1 Audio-Tokens: a toolbox for rating, sorting and comparing audio samples in the browser.

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Abstract

Here we describe a Javascript toolbox to perform online rating studies with auditory material. The main feature of the toolbox is that audio samples are associated with visual tokens on the screen that control audio playback and can be manipulated depending on the type of rating. This allows the collection of single- and multi-dimensional feature ratings, as well as categorical and similarity ratings. The toolbox (github.com/pwdonh/audio_tokens) can be used via a plugin for the widely-used jsPsych, as well as using plain Javascript for custom applications. We expect the toolbox to be useful in psychological research on speech and music perception, as well as for the curation and annotation of datasets in machine learning.

Keywords: Online experiments, Auditory perception, Rating, Javascript

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Collecting ratings from human participants is commonplace in behavioural research at multiple steps within a project. This includes validation and annotation of items to be included in a corpus (Ardila et al., 2019; Belin, Fillion-Bilodeau, & Gosselin, 2008; Paquette, Peretz, & Belin, 2013) or stimulus material for neuroimaging experiments (Charest, Kievit, Schmitz, Deca, & Kriegeskorte, 2014; Gold et al., 2019); but also to test hypotheses, such as perceptual differences between groups of participants (Atagi & Bent, 2016; Jack, Garrod, Yu, Caldara, & Schyns, 2012; Kutlu, Tiv, Wulff, & Titone, 2020) or the effect of experimental conditions and stimulus properties (Holz, Larrouy-Maestri, & Poeppel, 2021; Lavan, Scott, & McGettigan, 2016; McDermott, Lehr, & Oxenham, 2010; Thoret, Caramiaux, Depalle, & McAdams, 2020).

In research on speech and music, a common way to perform ratings is to first present an audio stimulus and subsequently present one or multiple rating scales (Belin et al., 2008; Holz et al., 2021). This sequential procedure requires the participant to hold the stimulus in working memory to perform the rating. This can be demanding for the participant, especially if multiple rating scales are used, or multiple audio stimuli are required to be rated at once. To alleviate this, a rating interface should allow the participant to control the playback of audio stimuli. At the same time, it is important that there is clear correspondence between playback controls and rating controls for individual audio stimuli, such as the multiple interfaces we outline below.

We present multiple rating interfaces in this paper that follow these constraints. They were inspired by two examples in the literature. The first one is called “Auditory free classification” (Clopper, 2008), which has been applied to non-native speech perception (Atagi & Bent, 2013, 2016). Participants are presented with a grid and multiple icons that control playback of audio stimuli from different speakers. These icons have to be arranged in the grid, forming as many

groups of speakers as the participant thinks there are. The second example is based on a study on voice classification (Lavan et al., 2020) where participants were given a PowerPoint slide with embedded audio samples (represented as icons). They had to sort the icons on the slides into identities by clicking and dragging them. Instructions were either to sort them into two identities or choose the number of identities by themselves. Both these examples show creative ways of integrating audio playback controls in the rating/sorting interface. Here we expand on these ideas to generate rating interfaces that span a wide range of rating types. We implemented these in a toolbox called Audio-Tokens, which is easy to use and can be integrated within existing experimental workflows (both online and in person studies).

Description of the toolbox

The interfaces we describe in this paper are based on the principle that each audio sample is represented by a coloured circle, which we will call a *token* (Fig. 1A). The user can control playback of the audio sample by hovering over the corresponding token (Fig. 1B). Ratings are performed by dragging tokens to different positions within an *arena* (here a rectangular box, Fig. 1C-D). In this paper, we introduce several rating types that are implemented in the toolbox by discussing some specific examples. The aim is to encourage researchers to use the tools in their own research.

Continuous ratings

One feature. This first example (Fig. 1) shows the case of rating audio samples along one specified feature. This is likely one of the most common tasks a researcher would ask from participants. An example from speech research would be accent judgments. Participants are asked

to listen to native or non-native speakers of a language and rate the strength of the foreign accent they perceive; either to study the process of second language learning with a focus on the speaker (Berken, Gracco, Chen, & Klein, 2016; Flege, Munro, & MacKay, 1995) or social factors that determine what people consider ‘accented’ or standard variants of a language (Kutlu et al., 2020). The rating is implemented by dragging tokens within the *arena* horizontally (left-to-right position: low-to-high rating). When all tokens have been placed in the arena, participants are able to submit the ratings using a button.

A common problem in many studies that use sequential presentations of stimuli for rating, is that participants might slowly drift in their ratings based on the stimuli presented before (Gerratt, Kreiman, Antonanzas-Barroso, & Berke, 1993). The advantage of our approach is that it allows the simultaneous rating of multiple audio stimuli. As a consequence, participants can base their ratings on comparisons between the different stimuli. With the current method, a batch of speakers is presented at a time, thereby the researcher can control more tightly the context of a given rating. For example, the same speaker can be presented in multiple randomly selected batches of speakers to average out the effects of context. In the current paper we are not trying to evaluate these effects of context, but we provide the tools to enable such studies.

The other rating interfaces in the toolbox follow the same principle. Different rating types are implemented by changing the arena layout and placement of tokens, constraining the dragging operations, as well as adding lines to represent connections between different tokens.

Figure 1: Rating audio samples along one feature. A) Multiple coloured circles (*tokens*) are placed next to a rectangular *arena*. B) Each token represents an audio stimulus which is played when hovering with the mouse. C-D) Tokens can be dragged horizontally to place a rating. In the jsPsych plugin, use rating type: *features*. Use the following link for an interactive version: https://pwdonh.github.io/audio_tokens/index_query.html?type=single_feature

Multiple features. The next interface allows for collecting ratings along multiple feature dimensions. An example of this would be rating clinically relevant features of speech impairments, e.g. Voice quality, Articulation and Prosody (Darley, Aronson, & Brown, 1969; Mollaei, Shiller, Baum, & Gracco, 2016). In the example shown in Fig. 2 there are three different *arenas*, which correspond to three feature dimensions. Tokens with the same colour represent the same audio file. Just like in the previous example, participants can drag tokens horizontally to place a rating. While hovering over a token, lines will appear that connect corresponding tokens (Fig. 2B). Again, in order to submit the ratings, all tokens have to be dragged into the arena.

Figure 2: Rating audio samples along multiple features. A) Three arenas are displayed corresponding to three different features to be rated. Tokens representing the same audio stimulus share colour and relative position. B) Tokens can be individually dragged to place ratings for the different features. Lines will appear that connect corresponding tokens. In the jsPsych plugin, use rating type: `features`, while specifying multiple feature labels. Use the following link for an interactive version:

https://pwdonh.github.io/audio_tokens/index_query.html?type=multiple_feature

Rating audio stimuli along multiple dimensions could be demanding for participants in a sequential setup. In the interface offered here, participants can re-play stimuli multiple times, and are helped by the matching colour and relative position of corresponding tokens. The connecting lines are an additional visual aid: instead of the average rating they emphasise the profile across the rated features, e.g. the profile of a patients' speech symptoms in the case of clinical speech evaluations.

Figure 3: Rating audio samples along two features. Two dimensional feature ratings can be placed in a 2D layout. In the jsPsych plugin, use rating type: `features2d`. Use the following link for an interactive version:

https://pwdonh.github.io/audio_tokens/index_query.html?type=features2d

As a special case, the plugin allows ratings along two features to be performed in one arena (Fig. 3), by allowing both horizontal and vertical dragging operations. An example would be rating emotional content of speech or music along the dimensions Valence and Arousal (Holz et al., 2021; Paquette et al., 2013). Lines appear during dragging operations as a visual aid: they connect the current token to the corresponding positions on the vertical and horizontal axis.

Categorical ratings

Fixed number of categories. Some research questions might require participants to sort audio recordings into discrete categories. In one scenario the categories are specified by the experimenter, for example in quality control (keep or reject) or voice identity sorting (Lavan et al., 2020): participants are asked to sort utterances recorded from two different speakers. In this

interface, several tokens will appear above two arenas (here labelled as ‘Category 1’ and ‘Category 2’, Fig. 4A-B). Tokens can be placed in the two arenas representing the two categories. The interface does not record where in the arena the tokens are dropped, because this is a discrete rating. Categories can be labelled as shown below, or they can be left blank if the question is less constrained (“Please sort these recordings into two piles.”).

Figure 4: Sorting audio samples. A) Fixed number of categories: Tokens are placed on top of two arenas representing two categories. B) Tokens can be sorted by dragging them into one of the arenas. In the jsPsych plugin, use rating type: `categories`. C) Variable number of categories: Tokens are placed around a circular arena and can be dragged freely inside it. Clusters are formed dynamically when tokens are dragged close to each other, highlighted by connecting lines. In the jsPsych plugin, use rating type: `cluster`. Use the following links for interactive versions:

https://pwwonh.github.io/audio_tokens/index_query.html?type=categories

https://pwwonh.github.io/audio_tokens/index_query.html?type=cluster

161

162 **Variable number of categories.** In another scenario, both the number of categories and
163 their labels are kept unspecified. Participants are asked to sort the recordings into as many
164 categories as deemed appropriate. For example Bent and colleagues (Bent, Atagi, Akbik, &
165 Bonifield, 2016) asked participants to group speakers of different regional or non-native accents
166 by perceived origin.

167 In this interface (Fig. 4C), tokens are placed around a circular arena, and can be dragged
168 freely within it. Clusters are formed dynamically when tokens are placed close to each other: all
169 tokens of the current cluster are highlighted by connecting lines. Again, the interface will record
170 only the category (cluster) membership and not the exact placement of the tokens, because this is
171 a discrete rating.

172

173 **Similarity ratings**

174 **Unconstrained similarity rating.** As the most unconstrained form of rating, we provide
175 an interface for similarity ratings where participants are free to place tokens in a circular arena
176 (Fig. 5A), similar to what has been used in the visual domain (Charest et al., 2014; Kriegeskorte
177 & Mur, 2012). In contrast to the interface described above, the actual placement coordinates are
178 recorded in the results. In addition, connecting lines are drawn between the currently dragged token
179 and all others while stroke width is scaled by the distance to the other tokens: this serves as a visual
180 analogue for stimulus similarity.

181

Figure 5: Rating the similarity of audio samples. A) Unconstrained similarity rating: The interface looks similar to Fig. 4C, however the actual position of tokens is recorded rather than category membership. Connecting lines emphasize the distance between tokens via the stroke width. In the jsPsych plugin, use rating type: `similarity`. B) Relative similarity rating: Three tokens are displayed at a time. Participants are asked to select the audio stimulus that is least similar to the other two by clicking on the corresponding token. In the jsPsych plugin, use rating type: `triplets`. Use the following links for interactive versions:

https://pwwonh.github.io/audio_tokens/index_query.html?type=similarity

https://pwwonh.github.io/audio_tokens/index_query.html?type=triplets

Relative similarity rating in the triplet task. The last option is to ask participants for judgements on relative similarity (Anikin, Bååth, & Persson, 2018; Hebart, Zheng, Pereira, & Baker, 2020; Raijmakers, Jansen, & Maas, 2004): Out of three stimuli, which one is the least similar to the other two (the odd-one-out). This interface differs from the others, since there are no

dragging operations. Instead, three tokens are shown on the screen at a given time and the odd-one-out is selected by a button click. If a trial consists of only three stimuli, it ends here. If there are more than three stimuli, the selected token will disappear and a new token will appear at its place. The participant can make a new decision: which one is now the odd-one-out? Since the decisions are made by mouse click the trial ends automatically and there is no submit button.

A similarity rating as in Fig. 5A can be demanding for the participant, especially as the number of tokens increases. Stimuli might differ on many dimensions, but the two-dimensional layout will require participants to ignore some of those dimensions. For placement of a token, participants have to simultaneously consider the similarity of the current to all the other stimuli, which could be highly demanding. The second task (Fig. 5B) is deliberately much simpler: the participant has to compare only 3 different stimuli and make a discrete judgement. This is a less expressive type of rating, but might be much easier and faster for participants to perform.

Usage of the toolbox

Implementation options

The basic tools are written in Javascript, because it is the predominant scripting language for the Web. The graphical elements are drawn in the browser as svg using the data visualization library d3¹. The rating tools can thus be flexibly used in any type of environment (e.g. personal or institutional web page). We tested functionality for Chrome and Firefox browsers.

More convenient than using plain Javascript, we implemented the toolbox as a plugin within the widely used jsPsych framework for running online experiments (de Leeuw, 2015). This means our tools can be easily integrated in existing behavioural experiments running on jsPsych.

¹ d3js.org

There are also multiple options of hosting jsPsych experiments such as Pavlovia², Jatos³ and others; all of which are described in the official jsPsych documentation⁴. Although built for online experiments, all experiments written in jsPsych can be performed in a laboratory setting as well, using a browser on a local computer.

Example script for jsPsych plugin

We go through the basic steps of setting up an experiment here. The complete experiment can be written in one html-file. This is the minimal page setup, excluding the jsPsych code:

```
<!DOCTYPE html>
<html>
  <head>
    <title>My experiment</title>
    <script src="scripts/jspsych.js"></script>
    <script src="scripts/jspsych-audio-tokens.js"></script>
    <script src="//d3js.org/d3.v4.min.js"></script>
    <script src="scripts/audio-tokens.js"></script>
    <link href="jspsych.css" rel="stylesheet" type="text/css">
  </head>
  <body>
  </body>
  <script>
    // All jsPsych code goes here
  </script>
</html>
```

Here we are first importing a few libraries:

- `d3.v4.min.js`: This is the d3-library on which the current toolbox is based, it is widely used for visualizing data in web environments

² pavlovia.org

³ www.jatos.org

⁴ jspsych.org

- `audio-tokens.js`: This is the Javascript code for the rating tools described in this paper.
- `jspsych.js`: This provides all the basic functionality of jsPsych
- `jspsych-audio-tokens.js`: This is the plugin that allows us to include the rating tools in a jsPsych experiment
- More jsPsych plugins can be loaded here in order to build your experiment, e.g. to display instructions

There is nothing written in between the `<body></body>` tags. This is normally where the content of a web page goes: here jsPsych takes care of displaying content according to the trial structure of the experiment.

In between the `<script></script>` tags we will add all the jsPsych code:

```
var single_feature_trial = {  
  type: 'audio-tokens',  
  ratingtype: 'features',  
  stimuli: ['data/speaker1.wav',  
            'data/speaker2.wav',  
            'data/speaker3.wav',  
            'data/speaker4.wav'],  
  label: ['Feature 1'],  
  anchors: [['low', '', 'high']],  
  force_listen: false  
}  
  
jsPsych.init({  
  timeline: [single_feature_trial],  
  on_finish: function() {  
    jsPsych.data.displayData();  
  }  
})
```

Here, `single_feature_trial` is the variable holding the parameters for a jsPsych trial:

- `type`: Here we tell jsPsych to display a trial using our plugin called ‘audio-tokens’

- 245 - `ratingtype`: This tells our plugin what rating type to use among the ones described
246 in this paper. Options are: `features`, `features2d`, `categories`, `cluster`,
247 `similarity`, `triplets`
- 248 - `stimuli`: This is an array containing the file paths of the audio stimuli for this trial
249 relative to the directory where the html file is stored.
- 250 - `label`: This specifies the label to be displayed for a given rating dimension (e.g.
251 valence, arousal, accentedness). See Fig. 1, the label on top of the arena.
- 252 - `anchors`: This specifies the labels displayed as the endpoints of the rating dimensions
253 (e.g. low-high, positive-neutral-negative)
- 254 - `force_listen`: This, if set to `true`, checks whether the participant has listened to the
255 whole audio file before allowing them to submit their ratings

256 Then the call to `jsPsych.init` starts the experiment. In this case, the experiment timeline
257 includes only one trial and the recorded data will be presented on the screen after the experiment
258 is finished. The data is by default formatted in json, and for the example trial looks like the
259 following:

```
[
  {
    "stimuli": [
      "data/speaker1.wav",
      "data/speaker2.wav",
      "data/speaker3.wav",
      "data/speaker4.wav"
    ],
    "ratings": [
      0.3,
      0.22142857142857142,
      1,
      0.6071428571428571
    ],
    "elapsed": [
      2.483076923076923,
      1.2666666666666666,
      1.1859259259259258,
      1.685840707964602
    ],
    "rt": 6644,
    "ratingtype": "features",
    "labels": [
      "Feature 1"
    ],
    "trial_type": "audio-tokens",
    "trial_index": 0,
    "time_elapsed": 11151,
    "internal_node_id": "0.0-0.0"
  }
]
```

260]

261 The following fields are specific to our plugin:

- 262 - ratings: An array containing the rating the participant gave. This differs depending
- 263 on the rating type. Here we get a number between 0 and 1 representing the horizontal
- 264 placement of each token (0: left, 1: right).
- 265 - elapsed: An array containing the number of times a stimulus has been played by the
- 266 participant. When hovering over a token, the corresponding audio stimulus is played in
- 267 a loop. In this example, the first stimulus was played approximately two and a half
- 268 times.
- 269 - rt: The time, in milliseconds, from starting the trial to submitting the ratings

The fields `stimuli`, `ratingtype`, `labels` and `anchors` are equivalent to the parameters specified in the experiment script. The remaining fields are generic jsPsych outputs.

Please refer to our Github repository⁵ for additional examples and the jsPsych documentation on multiple ways to save the data. This will also depend on what solution is used for hosting the experiment.

Conclusions

In this paper, we presented a new toolbox for collecting human ratings of audio samples through the browser. We think it is unique in the range of options that are available: using a consistent interface design, participants can be asked to rate audio stimuli on one or multiple feature dimensions, sort audio stimuli into two or more categories, or compare sets of audio stimuli using e.g. an odd-one-out procedure. As such, it adds substantial flexibility in the design of rating studies, which would otherwise be constrained by the sequential nature of the task (first listen then rate). In addition, it is possible to extend the toolbox to novel applications while preserving the basic principle: e.g. by changing arena layout, changing token placement, setting different constraints on dragging operations or allowing continuous manipulation of stimulus features through dragging operations (see e.g. Harrison et al., 2020). In conclusion, we hope that researchers will take advantage of the flexibility offered by the toolbox and that it can help generate new experimental designs and research questions.

⁵ github.com/pwdonh/audio_tokens

References

- Anikin, A., Bååth, R., & Persson, T. (2018). Human Non-linguistic Vocal Repertoire: Call Types and Their Meaning. *Journal of Nonverbal Behavior*, 42(1), 53–80.
- Ardila, R., Branson, M., Davis, K., Henretty, M., Kohler, M., Meyer, J., ... Weber, G. (2019). Common Voice: A Massively-Multilingual Speech Corpus. Retrieved from <http://arxiv.org/abs/1912.06670>
- Atagi, E., & Bent, T. (2013). Auditory free classification of nonnative speech. *Journal of Phonetics*, 41(6). doi:10.1016/j.wocn.2013.09.003
- Atagi, E., & Bent, T. (2016). Auditory free classification of native and nonnative speech by nonnative listeners. *Applied Psycholinguistics*, 37(2), 241–263.
- Belin, P., Fillion-Bilodeau, S., & Gosselin, F. (2008). The Montreal Affective Voices: a validated set of nonverbal affect bursts for research on auditory affective processing. *Behavior Research Methods*, 40(2), 531–539.
- Bent, T., Atagi, E., Akbik, A., & Bonifield, E. (2016). Classification of regional dialects, international dialects, and nonnative accents. *Journal of Phonetics*, 58, 104–117.
- Berken, J. A., Gracco, V. L., Chen, J.-K., & Klein, D. (2016). The timing of language learning shapes brain structure associated with articulation. *Brain Structure & Function*, 221(7), 3591–3600.
- Charest, I., Kievit, R. A., Schmitz, T. W., Deca, D., & Kriegeskorte, N. (2014). Unique semantic space in the brain of each beholder predicts perceived similarity. *Proceedings of the National Academy of Sciences of the United States of America*, 111(40), 14565–14570.
- Clopper, C. G. (2008). Auditory free classification: methods and analysis. *Behavior Research Methods*, 40(2), 575–581.

- 312 Darley, F. L., Aronson, A. E., & Brown, J. R. (1969). Differential diagnostic patterns of dysarthria.
313 *Journal of Speech and Hearing Research*, 12(2), 246–269.
- 314 de Leeuw, J. R. (2015). jsPsych: a JavaScript library for creating behavioral experiments in a Web
315 browser. *Behavior Research Methods*, 47(1), 1–12.
- 316 Flege, J. E., Munro, M. J., & MacKay, I. R. (1995). Factors affecting strength of perceived foreign
317 accent in a second language. *The Journal of the Acoustical Society of America*, 97(5 Pt 1),
318 3125–3134.
- 319 Gerratt, B. R., Kreiman, J., Antonanzas-Barroso, N., & Berke, G. S. (1993). Comparing internal
320 and external standards in voice quality judgments. *Journal of Speech and Hearing*
321 *Research*, 36(1), 14–20.
- 322 Gold, B. P., Mas-Herrero, E., Zeighami, Y., Benovoy, M., Dagher, A., & Zatorre, R. J. (2019).
323 Musical reward prediction errors engage the nucleus accumbens and motivate learning.
324 *Proceedings of the National Academy of Sciences of the United States of America*, 116(8),
325 3310–3315.
- 326 Harrison, P. M. C., Marjeh, R., Adolphi, F., van Rijn, P., Anglada-Tort, M., Tchernichovski, O., ...
327 Jacoby, N. (2020). Gibbs Sampling with People. Retrieved from
328 <http://arxiv.org/abs/2008.02595>
- 329 Hebart, M. N., Zheng, C. Y., Pereira, F., & Baker, C. I. (2020). Revealing the multidimensional
330 mental representations of natural objects underlying human similarity judgements. *Nature*
331 *Human Behaviour*, 4(11), 1173–1185.
- 332 Holz, N., Larrouy-Maestri, P., & Poeppel, D. (2021). The paradoxical role of emotional intensity
333 in the perception of vocal affect. *Scientific Reports*, 11(1), 9663.

- 334 Jack, R. E., Garrod, O. G. B., Yu, H., Caldara, R., & Schyns, P. G. (2012). Facial expressions of
335 emotion are not culturally universal. *Proceedings of the National Academy of Sciences of*
336 *the United States of America*, 109(19), 7241–7244.
- 337 Kriegeskorte, N., & Mur, M. (2012). Inverse MDS: Inferring Dissimilarity Structure from Multiple
338 Item Arrangements. *Frontiers in Psychology*, 3, 245.
- 339 Kutlu, E., Tiv, M., Wulff, S., & Titone, D. (2020). The Impact of Race on Speech Perception and
340 Accentedness Judgments in Racially Diverse and Non-Diverse Groups. *PsyArxiv*.
341 Retrieved from <https://psyarxiv.com/hv25r/>
- 342 Lavan, N., Merriman, S. E., Ladwa, P., Burston, L. F. K., Knight, S., & McGettigan, C. (2020).
343 “Please sort these voice recordings into 2 identities”: Effects of task instructions on
344 performance in voice sorting studies. *British Journal of Psychology*, 111(3), 556–569.
- 345 Lavan, N., Scott, S. K., & McGettigan, C. (2016). Laugh Like You Mean It: Authenticity
346 Modulates Acoustic, Physiological and Perceptual Properties of Laughter. *Journal of*
347 *Nonverbal Behavior*, 40(2), 133–149.
- 348 McDermott, J. H., Lehr, A. J., & Oxenham, A. J. (2010). Individual differences reveal the basis of
349 consonance. *Current Biology: CB*, 20(11), 1035–1041.
- 350 Mollaei, F., Shiller, D. M., Baum, S. R., & Gracco, V. L. (2016). Sensorimotor control of vocal
351 pitch and formant frequencies in Parkinson’s disease. *Brain Research*, 1646, 269–277.
- 352 Paquette, S., Peretz, I., & Belin, P. (2013). The “Musical Emotional Bursts”: a validated set of
353 musical affect bursts to investigate auditory affective processing. *Frontiers in Psychology*,
354 4, 509.
- 355 Raijmakers, M. E. J., Jansen, B. R. J., & Maas, H. L. J. van der. (2004). Rules and development in
356 triad classification task performance. *Developmental Review: DR*, 24(3), 289–321.

- 357 Thoret, E., Caramiaux, B., Depalle, P., & McAdams, S. (2020). Learning metrics on
358 spectrotemporal modulations reveals the perception of musical instrument timbre. *Nature*
359 *Human Behaviour*. doi:10.1038/s41562-020-00987-5