreysa, Helene[1]; Altmann, Carolin S.[1,2]; Schneider, Dana[1]; Zäske, Romi[1,2]; & Stefan R. Schweinberger[1]:

Explicit and implicit judgments of voice attractiveness and trustworthiness: Two pupillometry studies

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Arousing and emotionally relevant stimuli, as well as social signals such as perceived eye contact and facial expressions, have all previously been claimed to result in measurable pupil dilations of a perceiver (e.g., Laeng & Falkenberg, 2007; Petit & Ford, 2015). Consequently, it seems plausible that this pupil dilation is modulated by attractiveness of faces (Kreysa, Blatz, & Schweinberger, 2013) or voices. To test this prediction for voices, we used spoken sentence stimuli from the Jena Speaker Set (JeSS; Zäske, Skuk, Golle, &

Schweinberger, in prep.) which provides ratings of attractiveness of the respective voices (as well as other ratings). Equal numbers of male and female students participated in two studies (Experiment 1: N = 36; Experiment 2: N = 24), which differed only in the task: Participants were asked (a) either explicitly to rate the attractiveness of 18 high- and 18 low-attractive voices (Experiment 1), or (b) to rate the trustworthiness of the same speakers (Experiment 2). Each voice was heard speaking four different short sentences. While explicit ratings of attractiveness and trustworthiness were highly correlated between the two studies, Experiment 1 found only a marginal effect of attractiveness on pupil dilation around 4000 ms following stimulus onset ($F[1, 35] = 2.9$, $p = .09$), with attractive voices leading to smaller dilations. In contrast, when participants rated trustworthiness, an interactive effect of underlying voice attractiveness and speaker gender extended from 3000 ms to 5500 ms (all $Fs[1, 21]) > 5.0$, $ps < .03$): Attractive female voices led to substantially smaller dilations than attractive male voices and unattractive voices of either gender.

Overall, these studies suggest that effects of voice attractiveness on the pupil are small, occur comparatively late, and, somewhat unexpectedly, tend to show smaller dilations for attractive stimuli than for unattractive ones. Interestingly, the judgment task itself affected both the size of the effect and the extent to which voice gender played a role in the pupil response to attractive vs. unattractive voices. It may be that the level of cognitive effort involved in the respective tasks played a moderating role, allowing attractiveness effects to show up only during more demanding judgment tasks. Alternatively, voices speaking everyday sentences may not actually differ sufficiently in attractiveness to produce reliable effects; this could be substantially different for singing voices, which may vary more dramatically in aesthetic quality.

Kreysa, H., Blatz, L. & Schweinberger, S.R. (2013). Pupillary responses to perceived gaze direction and facial attractiveness. In K. Holmqvist, F. Mulvey & R. Johansson (Eds.), Book of Abstracts of the 17th European Conference on Eye Movements, 11-16 August 2013, in Lund, Sweden. Journal of Eye Movement Research, 6(3), 563.

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Lange, Elke B.; Pieczykolan, Aleksandra; Trukenbrod, Hans; & Lynn Huestegge:

The rhythm of cognition – Effects of an external auditory pacemaker on oculomotor control in exemplary cognitive tasks (reading and visual search)

Eye-movement behavior is inherently rhythmic. Even without cognitive input, eyes never rest but continue to program saccades 3 to 4 times a second. Based on an embodied view of cognition, we asked whether the mental processing in visual cognitive tasks is also rhythmic in nature by studying the effects of an external auditory pacemaker (rhythmic background music) on the speed of an autonomous saccade timer in exemplary cognitive tasks (reading and visual search). While in applied settings background music has been demonstrated to impair reading comprehension, any differential effect of musical tempo on eye-movement control in these two tasks has not been investigated so far. We implemented a tempo manipulation in four steps as well as a silent baseline condition while participants completed a text reading or a visual scanning task, which differed in terms of underlying cognitive processing requirements. The results revealed that an increased speed of the musical pacemaker speeded up fixations in text reading, and the presence (vs. absence) of the pacemaker generally reduced overall reading time. In contrast, visual scanning was unaffected by the auditory pacemaker. Results are interpreted as evidence against a cognitive load account (i.e., that spare resources during low-demand visual scanning allow for enhanced processing of the external pacemaker) and in favor of an entrainment of the oculomotor saccade timer in cases involving highly automatized oculomotor control routines (i.e., in text reading).

Liao, Hsin-I[1]; Yoneya, Makoto[1,2]; Kashino, Makio[1,2]; & Shigeto Furukawa[1]:

What does pupil tell about musical processing?

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In our series of studies, we demonstrated that pupillary dilation response (PDR) is a valid physiological index of surprising and salient auditory events. Specifically, we found that pupil size becomes larger (1) when listening to the sounds that are evaluated as more salient, or louder, after the stimulus presentation (Liao et al., 2016a), or (2) when a deviant auditory oddball is presented regardless whether the listener's attention is focused on or drawn away from the auditory stream (Liao et al., 2016b).

The stimuli used in these previous studies were either shortly presented (less than 500 ms) at discrete frequency (ISI longer than 9 s), or with simple acoustic structure (oddball presented against the background of repetitively presented tones). Therefore it remains unknown whether and how the PDR may also reflect the 'surprise' in long, continuous, and yet structured auditory stimuli, e.g., music. To examine this issue, we used 15 episodes of musical tunes, selected from three genres: classic, jazz, and rock. Participants listened to each of the musical tunes for 90 s while their pupillary responses were recorded by an infrared eye-tracker camera (Eyelink Desktop Mount, SR Research Ltd.). They listened to the musical tunes twice, each presented in two different sessions, within which the order was randomized. In the first session, they continuously rated how surprising the episode moment by moment while listening, namely the degree of musical change from the previous passage, by a sliding bar continuously in the range of 0 - 10. In the second session, they listened to the musical tunes again but were not involved in any task.

The pupil diameter data obtained from both sessions were time-aligned to the rating data obtained from the first rating session, and the periods with the rating score of >7 and <3 were extracted. In both sessions, mean pupil diameter was larger during the period when the participants (once) considered the episode was surprising (i.e., above 7) than monotonous (i.e., below 3). The results cannot be explained by mere power change.

We also evaluated contributions of factors not related to music per se, such as motor command and decision making, to PDR. We aligned the pupil data time-locked to the rating change moments. Pupil size increased when the rating was about to change, regardless of whether the rating score was increased or decreased. This rating-change related PDR was observed only in the first rating session, but not in the second passive listening session.

These results indicate that PDR reflects not only rating change, which is presumably related to motor command and/or decision-making (see also Einhäuser et al., 2010), but also the degree of "surprise" in music, which is independent of task involvement, and cannot be explained merely by acoustical amplitude change.

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Liao, H.-I., Kidani, S., Yoneya, M., Kashino, M., & Furukawa, S. (2016). Correspondences among pupillary dilation response, subjective salience of sounds, and loudness. Psychonomic Bulletin & Review, 23(2), 412-425.

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Lörch, Lucas; Fehringer, Benedict; & Stefan Münzer:

Reading music. How tonality and notation influence music reading experts' eye movements, pupil dilation and performance in a pattern-matching task.

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Eye movements and pupil dilation offer viable information for the study of perceptual and cognitive processes. The distance of saccades and the number of fixations can reveal the size of perceptual units. The index of cognitive activity, which is based on high-frequency changes in pupil dilation, indicates cognitive workload and exhaustion irrespective of changes in the exposure to light. By measuring both eye movements and pupil dilation during the reading of notated melodies, this study makes a novel contribution to a deeper understanding of music reading expertise.

Empirical evidence supports the notion that music reading experts' efficient perception and accurate decoding is based on a familiar structure of the notation. We manipulated the tonal structure and visual display of notated melodies to explore how they influence perception and decoding. Music students performed a silent reading pattern-matching task with sequentially presented melodies. We measured their task performance, eye movements and pupil dilation. The melodies varied on two factors, tonality (tonal vs. atonal) and notation (regular vs. irregular). We analyzed differences in behavioral measures (reaction time, accuracy) and eye tracking measures (number and duration of fixations, number and distance of saccades) between the different types of melodies. Moreover, we performed several exploratory analyses on the index of cognitive activity. The visual complexity of the note lines, which was parallelized between the conditions, was used as an additional factor in these analyses.

Both tonality and notation had a significant influence on accuracy and reaction time. Eye tracking measures were only weakly influenced by the notation of the melodies. We explain this finding with reference to characteristics of the task. Due to the serious time limit, participants always aimed to read the note lines until the end, but they were not able to process items with an unfamiliar structure in the limited time. Accordingly, behavioral data showed clear effects, while differences in eye movements between the conditions were rather small and inconsistent. The index of cognitive activity was not influenced by tonality, notation or exhaustion, but by visual complexity. Participants needed more cognitive resources when reading note lines with a higher complexity. The index of cognitive activity seems to be a valid measure in the context of music reading, but future studies should investigate why it is sensitive to complexity and not to structural irregularity.

Marandola, Fabrice:

Eye-Hand synchronisation and interpersonal interaction in xylophone performance: A comparison between African and Western percussionists

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Research on music and eye-movement has largely been dedicated to sight-reading, although some recent research has looked at the interaction between musicians and audience as well as between conductor and musicians, or aimed to develop new musical interfaces (see [1], [2], [3] and [4] for examples in these different areas). However, music performance in score-free conditions has seldom been studied, and xylophone performance – where eye-hand synchronization plays an important role during learning and performance phases – has never been explored using eye-tracking devices. This paper presents results from an interdisciplinary project dedicated to the study of instrumental gesture (Gesture-Acoustic-Music, Sorbonne Universités, 2015-17). Based on measurements realized with an eye-tracker system (ASL MEXG-60Hz), the study examines gaze-related performing strategies in xylophone music and compares traditional musicians from three different ethnic groups from Cameroon (Bedzan Pygmies, Tikar and Eton) with classical percussionists from Canada.

Following previous ethnomusicological research [5, 6, 7], I worked with 21 xylophonists from Central Cameroon, using two types of instruments: Tikar and Bedzan Pygmies play on banana-trunk xylophones, standing side by side in pairs, striking the ends of the large keys loosely placed on banana-trunks, while Eton musicians play individually on multiple-resonators xylophones, where the keys are attached to the frame and struck in the centre, organized in small ensembles of 3 to 7 instruments. Measurements were realized in context (i.e. during live performances), and aimed to determine in which proportions the xylophonists were using their gazes during the performance to communicate with each other, to communicate with the audience, and to look at their instruments to perform accurately. Another set of measurements involved a series of musical tasks similar to those performed by classical western musicians, such as scales using conjunct-degrees or thirds – both techniques being used during traditional performances by the soloists. The goal was to compare eye-hand synchronization strategies between musicians who learn in an oral-tradition context (Cameroon), with performers following a formalized training program widely based on score reading. In Canada, measurements took place in laboratory conditions with 9 university students and involved a series of technical exercises based on scales, which aimed to evaluate the effect of speed and expertise on eye-hand synchronization.

Preliminary results tend to demonstrate that musicians from Cameroon spend a significant amount of time looking away from their instruments (or closing their eyes), denoting a strong mental representation of their instrument in space. Among western musicians, this first study shows that accuracy is highly dependent on a performer's capacity to anticipate the notes to be performed with his gaze, with a strong correlation between expertise, accuracy and performance speed. Interestingly, the same type of anticipation can be observed in eye-movement with both Cameroonian and Western musicians executing the same type of musical tasks.

Methodical and technical challenges encountered during the realization of the study will also be discussed, and suggestions will be made to develop a new set of observations to confirm the results of this preliminary study.

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Marcum, Travis; & Robert Duke:

Perceptual acuity and music teaching: Tracking teacher gaze

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Perceptual precision is a requisite component of music teachers' ability to structure learning experiences that lead to students' accomplishment of proximal goals. We used eye-tracking technology in a series of three studies to measure music teachers' visual gaze in relation to moment-to-moment attention and instructional outcomes. Results from these studies provide insight into the deployment of attention among novice and expert music teachers.

I. We recorded an artist-level violin teacher and a highly skilled graduate violinist teaching 5-min violin lessons to a student of their own and a novel student, and examined the frequency and duration of teachers' visual fixations in relation to their approaches to accomplishing instructional goals. Fixation targets and fixation durations for the artist teacher were similar, whether she was teaching a student of her own or a new student. The graduate student's fixation targets and durations were similar to those of the expert in the lesson with the familiar student, but were very different when teaching a novel student. The artist-teacher's visual gaze patterns reflected a clarity of attentional focus on fundamental principles of musicianship in both lessons.

II. To determine whether auditory input affects the visual focus of highly skilled violin teachers, we projected a life-size image of a violinist performing a short music excerpt. Eight expert teachers observed the video twice, and following each viewing described what they noticed about the student. In half the presentations, the sound was turned off. We found no meaningful differences in gaze patterns between the first and second viewings, nor did we find differences between presentations with and without the audio. While there was variation among teachers in the percentage of total fixation time allocated to specific targets, none of the variance could be attributed to the presence or absence of an auditory stimulus.

III. Four violin teachers (freshman, senior, graduate student, and artist teacher) each taught a 5-minute lesson to a familiar student. We identified the proximal performance goals in each lesson and examined visual fixations in relation to those goals. We found marked differences in the sequence and duration of fixations among the four teachers, with fixations becoming longer and more-often focused on relevant targets with increasing levels of teacher expertise. The artist teacher's longer fixations reflect a greater depth of perception with regard to the physical motions involved in violin playing. Whereas the freshman teacher, for example, moved more frequently among multiple targets, with mean fixation durations that were approximately half the durations of the artist teacher's, the artist teacher gathered more information with each fixation, and provided more effectively sequenced instruction. We also found that the expert teacher fixated longer than the less expert teachers on targets that were the focus of verbal directives after the directives were given.

These data illustrate the utility of visual gaze analysis in examining the thinking of expert music teachers and reveal differences in thinking among varied levels of teacher expertise.

Plöchl, Michael; & Jonas Obleser:

Do auditory rhythms influence eye movement statistics?

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Musical rhythms can elicit motor activity, as for example when we unconsciously start to tap our foot to the beat of a song. This raises the question what causes this kind of sensorimotor coupling. Possible answers may come from three lines of observations: Firstly, active sampling of the environment, such as sniffing, whisking, or shifting the line of gaze, usually occurs in regular intervals at a rate of about 1–10 Hz1. Secondly, perceptual processes like stimulus detection performance and attention display rhythmic modulations in the same frequency range on both, a behavioral and a neural level2,3. Finally, rhythmic sounds have been shown to entrain neural oscillations as well as auditory detection performance4. Altogether these observations have led to the hypothesis that neural low frequency oscillations (<10 Hz) might serve as a mechanism that links and coordinates perception and motor behavior1.

To test this idea, we investigated, whether it is possible to influence the timing of motor behavior by means of auditory entrainment. In a first experiment, we measured the eye movements of 10 participants in a free viewing paradigm with simultaneous auditory stimulation. Participants freely moved their eyes over either a blank grey screen or a scene from a picture book ("Where is Waldo?"). At the same time, they passively listened to either rhythmic or arrhythmic auditory click trains at different temporal frequencies between 3 and 5 Hz. We investigated whether eye movements synchronize with rhythmic auditory stimulation in terms of an increase or decrease in saccade frequency and/or higher temporal precision as compared to irregular sound conditions or silence. Consistent with the literature5, our participants performed an average of 1 to 2 saccades per second when there was no structured visual input (blank screen), and 4–5 saccades when an image was displayed on the screen. Auditory stimulation, however, had no significant impact on saccade frequency or timing, neither in the rhythmic nor in the arrhythmic condition.

These observations suggest, that in the absence of a task, sensory and motor systems are not inherently coupled across modalities. Instead, sensorimotor synchronization might be mediated via attention. Moreover, in musical rhythms (unlike the uniform clicks we used here) the basic pulse is subdivided into more complex patterns of more and less emphasized beats. Consequently, the differently emphasized beats might act as separate but synergic entrainers each with its own temporal frequency and thus

may have a stronger impact on oscillatory integration mechanisms in the brain. In a series of audio-visual eye tracking experiments, we are currently exploring these possibilities.

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Puurtinen, Marjaana:

The interplay of rhythm symbols, melodic patterns and expertise during music reading: A review of eye-movement studies in 1994-2017

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Research on eye movements during music reading has gained popularity in recent decades, but the field remains an emerging one and, therefore, quite understandably, lacking in methodological coherence. Despite this fragmentation, one overall finding of recently published work in the field is that the visual processing of music notation is affected both by top-down and bottom-up factors (e.g. Penttinen, 2013; Penttinen, Huovinen, & Ylitalo, 2015; Rosenmann, Altenmüller, & Fahle, 2016, Wurtz, Müeri, & Wiesendanger, 2009). Of these, top-down factors have been the more commonly addressed: increase in musical expertise, for instance, seems to have the overall effect of decreasing average fixation durations and (in temporally controlled comparisons) increasing fixation frequency during music reading. Expertise may also result in an overall increase in the average size of the eye-hand span (e.g., Madell & Hébert, 2008; Penttinen et al., 2015).

The effects of the standard features of music notation itself, the bottom-up factors, have not been systematically addressed, however, although the study of the effects of basic music-structural features was already called for by Madell and Hébert in 2008. Some studies have examined eye movements during the performance of more or less „complex" musical material (see, e.g., Rosemann, et al., 2016; Wurtz, et al., 2009) but, considering the multidimensionality of Western music notation, a more detailed examination of the stimulus features seems warranted. Think, for instance, of a pianist sight-reading and performing a pattern of four 16th-notes that consists not of a scale-like succession of notes but of larger melodic intervals. How, in such a case, would we differentiate which factor is causing a longer fixation duration, for example? How would we know if it results from the melodic or the rhythmic elements of the pattern, or a surprising harmonic progression, or a combination of some or all of these elements? Furthermore, how does the level of expertise come into play in such findings?

In order to increase systematicity in this research, and to enable us to create solid hypotheses and explanations concerning the visual processing of music notation, a baseline understanding of the role that these bottom-up factors play in music reading is needed. Hence, to support the systematic designing of future experiments, I review the findings of eye-tracking studies from 1994 to the present day (including our own ongoing, not-yet-published work) from the perspective of what these studies reveal about the eye-movement and eye-hand span effects of standard features of Western music notation (namely symbols depicting rhythm and melody) as well as the interplay of these with musical expertise. Such findings may be found to be mentioned as minor outcomes in published papers, or, if not stated, may be deduced from the method descriptions included. In this presentation I will focus on music reading during a musical performance, that is, sight-reading or rehearsed reading, and ignore music-reading tasks that only contain note identification or pattern-matching (i.e., tasks that we call silent reading; Penttinen, 2013).

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Rodziewicz, Agata; Krejtz, Izabela; Kosmowska, Katarzyna; Krejtz, Krzysztof; Gajos, Agnieszka; & Justyna Iwańska:

Similarities between text and music reading

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Previous research suggest that during music and text reading, the same cognitive processes are used, including phonological awareness and auditory working memory (e.g., Patel, 2013; Tierney, Krauz, 2013). The main goal of the study was to investigate similarities between eye-movements during text and music notes reading. We verified whether in music reading with observe similar effects to word-frequency and word-length effects typical for reading process (e.g., Joseph, Liversedge, Blythe, White, Rayner, 2009) .

The participants of the study were children (N = 37, 7-14 y. o.) attending primary music school. In the first task, children were reading single sentences in which the number of syllables and word frequency were manipulated. In the second task, they were asked to clap the rhythm of music. We controlled the meter and difficulty of notes. We measured total fixation time and cognitive load with changes of pupil size.

As expected, reading time of difficult words correlated with the time of looking at more difficult bars. We observed the effect of word frequency and length on eye movements indices, as well as the effect of rhythm difficulty. In addition, the pupil size was the smallest with easy rhythm (quarter note). The similarities between reading musical notation and test reading can be used to design a reading training based on musical notation to stimulate reading fluency.

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Simurra, Ivan Eiji[1]; & João Ricardo Sato[2]

Analysis of pupil diameter during the listening of orchestral timbres: A case study.

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This abstract presents a concept of proof of pupillary response during an experiment on timbre characteristics of orchestral instruments on emotional states. According to Babiker, Faye and Malik (2013) pupil diameter was found to be a reliable proxy to measure human's emotion and engagement under certain experimental conditions (ex.: constant luminance).

Five participants volunteered to participate in this case study (both undergraduate students and graduate students of the Federal University of ABC – Brazil). Participants were between 20-42 years old. There were both musicians and non-musicians. Participants were briefly instructed and informed about the experiment which lasted around eight minutes (Thirty-three stimuli of five seconds each with fifteen seconds of interval between each stimulus).

The sound database stimuli were designed to cover some aspects belonging to contemporary music techniques primarily to create new sounds and textures by focusing on the blending of varied timbres and also the presence of the so-called extended instrumental techniques (GRIFFITHS, 1978; PADOVANI & FERRAZ, 2011). The whole framework was based on music by composers like Ravel, Debussy, Stravinsky, Messiaen, Schoenberg, Ligeti, Grisey, Scelsi, Lachenmann, Xenakis and Sciarrino. In total, there are thirty-three auditory stimuli each with a duration of 5.0 seconds. Most of them were based on the overture of each composition. There are three groups of stimuli: a) eleven auditory stimuli based on the original overture of each composition; b) eleven sound stimuli changing the instruments that took part of the group 'a'; and c) eleven sound stimuli changing the instrumental techniques from group 'b'.

Audio recordings were performed in Audacity software and the audio samples used to generate the sound textures belong to two databases [BALLET; BORGHESI; HOFFMANN; LÉVY, 1999] and [Barbancho et. al, 2013]. Such short samples (~7 seconds) were composed by seventeen musical instruments (accordion, tuba, bassoon, clarinet, trumpet, contrabass, alto saxophone, flute, guitar, harp, horn, oboe, trombone, violin, viola, Cello and piano) playing sonorities related to some aspects of the sound of contemporary instrumental music in different musical dynamics such as pianissimo, mezzo-piano and fortissimo.

Our experimental setup consisted on a VT3 Eye tracking hardware (sampling rate of 60 Hz) alongside with Mangold vision Software. During the experiment participants heard stimuli directly through headphones at constant and com-

fortable level. During the experiment, participants were asked to rate all the thirty-three sound stimuli over either a 'positive' or 'negative' valence after the listening session for each of the five-second stimuli.

Our findings suggest an increase in pupil diameter during the listening experiment and a decay to baseline during the pause between each stimulus. In this conference, we will show the individual responses of each subject in order to demonstrate the consistency of the findings across subjects.

The main purpose of the investigation in this stage of the research focuses on the assessment of pupil diameter as a good index to retrieve individuals' engagement or/and emotional states related to the singularities belonging to the sound universe of contemporary music.

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Skaansar, Jo Fougner[1]; Danielsen, Anne[2]; & Bruno Laeng[1]:

Pupil response reflects processing of musical micro- and polyrhythm. A study of musicians versus non-musicians.

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The study looked at the effect on 'mental effort' (as indexed by pupillometry; Kahneman, 1973) of microtiming deviations and cross rhythmic counter-rhythms in groove-based musical excerpts (cf. Danielsen, 2016; Danielsen, Jensenius, & Haugen, 2015). Professional jazz musicians (N= 16) and non-musicians (N= 16), matched demographically, were exposed to – in Experiment 1 – double bass and drum set-grooves consisting of microtiming deviations of different magnitude (-70 ms <X< 90 ms), and – in Experiment 2 – to a groove-based tune with a polyrhythmic event (4 against 3) that was contrasted with a control condition (borrowed from Vuust et al., 2006). In both experiments, all musical stimuli were presented in a passive condition ('listening only') and an active tapping-condition ('synchronizing with the beat'). Results of Experiment 1 showed a significant effect of microtiming deviations on pupil size; deviation magnitude was positively related to pupillary dilations in both groups. In fact, the microtiming musical excerpts did not, with few exceptions, generate significant differences in pupil response between the musicians and the non-musicians. The 'on-the-grid' microtiming clips were generally rated as 'groovier' than the timing deviated clips. On these subjective ratings, the musicians showed increased responsivity to microtiming compared to the non-musicians, although this difference was not reflected in pupillary responses. Inclusion of an 8-note hi-hat pattern decreased the overall pupil response, suggesting a 'time-keeper'-effect. Results of Experiment 2 showed that exposure to cross rhythmic counter-rhythms was also found to be related to larger pupil sizes, compared to similar but non-polyrhythmic events. The professional musicians showed more sustained pupil responses over the clip period than the non-musicians did. In general, tapping the beat while listening yielded higher psychophysiological effects (more mental effort) than when listening only.

To our knowledge, this is the first study to investigate how the common rhythmic phenomena of microtiming and polyrhythm are reflected in measures of mental effort.

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Tang Poy, Colleen[1]; & Matthew Woolhouse[2]:

Effect of dance synchrony on perceived levels of attractiveness: A pupillary dilation study

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A significant amount of research has sought to link human entrainment and dance with social bonding, affiliation and communication. Consistent with this research, eye-movement experiments have shown increased gaze times for people observing dancers moving to a synchronous musical beat versus asynchronous, suggesting that there is a preference for audio-visual congruence, particularly with respect to dance. In contrast to bonding and socially motivated re-

search, this study sought to investigate a complementary but alternative evolutionary-adaptive explanation for the geographical and historical ubiquity of dance: namely, that dance evolved to increase the likelihood of procreation. In this eye-tracking study, participants watched seven choreographed dance videos, each with a different level of synchrony—pairs of dancers performed to fast-, medium-, or slow-tempo music, and each dancer performed fast or slow choreography. This resulted in the following conditions: (1) dancers and music completely synchronous; (2) only one dancer synchronous with music; (3) dancers synchronous with each other but not with music; and (4) dancers and music completely asynchronous. While participants watched the videos, eye-movements, pupil dilations, and subjective ratings of attractiveness were recorded. Results showed that synchronous dancers were perceived as more attractive (according to pupil dilations and attractiveness ratings). However, significant differences between only some of the conditions suggests that a hierarchy of synchrony between the dancers drove differences in perceived attractiveness; e.g. lower attractiveness ratings were obtained for Condition 3 (only one dancer synchronous with music) than Condition 4 (complete asynchrony). This study contributes to a more nuanced understanding of dance's possible evolutionary origins, and provides further evidence that pupil dilation can be used as a proxy for attraction.

Timoshenko, Maria; Björk, Cecilia; & Fritjof Sahlström:

From unknown musical score to mature performance. A mixed-methods study of the learning process in a student choir

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Eye-tracking technology has been used in a considerable number of studies to examine sight-reading during instrumental and solo song performance (recently e.g. Arthur, Khuu & Blom, 2016; Cara, 2017; Penttinen, Huovinen & Ylitalo, 2014) indicating, notably, that musicians develop fluency and ability to anticipate technical difficulties through well-integrated representations of musical structure (Drai-Zerbit, Baccino & Bigand, 2012). So far, the field of choral singing has received less attention from researchers who analyse musical learning with eye-tracking methods alone or in combination with other methods. The purpose of this study is to examine learning processes during different phases of authentic choir rehearsals, focusing on qualitative and quantitative changes in individual singers' performance as well as in the choir as a whole.

Initial data have been collected during two 60-minute rehearsals in a student choir consisting of 24 amateur singers (SATB), including two members selected for closer observation and in-depth interviews. During the first rehearsal, a choral piece unknown to the singers was introduced. The learning process was then followed from sight-reading to performance of the entire work from memory. Rehearsal sessions included quiet individual sight-reading, prima vista singing, pronunciation practice and group singing. Sessions were audio and video recorded and eye-tracking data were collected using Tobii Pro Glasses 2 and SMI Eye Tracking Glasses 2 Wireless (ETG 2w). In addition, participant response about the learning process was generated through semistructured interviews with the two selected singers and through questionnaires completed by all choir members.

Monitoring of recorded eye-tracking data focuses on 1) orientation and development of sight-reading, 2) processing and memorizing of the new musical material, and 3) interaction between singers and conductor. Preliminary results suggest that singers' focus shifts from an emphasis on the details of the score in the beginning of the rehearsal to attention on the whole score towards the end. It also shows relations between moments when singers actively practice their own parts, led by the conductor, and moments when they listen to other parts being rehearsed while simultaneously engaging in self-directed practice, humming difficult passages in their own part.

The study sheds light on how overall competence in choir score reading develops and how the singers make use of various details from the score to help them perform their own task. One insight from the qualitative interviews is that the music seems to support memorizing of a foreign language text. Further analysis of the choir singers' gaze orientation and attention focus is expected to improve understandings about the interrelation between awareness of tonality, harmony, and larger musical structure (phrase and form) and audible changes in fluency, confidence and expressivity in performance.

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Tordini, Francesco[1,3]; & Fabrice Marandola[2,3]:

Exploring the eye-hand span in score-free conditions. Experiences with xylophonists and drummers

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The use of gaze movements as a window onto attention processes and on how humans parse the information coming from the visual world has a century-long history [1,2]. A large number of well tested paradigms and analysis techniques are now available [3], with application areas spanning several fields, from neuroscience and psychology, to human factors, and interactive arts [2]. In music, eye-tracking is used to study, for example, emotional valence and arousal during music listening and performance [4], or sensory-motor coordination with score reading paradigms [5-7], particularly sight-reading [8-10]. The majority of studies addressing sensory-motor coordination in musicians use a sight-reading paradigm and the eye-hand span to measure and compare the performances of novice and expert players.

However, there is no study addressing the eye-hand span in score-free conditions. Score-free settings are common, for example, with xylophonists, drummers and, more generally, percussionists. In this context, we explored the use of latest generation Tobii wireless eye-tracking glasses with xylophonists and drummers. The use of wireless headsets is particularly important to maximise the sense of comfort and freedom of the musician and, therefore, reduce the gap between the laboratory and real-life settings.

We first describe the methodological and technical challenges experienced during a preliminary eye-tracking study that aimed to observe the eye-hand coordination patterns in the performance of novice xylophonists and drummers playing in score-free conditions. Effects of musician's posture, head-sway, and extreme (yet natural for percussionists) use of peripheral vision on gaze-tracking data quality are discussed.

Second, we compare the eye-hand span of advanced and experienced xylophonists in score-free conditions and we summarize the technological requirements needed to collect reliable gaze data with this class of percussionists.

Finally, we suggest a few guidelines for the design of a paradigm to be used for characterising the eye-hand span in score-free conditions. We also highlight the key role played by the use of portable, sleek, wireless eye-tracking glasses in achieving ecologically valid experimental designs.

Indications and suggestions are given about the use of gaze-tracking in score-free conditions for potential pedagogical applications, the development of a typology of relationships related to eye-hand coordination and anticipation patterns, application in musical fields such as jazz and world music.

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Gaze behaviour in musical trios: methodological issues and analytical claims

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Investigations into nonverbal behaviour in ensemble playing have often focused on bodily movement. Even though the study of gaze behaviour would be a useful addition to this research, very few studies actually measured eye gaze during performance. Occasionally, observations regarding eye gaze are mentioned in studies that take on a broad view on nonverbal behaviour in ensemble playing (e.g. Davidson, 2012; Davidson & Good, 2002; Williamon & Davidson, 2002). Kawase (2009) claims to be the first to have measured gaze behaviour. In addition, he succesfully related it to synchronisation and leader-follower relationships (Kawase, 2014a; 2014b).

The studies by Kawase analyse gaze behaviour using video data. Our study implements the recently developed technique of mobile eye-tracking that guarantees a more fine-grained measurement of gaze behaviour and only a minimal

loss of ecological validity. As such, our study aims to be a pioneering study – alongside Morgan, Gunes and Bryan-Kinns (2015) and Yamada et al. (2014) – both in terms of research interest and data collection method.

The aim of our study is to describe gaze behaviour in musical trios with a specific interest in those moments when gaze is directed at one of the partners, as well as their relation to characteristics of the score, bodily movement and sounding music. For this purpose four trios have been recorded using mobile eye trackers (Tobii Pro Glasses 2), external cameras and an audio recorder. The musicians were selected on the basis of their musical abilities as judged by the chamber music coordinator of one of the contributing institutions (LUCA School of Arts). They neither played chamber music with each other before, nor did they ever play the composition chosen for the recording session. They were asked to rehearse a two-minute excerpt from Milhaud's Suite for violin, clarinet and piano during a single session according to the following schedule: individual practice (30') – rehearsal (30') – run-through – rehearsal (30') – run-through – run-through. Except for the individual practice the entire session was recorded.

Multiple options for data analysis are possible with the current data set. Our current focus is on melody transfers (i.e. moments where the melody in one voice is transferred to another). The excerpt from Milhaud's Suite contains 21 such moments and was chosen in order to test the hypothesis that 'melody takers' and 'melody yielders' would show distinct gaze behaviours. Thus, we describe the occurrence of 'gaze events' (i.e. moments when gaze is directed at one of the partners) in relation to melody transfers and compare this relationship per individual musician, per trio and per run-through. In a next stage, we intend to contextualise our observations further by looking at bodily movement and sounding music and at the relationship between rehearsals and run-throughs.

We expect that this kind of analysis can also be conducted from vantage points other than melody transfers. As the study is still ongoing, we mainly present the aims and methology. By sharing some preliminary results we also hope to demonstrate the potential of a multimodal data set for analysing the interactions between musicians.

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Widmann, Andreas[1]; Wetzel, Nicole[1,2]; & Erich Schröger[1]:

Auditory attention, prediction, and surprise as reflected by eye movements and pupil dilation

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The contribution will give an overview over a series of five experiments examining the impact of different aspects of auditory sensory processing and auditory attention on eye movements and pupil dilation.

In a simplified score-reading paradigm we examined the frequency and latency of small saccades in response to sounds predicted by visual symbols. A sharp increase of saccade frequency was observed only for sounds congruent but not for sounds incongruent to the corresponding symbol already about 80 ms after sound onset reflecting the overt orienting of attention towards the next symbol indicating rapid categorization of sounds. In an active auditory three-tone oddball paradigm we observed a sustained inhibition of micro-saccades in response to rare targets but not in response to frequent standards or rare distractors with a latency of again about 80 ms after sound onset. In a passive oddball paradigm participants were watching a video. Rare novel sounds elicited a transient inhibition of saccades as early as about 50 ms after sound onset. The inhibition of (micro-)saccades presumably reflects the allocation of auditory attentional resources. We conclude that deviance detection and sound categorization are fast, considerably faster than assumed previously on the basis of EEG data.

In a second line of research we measured changes of the pupil diameter in response to rare neutral vs. emotionally arousing novel sounds in a passive auditory oddball paradigm. A bi-phasic pupil dilation (PDR) was observed in response to all novels presumably reflecting arousal and orienting of attention. The contributions of the parasympathetically innervated sphincter muscle (early component) and the sympathetically innervated dilator muscle (late component) could be successfully separated by means of the manipulation of lighting conditions and principal component analysis. Only the late component was selectively enhanced in response to emotionally arousing sounds. Differential ef-

fects of varying deviant sounds in an auditory oddball paradigm could even be shown in pre-verbal 14-month old infants and adults. In response to simple frequency deviants a PDR was observed only in adults but not in infants. In response to potentially emotionally arousing deviants the late sympathetic PDR component was selectively enhanced in infants compared to adults indicating enhanced emotional sensitivity.

In summary, the observation of eye movements and pupil dilation offers a rich variety of approaches to study processes of auditory perception, cognition, and attention across a wide range of age groups.

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Ylitalo, Anna-Kaisa[1]; Särkkä, Aila[2]; Puurtinen, Marjaana[3]; & Erkki Huovinen[4]:

Statistical modelling of eye movements during simple sight-reading

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This study aims at modelling the visual processing of music notation during sight-reading. The motivation is to depict the eye movement sequences as temporal processes instead of just considering aggregated information, such as how fixations are allocated to individual notes (Kinsler & Carpenter, 1995; Madell & Hébert, 2008). Therefore, we develop a statistical model that could be used to reveal characteristics of the eye movement process, and study which features of the stimulus melody might affect eye movements. Previously, eye movement sequences have been modelled by point processes (see e.g. Penttinen & Ylitalo, 2016), but only in the case of picture viewing.

The data set exploited in this study consists of 37 adult pianists' sight-reading eye movements and concurrent performances of twelve simple melodies. The melodies are of three conditions, differing in terms of the local complexity of the melody. Six melodies were performed in a slower (60 bpm) and other six in a faster (100 bpm) tempo. Here, we concentrate on eye movements related to the melodies played in the faster tempo and develop a subject level model in each condition. The model can be used to compare the different conditions in order to study how the local complexity affects visual processing of the performed melody.

As a result of our on-going work, we will present a baseline model for eye movements during a simple sight-reading task. The baseline model relies on information on the locations of fixations as well as on their temporal order, meaning that we are modelling the scanpath of the gaze (see e.g. Holmqvist et al., 2011). The temporal constraint and linear structure of sight-reading pose challenges for the modelling. The aim is that the developed model could later be expanded to consider more components, such as fixation durations or information on the note values of the stimulus melody.

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Getting around in Frankfurt

Getting around in Frankfurt

Although Frankfurt may be mostly famous for its financial comings-and-goings (227 different banks on a population of approx. 730,000 people), the city has a rather rich cultural life as well. There's the Frankfurt Book Fair in October, of course, but there's also a surprising wealth of museums and other cultural venues. Below, you'll find a non-exhaustive overview with some highlights you might catch while staying in Frankfurt.

Just a few basics: public transport tickets are valid on all types you might need (transferring from the subway (U-Bahn/S-Bahn) to the tram doesn't require a new ticket). Tickets cost €2.90 for a single, but if you're going 3 stations or less, you can buy a Kurzstrecke (Short Distance) for €1.80. If you know you will take more than 2 rides a day-ticket is a good option. It costs 7,20 € and last until 3 o'clock p.m..

Smoking is still allowed in some bars, never in restaurants.

One tip for non-German visitors: keep cash on you. Not all bars/restaurants accept debit or credit cards, and it's unusual to pay with a credit card in supermarkets and small shops (though they might take it; all supermarkets take Maestro debit cards [not Master: Maestro]). Some bars do, some bars don't – it's best to ask before you sit down. All museums accept cards.

Museums

MMK 1, 2 & 3

The Museum of Modern Art (MMK – Museum für Moderne Kunst) has three branches. The main one houses changing exhibitions on the ground floor of its labyrinthine building and displays a wealth of modern and contemporary works on the upper levels (e.g. Duchamp, Beuys, and Liechtenstein, and Ai Weiwei, Thomas Demand and Jeff Wall). The buildings of the MMK2 (across town) and MMK3 (across from the MMK1) host changing exhibitions. You can buy a combi-ticket (€16) for all 3 venues, or separate tickets for MMK1 (€12), MMK2 (€8) and MMK3 (€6). Opening hours: Tue-Su from 10-18h; and Wed from 10-22h.

Current exhibitions:

MMK1: Carolee Schneemann – Kinetic Painting
Info: Domstrasse 10 III S+U Station Konstablerwache + 5min., tram stop Börneplatz + 2.5min.

MMK2: (no exhibition, new show being prepared)

MMK3: Deutsche Börse Photography Foundation Prize 2017
Info: Domstrasse 3, Across from the MMK1, 17sec.

SCHIRN KUNSTHALLE

As a Kunsthalle ("art centre" or "exhibition hall"), the Schirn doesn't have its own, permanent collection but creates exhibitions from borrowed collections. The quality is usually very high and the variety of artists and themes stunning.

Current exhibition: HOW DOES PEACE ACTUALLY WORK? In a discursive group exhibition, the SCHIRN heads away from that familiar territory. International artists present works that offer a new, contemporary perspective on this topic.

Info: Römerberg III €9 III Opening hours: Tue, Fri-Su: 10-19h; Wed & Thu: 10-22h III U-Bahn station Dom/Römer + 34sec., tram stop Römer/Paulskirche + 1min.

STÄDEL MUSEUM

The Städel is the most respectable and one of the finest museums of the city with a collection that spans 700 years of art history, terminating in the present with a very, fine stockpile of modern and contemporary art in the enormous basement annex, with stunning pieces by among others Klein, Kippenberger, Bacon, Kiefer, Fontana and Neo Rauch. On the upper floors, you'll find the temporary exhibitions, as well as a superb permanent hoard of works from all the ages, with Medieval masterworks and pieces by artists such as Vermeer, Van Eyck, Bosch, Holbein and a very famous Botticelli, as well as works by Beckmann, Renoir, Degas and Ernst.

Current exhibitions: Géricault bis Toulouse-Lautrec, Matisse Bonnard

Info: Schaumainkai 63 III €14 III Opening hours: Tue, Wed, Sa, Su: 10-18h; Thu & Fri: 10-21h. III U-Bahn station Schweizer Platz + 8min; tram stop Otto-Hahn-Platz + 1min; U-Bahn & tram Willy-Brandt-Platz + 11min

LIEBIEGHAUS SCULPTURE MUSEUM

Right next to the Städel lies this wonderful villa with a huge sculpture collection. The Liebieghaus pieces hail from antiquity, the Middle Ages, the Renaissance and Neoclassicism. It's usually rather quiet there, and their courtyard café is one of the finest places to hang out in the city (reading a book at the café is reason enough to go there).

Current exhibitions: permanent exhibition with their "open depot" and a small exhibition with sculptures that were acquired between 1939-1945.

Info: Schaumainkai 71 III €10 (café entry is free) III Opening hours: Tue, Wed, Fri-Su: 10-18h; Thu: 10-21h. III U-Bahn station Schweizer Platz + 8min; tram stop Otto-Hahn-Platz + 1min; U-Bahn & tram Willy-Brandt-Platz + 11min

SENCKENBERG MUSEUM OF NATURAL HISTORY

Senckenberg Museum has a wide variety of prehistoric sights, a plethora of fossils, a cornucopia of whales and other sea mammals, and a treasure trove of stuffed mammals, birds, insects, lizards, and more. The current temporary exhibition is about the Senckenberg society which celebrates its 200th birthday this year.

Info: Senckenberganlage 25 III €8 III Opening hours: Mo, Tue, Thu, Fri: 9:17h; Wed: 9-20h; Sa & Su: 9-18h. III U-Bahn station Bockenheimer Warte + 4min

Bookstores

WALTHER KÖNIG ART BOOKSTORE

One of many in a German chain of art bookstores with branches in the UK, Italy, Austria and the Netherlands as well. The chain also provides in the museum shop needs of most of the larger museums in Berlin. Famous for its own publishing house as well as its great stock and fine offer of discounted books.

This store is in/next to the great Kleinmarkthalle, where one can shop for artisanal and exotic produce and drink wine all day long; very close to the MMK1.

Info: Hasengasse 5 ||| Opening hours: Mo-Fr: 10-19h; Sa: 10-18h. ||| S+U Station Konstablerwache + 4min., tram stop Börneplatz + 4min

HUGENDUBEL ENGLISH BOOKSHOP

Frankfurt is famous for its Book Fair but not for its bookstores, unfortunately. For all non-German speakers who need a new novel to occupy them on their return trip, the separate English Bookshop in the massive, German-language Hugendubel is the only real place to go. Mostly stocked with recent publications and modern classics, the store also offers a sufficient selection of nonfiction and some Italian, French and Spanish books. Brace yourself, this store is right smack in the middle of the city's shopping district, which is not the most esthetically or sensory pleasing place to be.

Info: Steinweg 12 (entrance to English section on the Biebergasse) ||| Opening hours: Mo-Wed: 9:30-20h; Thu-Sa: 9:30-21h. ||| S+U Station Hauptwache + 2min

Drinking

Frankfurt has plenty of bars, from shabby pubs to the fanciest cocktail lounges. Sachsenhausen (the city district south of the river) offers a lot of venues, although many of them are very 'touristy'. The Bahnhofsviertel (the district surrounding the train station) has been bustling & happening for a while now. The streets can still feel (and sometimes be) somewhat grungy, but it's usually perfectly safe. Try the Münchener Strasse for beers in bars or on the street and prowl the side streets for lots of great food. Otherwise, try one of these:

NAÏV

In the area of Konstablerwache we find Frankfurt's beer heaven, with all the craft brews and IPA's your tongue could ever hope to find. Nobody's ever counted, but they must have hundreds of beers. Also a large outdoor area and nice food. (Cash and cards)

Info: Fahrgasse 4 ||| S+U Station Konstablerwache + 5min; tram stop Börneplatz + 2.5min ||| Mo-Fri: 17-01h; Sa-Su: 12-01h

MAINGOLD

Whether the weather is wonderful or watery, Maingold is always comfortable. Great atmosphere, good coffee, good cakes, great breakfast (although for weekend breakfasts, a reservation is usually required). (Cash only)

Info: Zeil 1 ||| S+U Station Konstablerwache + 6min ||| Mo-Su: 12-01h

MAINCAFÉ

When the weather's great and you feel like taking a stroll along the riverfront (which, honestly, can be quite nice), you might find the Maincafé right on the water, two minutes away from the Städel Museum. A great place to hang back, or to bring your own beers and just enjoy their music on the weekends.

Info: Schaumainkai 50 ||| U-Bahn station Schweizer Platz + 8min; tram stop Otto-Hahn-Platz + 1min; U-Bahn & tram Willy-Brandt-Platz + 11min ||| Mo-Su: 10-23h, depending on weather conditions

JAZZKELLER

The Jazzkeller is a quite famous venue with concerts nearly every weekend.

Info: Kleine Bockenheimerstr. 18a ||| U-Bahn station Alte Oper or Hauptwache ||| Prices differ from 5-15€

Food

There's a million places to eat in the city, and these are just a few

HIGEMATSU (Japanese)

Great sushi and other dishes for very reasonable prices, in/close to the city center, quite close to the MPI. (Cash and card)

Info: Meisengasse 11 ||| U-Bahn station Eschenheimer Tor + 6min; S+U Station Hauptwache + 5min. ||| Tue-Su: 18:30-21:45h

KLOSTERHOF (Swiss)

For everyone who loves German dining: this is a Swiss exaggeration of that. Huge schnitzels in a million varieties, more potatoes than you could ever eat and huge pints of beer to go with it. It might be difficult to eat vegetarian here. On weekend, a reservation is advisable. (Cash, card unclear).

Info: Weißfrauenstraße 3 ||| U-Bahn & tram Willy-Brandt-Platz + 3min ||| Tue-Su: 11:30-01:00h

A TAVOLA (Italian)
Great Italian food and great wines in Sachsenhausen (all U-Bahns from the MPI go to Sachsenhausen). Limited seating.

Info: Diesterwegstrasse 4 ||| U-Bahn Schweizer Platz + 30sec ||| Tue-Su: 17-23h

PAK CHOI (Chinese) ||| in the Bahnhofsviertel
Better bring the big belt and some (new) friends, because dining at Pak Choi is both a community experience and an exhausting enterprise: you just can't stop eating. Put lots of dishes in the center of the table and share it all. Special recommendation: the fried eggplant (aubergine), and the roasted peanuts.

Info: Elbestrasse 12 ||| U+S station Hauptbahnhof + 6min; tram stop Weser-/Münchener Strasse + 2min |||Tue-Su: 17:30-23h

LAM FRÈRES (Vietnamese) ||| in the Bahnhofsviertel
Big, delicious dishes and great hosts. It's especially nice to build your own rolls, right there at the table.

Info: Weserstrasse 12 ||| U+S station Hauptbahnhof + 7min; tram stop Weser-/Münchener Strasse + 1.24min ||| Tue-Su: 17:30-23h

FLETCHER'S (Hamburgers) ||| in the Bahnhofsviertel
There's a bit of a hamburger craze going on in the city. Fletcher's is in the Train Station District, offers great burgers and has good vegetarian options.

Info: Münchener Strasse 11 ||| U-Bahn station Willy-Brand-Platz + 4min; tram stop Weser-/Münchener Strasse + 2min ||| Su-Thu: 11:30-22h; Fri & Sa: 11:30-23h

Places to relax

Frankfurt has a lot of parks and gardens around and even in the city-center. Beside the regular parks there are some special gardens that can be visited without a fee. These are:

CHINESE GARDEN
Surrounded by thick walls and shielded from the hectic pace of the city, the garden has been constructed according to the model of the Shiukou Gardens in Huizhou.

Info: U4 Merianplatz – Beginning of Berger Straße ||| Opening hours: 9:00h until dark

GRÜNEBURGPARK
This big park in the center of Frankfurt is the perfect place for long or even short strolls. Nice bonus is the little café which is placed in a tower.

Info: Starting from the Institute just walk until the end of Grüneburgweg and then turn into August-Siebert-Straße and continue walking until you're in the green.

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