*Ein Bild, das Text, Schrift, Grafiken, Design enthält.

KI-generierte Inhalte können fehlerhaft sein. Institut für Psychologie*

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**Analysis Plan**

**Time-dependent Specificity of Pre-Speech Auditory Modulation**

**General Remarks**

This document contains the planned analyses for the research project ‘Time-dependent Specificity of Pre-Speech Auditory Modulation’. All planned analyses are subject to the proviso that the data permit the application of the respective procedure. If, for example, the assumptions for a particular method are not met, equivalent (e.g. non-parametric) procedures are used. All analyses are tagged with a unique name, which is also stated in the analysis code (as a comment). Thus, every analysis can be identified in the analysis code quickly. BEH analyses (e.g. BEH1) concern behavioural data. ERP analyses (e.g. ERP1) concern ERP data. SVM analyses (e.g. SVM1) concern the analysis of EEG data using SVMs. DESC analyses (e.g. DESC1) concern purely descriptive analysis of multiple data types. FAL analyses (e.g. FAL1) concern FAL questionnaire data. NASATLX analyses (e.g. NASATLX1) concern NASATLX questionnaire data. SAM analyses (e.g. SAM1) concern SAM questionnaire data. Analyses concerning specific hypotheses are marked as MAIN\_*analyis* (e.g. MAIN\_ERP1). Other analyses are conducted for exploratory and sanity purposes only. The terms ‘trial’ and ‘epoch’ are used interchangeably.

**Behavioural Analysis**

**Preprocessing**

The following preprocessing is applied.

1. The raw .wav files (one per trial) are loaded into Praat.
2. The maximum intensity of each recording in dB is extracted.
3. The intensity range of each recording in dB is extracted.
4. The following algorithm is applied to classify trials as sounding trials (i.e. trials in which subjects produced a syllable) and silent trials (i.e. trials in which subjects did not produce a syllable):
   1. If the maximum intensity is larger than 47.5 dB and the intensity range is larger than 12 dB a trial is classified as a sounding trial.
   2. To TextGrid (silences) is applied to extract on- and offsets. If the function is not able to extract more than 1 intervall (e.g. when classifying the whole recording as sounding) the chance is high that now real response took place. Thus, in that case, the trial is re-classified as a silent trial.
   3. If more than one intervall could be extracted the F0 and the vocal onset time is extracted. If the extraction of either variable is not possible, leaving a ‘undefined’ value, the trial is re-classified as a silent trial.

This algorithm and its tresholds were developed using pilot data. Its accuracy was verified by human observation on multiple occasions during the development phase.

1. After labeling all trials as sounding or silent and extracting the F0 and the vocal onset time, the data is exported and loading into Matlab. Before extracting the F0, the recording is cut to only include the sounding part (i.e. the silence in the recording before (and after) the syllable is being cut).
2. After performing multiple sanity checks, the trials are marked as being bad based on the following criteria:
   1. If a trial with the task condition active was classified as a silent trial.
   2. If a trial with the task condition passive was classified as a sounding trial.
   3. If the vocal onset time in a given trial was differing more the 3 SDs from the M.
   4. If the F0 in a given trial was differing more the 3 SDs from the M.

Trials which are identified as bad by either the EEG preprocessing (see below) and/or the behavioural preprocessing are rejected.

**BEH1**

**Description:** Analysis BEH1 concerns the fundamental frequency (F0) of the auditory probes (unaltered and altered) relative to the distribution of the F0 of the vocal responses during the experiment.

**Transformations/Indices:** The mean (M) and the standard deviation (SD) of each subjects’ F0 distribution (based on the vocal responses made during the experiment, not during the stimuli recordings) are extracted. The F0 values of the auditory probes (unaltered and altered) are z-standardized relative to the M and th SD of the F0 distribution (based on the vocal responses made during the experiment, not during the stimuli recordings).

**Exlusion/Inclusion:** Per definition only trials including vocal responses are included to extract the M and SD of the F0 distribution.

**Statistical procedures:** A paired T-Test is performed.

**Outcome:** Z-transformed probe F0 value.

**Variables & Interactions:** Probe-type (unaltered, altered).

**BEH2**

**Description:** Analysis BEH2 concerns how the F0 of the vocal responses during the experiment is influenced by a probe being presented.

**Transformations/Indices:** The F0 values of the vocal responses are z-transformed relative to their own M and SD. Further, the mean z-transformed F0 value for probe and no-probe trials is extracted, leaving each subject with 2 values (one for probe and one for no-probe trials).

**Exlusion/Inclusion:** Per definition only trials including vocal responses are used.

**Statistical procedures:** A paired T-Test is performed.

**Outcome:** Z-transformed F0 value.

**Variables & Interactions:** Probe (yes, no)

**BEH3**

**Description:** Analysis BEH3 concerns how the F0 of the vocal responses during the experiment is influenced by probe-type and probe-onset.

**Transformations/Indices:** The F0 values of the vocal responses are z-transformed relative to their own M and SD for each subject. Further, the mean z-transformed F0 value for each combintion of probe type and probe onset is extracted, leaving each subject with 4 values (one for each combination).

**Exlusion/Inclusion:** Per definition only trials including vocal responses and probes are used.

**Statistical procedures:** A repeated-measures analysis of variance (rmANOVA) is performed.

**Outcome:** Z-transformed F0 value.

**Variables & Interactions:** Probe-type (unaltered, altered) \* Probe-onset (early, late).

**BEH4**

**Description:** Analysis BEH4 concerns how the vocal onset time is influenced by a probe being presented.

**Transformations/Indices:** The vocal onset times are z-transformed relative to their own M and SD. Further, the mean z-transformed vocal onset time for probe and no-probe trials is extracted, leaving each subject with 2 values (one for probe and one for no-probe trials).

**Exlusion/Inclusion:** Per definition only trials including vocal responses are included.

**Statistical procedures:** A paired T-Test is performed.

**Outcome:** Z-transformed vocal onset time for each subject.

**Variables & Interactions:** Probe (yes, no).

**BEH5**

**Description:** Analysis BEH5 concerns how the vocal onset time is influenced by probe-type and probe-onset

**Transformations/Indices:** The vocal onset times are z-transformed relative to their own M and SD for each subject. Further, the mean z-transformed vocal onset time for each combintion of probe type and probe onset is extracted, leaving each subject with 4 values (one for each combination).

**Exlusion/Inclusion:** Per definition only trials including vocal responses and probes are included.

**Statistical procedures:** A rmANOVA is performed.

**Outcome:** Z-transformed vocal onset time.

**Variables & Interactions:** Probe-type (unaltered, altered) \* Probe-onset (early, late).

**BEH6**

**Description:** Analysis BEH6 concerns how the F0 of the vocal responses during the experiment is influenced by the block of the experiment.

**Transformations/Indices:** The F0 values of the vocal responses are z-transformed relative to their own M and SD for each subject. Further, the mean z-transformed F0 value for each block is extracted, leaving each subject with 8 values (one for each block).

**Exlusion/Inclusion:** Per definition only trials including vocal responses are included.

**Statistical procedures:** A rmANOVA is performed.

**Outcome:** Z-transformed F0 value.

**Variables & Interactions:** Block (1,2,3,4,5,6,7,8)

**BEH7**

**Description:** Analysis BEH7 concerns how vocal onset time is influenced by the block of the experiment.

**Transformations/Indices:** The vocal onset times are z-transformed relative to their own M and SD for each subject. Further, the mean z-transformed vocal onset time for each block is extracted, leaving each subject with 8 values (one for each block).

**Exlusion/Inclusion:** Per definition only trials including vocal responses are included.

**Statistical procedures:** A rmANOVA is performed.

**Outcome:** Z-transformed vocal onset time.

**Variables & Interactions:** Block (1,2,3,4,5,6,7,8)

**ERP Analysis**

**ICA Preprocessing**

The following preprocessing steps are applied to ensure the best possible ICA estimates.

1. Not needed channels used for marker purposes are removed.
2. The channel locations are added.
3. A 1 Hz Highpass-Filter is applied.
4. Bad channels are identified and removed using the bemobil\_...
5. The continous data is epoched into 1s segments.
6. Bad epochs are marked and removed based on probability.

After these steps, the ICA is run. The extracted weights are later applied to the data (see below). I advance of the preprocessing steps, the raw data is loaded into Matlab and a costum script is used to set the EEG-Markers to the onset of the audio probes. This is done by the audio files of the probes containing both the probe (in the right channel) and a ‘rectangle’ (in the left channel). The left channel is fed into a separate EEG amplifier. With the onset of the ‘rectangle’ can be detected in the EEG data, allowing for a precisly timed marker. The right channel (containing the real audio file of the probe) is played back to the participants.

**Preprocessing**

The following preprocessing is applied to ensure a high signal quality.

1. Not needed channels used for marker purposes are removed.
2. The channel locations are added, and the markers are renamed.
3. A 0.3 Hz – 30 Hz Bandpass-Filter is applied.
4. Bad channels are identified and removed using the bemobil\_...
5. Previoulsy extracted ICA weight are applied and bad components are removed using the ICLabel Plugin.
6. Previously identified bad channels are interpolated.
7. The continous data is epoched -200ms – 400ms around relevant markers.
8. Bad epochs are marked as being bad based on absolute amplitude and probability.

Epochs which are identified as bad by either the EEG preprocessing and/or the behavioural preprocessing (see above) are rejected. I advance of the preprocessing steps, the raw data is loaded into Matlab and a costum script is used to set the EEG-Markers to the onset of the audio probes (for details, see above).

Subsequently, ERPs are extarcted by averaging over trials. All analyses concering ERPs components exclusively use electrode E01 (equivalent to electrode Cz).

To ensure that the ERPs best reflect auditory processing, the following correction is applied. In addition to the ERPs time-locked to the auditory probes, control ERPs time-locked to the probe-onset time during the no-probe trials are also extracted. The latter are thought to reflect only non-auditory processing (e.g. processing related to motor, visual, linguistic or cognitive operations), whereas the former reflect both auditory and non-auditory processing. To isolate the signal reflecting auditory processing, the (no-probe) control ERPs are subtracted from the (probe) ERPs. We acknowledge that this procedure relies on purely addictive effects and therefore is not able to correct any interactions between auditory and non-auditory processing. Still, this procedure provides the best estimate of the true auditory response. Furthermore, previous studies investigating Pre-Speech Auditory Modulation (PSAM) have used this procedure, so its use in this study is necessary to allow comparisons.

**MAIN\_ERP1**

**Description:** Analysis MAIN\_ERP1 concerns how N1 ERP amplitudes are influenced by probe-type, probe-onset and task.

**Transformations/Indices:** -

**Exlusion/Inclusion:** Per definition, only probe trials are included.

**Statistical procedures:** A linear mixed model with random intercept and fixed slopes is applied.

**Outcome:** N1 Amplitude

**Variables & Interactions:** Task (active, passive) \* probe-type (unaltered, altered) \* probe-onset (early, late)

**Notes:** To further investigate the relationships, MAIN\_ERP2 is conducted. The aim of MAIN\_ERP1 is to investigate whether there is a significant difference between the active task condition and the passive task condition (i.e. PSAM occurs). To further investigate the characteristics of the PSAM effect the analysis MAIN\_ERP2 is conducted.

**MAIN\_ERP2**

**Description:** Analysis MAIN\_ERP2 concerns how the PSAM effect is influenced by probe-type, probe-onset.

**Transformations/Indices:** (The PSAM effect is defined as the N1 ERP amplitude in the active task conition – (minus) the N1 ERP amplitude in the passive task conition. A negative PSAM effect refers to the suppression of N1 amplitudes during the active task condition (e.g., Daliri & Max, 2016).)

**Exlusion/Inclusion:** Per definition, only probe trials are included.

**Statistical procedures:** A linear mixed model with random intercept and fixed slopes is applied.

**Outcome:** N1 Amplitude

**Variables & Interactions:** Probe-type (unaltered, altered) \* probe-onset (early, late)

**Planned Contrasts:** Planned contrasts inlcude the comparision of probe-type (unaltered, altered) for each level of probe-onset (early, late).

**SVM Analysis**

**SVM1**

**Description:** Analysis ERP1 concerns

**Transformations/Indices:**

**Exlusion/Inclusion:**

**Statistical procedures:** A rmANOVA is performed.

**Outcome:**

**Variables & Interactions:** Task (active, passive) \* probe-type (unaltered, altered) \* probe-onset (early, late)

**Descriptive Analysis**

**DESC1**

**Description:** Analysis DESC1 concerns how the F0 is influenced by sex.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and the SD are extracted for each sex.

**Outcome:** Sex.

**FAL Analysis**

**FAL1**

**Description:** Analysis FAL1 concerns the average age of the included participants.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and the SD are extracted.

**Outcome:** Age.

**FAL2**

**Description:** Analysis FAL2 concerns the sex of the included participants.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The numbers of male, female and divers participants are extracted.

**Outcome:** Sex.

**FAL3**

**Description:** Analysis FAL3 concerns the education of the included participants.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The numbers of participants with high, medium and low education are extracted.

**Outcome:** Education.

**FAL4**

**Description:** Analysis FAL4 concerns the occupation of the included participants.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The numbers of students, workers and unemployed are extracted.

**Outcome:** Occupation.

**NASA-TLX Analysis**

**NASATLX1**

**Description:** Analysis NASATLX1 concerns the mental demand dimension of the NASA-TLX.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mental Demand.

**NASATLX2**

**Description:** Analysis NASATLX2 concerns the physical demand dimension of the NASA-TLX.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Physical Demand.

**NASATLX3**

**Description:** Analysis NASATLX3 concerns the performance dimension of the NASA-TLX.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Performance.

**NASATLX4**

**Description:** Analysis NASATLX4 concerns the effort dimension of the NASA-TLX.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Effort.

**NASATLX5**

**Description:** Analysis NASATLX5 concerns the frustration dimension of the NASA-TLX.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Frustration.

**SAM Analysis**

**SAM1**

**Description:** Analysis SAM1 concerns the mood dimension of the SAM during break 1.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM2**

**Description:** Analysis SAM2 concerns the mood dimension of the SAM during break 2.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM3**

**Description:** Analysis SAM3 concerns the mood dimension of the SAM during break 3.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM4**

**Description:** Analysis SAM4 concerns the mood dimension of the SAM during break 4.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM5**

**Description:** Analysis SAM5 concerns the mood dimension of the SAM during break 5.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM6**

**Description:** Analysis SAM6 concerns the mood dimension of the SAM during break 6.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM7**

**Description:** Analysis SAM7 concerns the mood dimension of the SAM during break 7.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM8**

**Description:** Analysis SAM7 concerns the mood dimension of the SAM during break 8 / after the experiment.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM9**

**Description:** Analysis SAM9 concerns the tiredness dimension of the SAM during break 1.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM10**

**Description:** Analysis SAM10 concerns the tiredness dimension of the SAM during break 2.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM11**

**Description:** Analysis SAM11 concerns the tiredness dimension of the SAM during break 3.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM12**

**Description:** Analysis SAM12 concerns the tiredness dimension of the SAM during break 4.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM13**

**Description:** Analysis SAM13 concerns the tiredness dimension of the SAM during break 5.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM14**

**Description:** Analysis SAM14 concerns the tiredness dimension of the SAM during break 6.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM15**

**Description:** Analysis SAM15 concerns the tiredness dimension of the SAM during break 7.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Tiredness.

**SAM16**

**Description:** Analysis SAM16 concerns the mood dimension of the SAM during break 8 / after the experiment.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** The M and SD are extracted.

**Outcome:** Mood.

**SAM17**

**Description:** Analysis SAM17 concerns how the mood dimension of the SAM is influenced by the block/break.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** A rmANOVA is performed.

**Outcome:** Mood.

**Variables & Interactions:** Break (1,2,3,4,5,6,7,8)

**SAM18**

**Description:** Analysis SAM18 concerns how the tiredness dimension of the SAM is influenced by the block/break.

**Transformations/Indices:** -

**Exlusion/Inclusion:** -

**Statistical procedures:** A rmANOVA is performed.

**Outcome:** Tiredness.

**Variables & Interactions:** Break (1,2,3,4,5,6,7,8), Tiredness