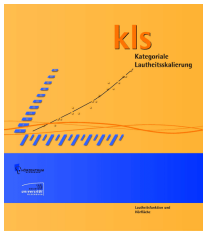
Oldenburg Measurement Applications

Software package for
audiometric and diagnostic
measuring methods

Operation manual

Categorical Loudness Scaling



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2 General remarks

The following documentation describes the operation of measurement application 'Categorical Loudness Scaling' using the software environment 'Oldenburg Measurement Applications'. This documentation is subject to change without notice.

3 Starting the Categorical Loudness Scaling

You can start the measurement application 'Categorical Loudness Scaling' from the start dialog of the 'Oldenburg Measurement Applications' by clicking the corresponding button. If there is no user and/or client selected you are prompted automatically for y selection. This operation is described in the documentation of the start dialog.

The next dialog shows a selection of all available measurements for the actual client (Figure 1).

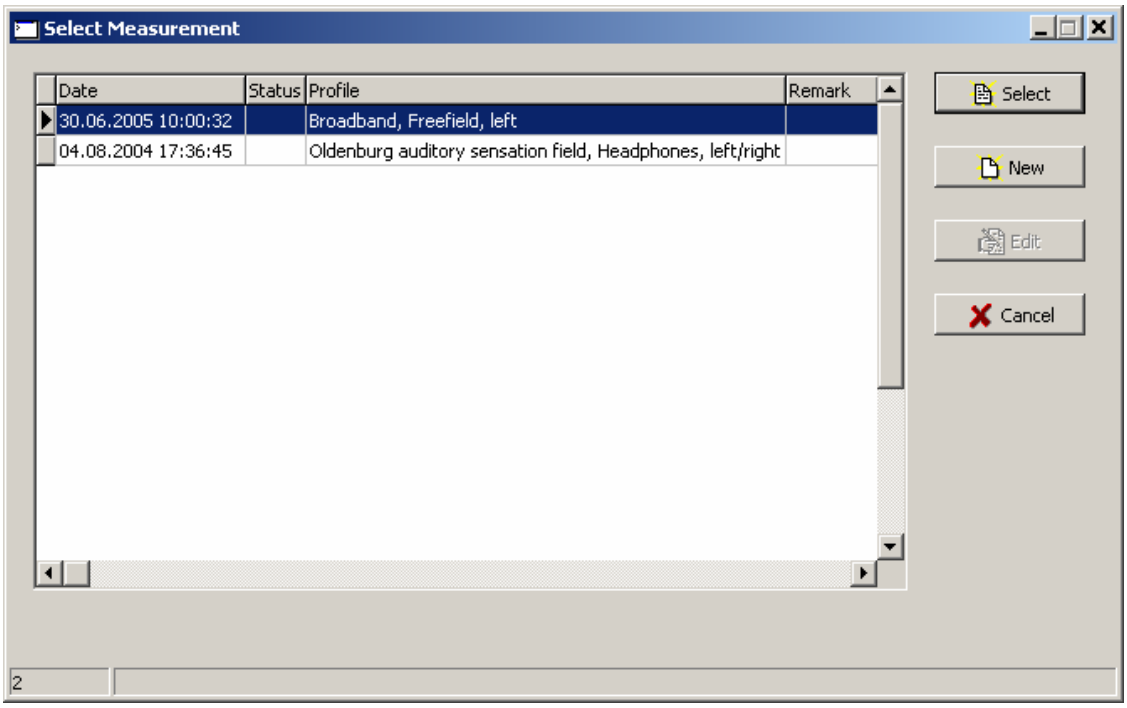


Figure 1

A particular measurement can be selected by a double click on the corresponding line or a single click followed by clicking the 'Select' button. The column 'Status' shows the current status of a measurement, i.e. if a measurement is new (empty, Status 'N'), if it was started but is incomplete (Status 'U') or if it is complete ('Status field empty'). If you select a complete Measurement it will be displayed in the measurement dialog. If you select an incomplete measurement, you can continue and complete this measurement. In these two cases please proceed with the description of the measurement dialog in paragraph 7.

4 Creating a new measurement

If no Loudness Scaling data are stored for the actual client or if you have selected 'New' in the measurement selection dialog when running the Categorical Loudness Scaling, the following dialog for selecting a measurement profile or variant respectively for creating a new measurement (Figure 2):

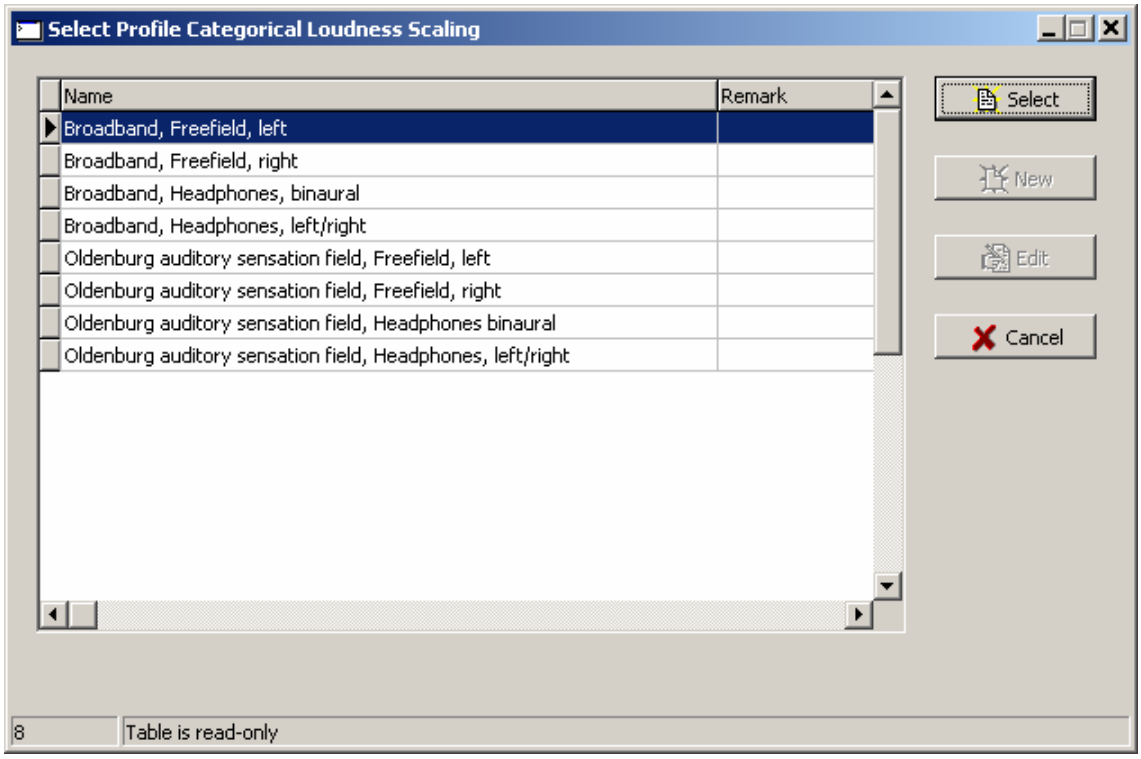


Figure 2

The available profiles may vary depending on the installation and configuration of the system. For a description of the specific profiles please refer to paragraph 8. As a rule the profile of a loudness scaling measurement determines the transducer type, the side and the signal type to use. These target specifications can not be changed subsequently. Additional settings such as details of the measurement procedure and frequencies for narrowband measurements can be adjusted later and can be changed subsequently.

First of all the selection determines the transducer type. For headphone measurements if the signals are always presented on the left and/or right side or binaural respectively. In freefield measurements the signals will always be presented separately (left/right or freefield channel 1/2). Usually the two freefield standard channels denoted 'Left' and 'Right' (following the headphone nomenclature).

The selection determines as well if the measurement will be executed using narrowband signals (the so called 'auditory sensation field') or with a broadband signal.

After this selection a dialog with additional settings for the measurement is displayed. These settings are adjusted according to the default settings of the selected profile. Some of the settings can be adjusted yet. This procedure is described in the following paragraph. If you accept the parameters by clicking 'Ok' the measurement dialog is displayed and the measurement can be started. This procedure is described in paragraph 7.

5 Settings

This section contains the description of various dialogs for adjusting or changing parameters of a measurement (depending on the selected profile). The corresponding dialog will be shown when creating a new measurement, when starting an empty measurement (containing no measured data) or if you press the 'Settings...' button on the measurement dialog.

The following figures are displayed for headphone measurements only. The dialogs for freefield measurements are very similar. Instead of 'headphone' followed by the name of the particular headphone you will find 'Freefield' (or similar) on the dialogs. In this way the transducer types can be distinguished at any time.

Depending on the selected profile the measurement will be executed using narrowband signals (the so called 'auditory sensation field') or with a broadband signal. In the following these two variants are described separately because they are displayed in different ways.

5.1 Narrowband measurements ('auditory sensation field')

If you have selected a profile for a narrowband adaptive headphone measurement for one particular side ('Oldenburg auditory sensation field, Headphones, left/right') the following dialog is displayed (Figure 3):

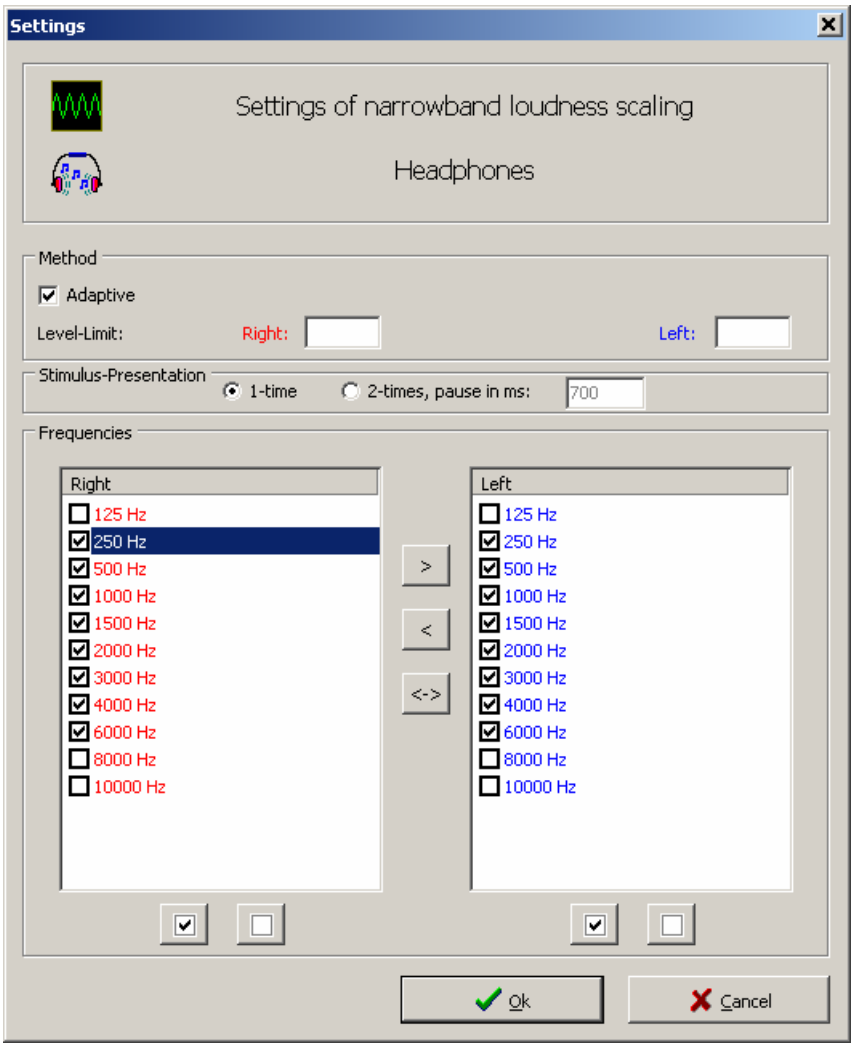


Figure 3

5.1.1 Frequencies

If you are creating a new measurement the standard frequencies are pre-selected automatically. In the area 'Frequencies' you select (check box checked) or deselect (check box unchecked) particular frequencies by clicking the corresponding check box at the left of the corresponding frequency. The corresponding narrowband signals are described in paragraph 10.

Clicking the button  below the frequencies will select all frequencies of the corresponding side.

Clicking the button  below the frequencies will deselect all frequencies of the corresponding side.

To synchronize the frequency selection of both sides use the three buttons between both sides. Clicking the  button will copy the selection from the left to the right side, clicking the 

will copy the selection from the right to the left side. Clicking the button <-> will select every frequency on both sides that is selected on one side at least.

For binaural measurements, i.e. the presentation of signals on both sides simultaneously, the frequencies will only be displayed for one 'side': binaural. In this case the synchronization buttons are not displayed.

If you invoke the settings dialog to change the settings of an existing measurement, where one or more frequencies are already measured, you can add or remove new frequencies or remove already measured frequencies anyway. If you add frequencies the measurement will change to status 'incomplete' in any way and can be restarted. The new frequencies will be measured automatically. If you remove frequencies that were already measured, the corresponding loudness functions will not be displayed any more and will not be considered in the auditory sensation fields. However the measurement data are not deleted. If you reselect the corresponding frequency in the settings dialog the data are displayed again. If you can to clear measured data of a particular loudness function because they contain invalid answers, this can be achieved using the context menu of the loudness function (see paragraph 7.4).

5.1.2 Method

In addition to the frequency selection some more parameters can be adjusted that will have an effect on the measurement method. Some of these parameters will be shown on the measurement dialog in the area 'Setting' (see paragraph 7).

Adaptive

In the area 'Method' first of all the adaptive mode can be changed. Depending on the configuration this option may vary and may be enabled or disabled. In adaptive mode (this is usually the default setting) you can enter an upper level limit for each side (channel) if required (for special measurements), if the edit fields 'Level-Limit' are visible. This level (the unit depends on the signal type to be used) will not be exceeded on the corresponding side during the complete measurement.

Attention: The declaration of an upper level limit may influence the measurement result (the so called 'range effect'). Measurement results obtained in this way therefore may deviate from results obtained with the standard settings and can not be compared to standard measurements. Please note that this holds for comparisons to the reference data (mean data for particular configurations) as well. Note the warning concerning this issue that may be displayed after changing the corresponding settings.

Constant (non-adaptive)

If the option 'Adaptive' is unchecked or disabled the measurement will be executed in the so called 'constant' mode (non-adaptive). In this case some more parameters are displayed and may be adjustable (depending on the configuration, Figure 4):

Figure 4

'Minimum-Level' and 'Maximum-Level' determine the minimum or maximum level respectively a particular frequency or signal will be presented. **Attention:** These levels have to be adjusted according to the individual hearing loss.

The number of 'level-Intervals' determines the number of levels (between minimum and maximum level) will be presented. For example a number of 9 intervals will result in a total number of 10 different levels (including minimum and maximum level) to be presented. In the

example shown above the levels 10, 20, 30 … 100 will be presented. The number of 'Repetitions' determines how often each level will be presented (the default setting should preferably not be changed).

Attention: These parameters have to be adjusted separately for each frequency. To achieve this, the corresponding frequency has to be highlighted (click on the frequency or signal name) and the parameters have to be adjusted subsequently. If you select the option 'apply to all (editable fields)' the actual settings are applied to all frequencies or signals respectively. If any changes were applied to these settings it is highly recommended to double-check the settings for all frequencies or signals respectively by calling dialog again (using the dialog for changing measurement settings).

Attention: The specific settings (level range, number of intervals and repetitions) in non-adaptive measurements may influence the measurement result (the so called 'range effect'). Measurement results obtained in this way therefore may deviate from results obtained with the other settings and can not be compared to standard measurements. Please note that this holds for comparisons to the reference data (mean data for particular configurations) as well. Note the warning concerning this issue that may be displayed after changing the corresponding settings.

5.1.3 Stimulus-Presentation

A double presentation of the stimuli '2-times' can be selected besides the default setting '1-time' in the area 'Stimulus-Presentation' (Figure 5):

Figure 5

When selecting '2-times' presentation (two times subsequent presentation) the intermission ('pause') between the two presentations can be determined using the input field 'pause in ms' (specify pause in milliseconds) If the double presentation is activated, the actual trial can be cancelled in case of too loud presentation after the first presentation by selecting the answer 'extremely loud' (or the highest available category respectively) immediately.

By clicking 'Ok' the settings are accepted and the measurement dialog is displayed (see paragraph 9). However, if you click 'Cancel' the action is aborted. If a new measurement was to be created the software will return to the start dialog. If the settings dialog was called for a stored measurement all changes are discarded and the software will return to the measurement dialog.

5.2 Broadband measurements

If you have selected a profile for a broadband headphone measurement for one particular side (Broadband, Headphones, left/right) the following dialog is displayed (Figure 6):

When creating a new measurement one standard signal is pre-selected. In the area ‘Signals’ you can select (check box checked) one broadband signal for each side. Usually you can select **one** signal per side only. If you want to change the selection you have to deselect (check box unchecked) the selected signal first because the simultaneous selection of more than one broadband signal is not permitted. The available signals are described in paragraph 10.

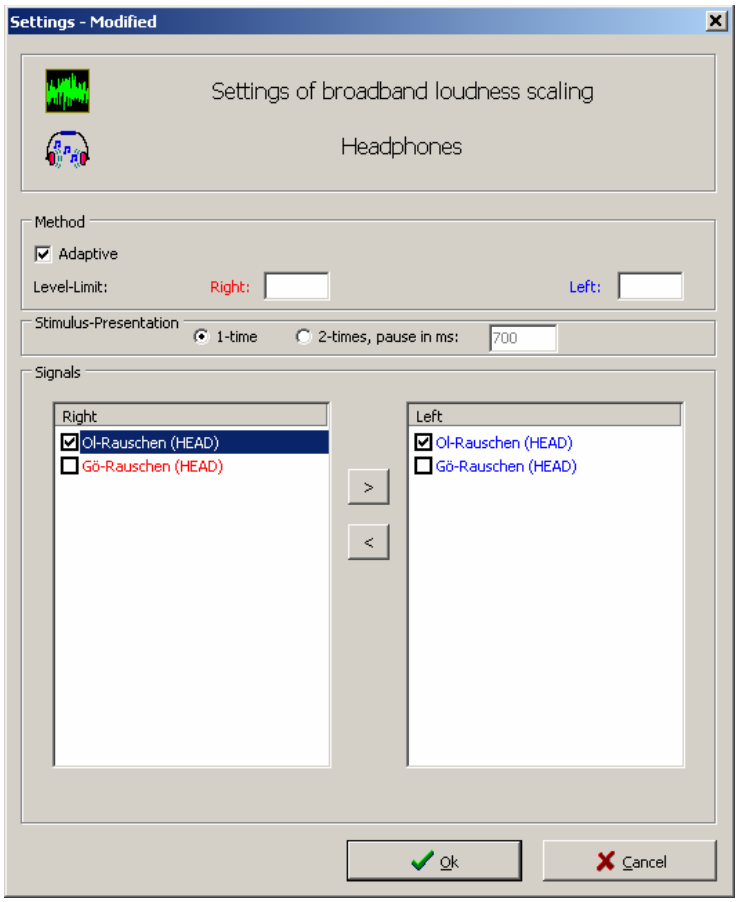


Figure 6

Two buttons for synchronizing the signal selection for both sides are located in the middle of the two selection boxes. Clicking the > button copies the selection from the left side to the right side, clicking the button < copies the selection from the right side to the left side.

For binaural measurements, i.e. the presentation of signals on both sides simultaneously, the frequencies will only be displayed for one ‘side’: binaural. In this case the synchronization buttons are not displayed.

The adjustment of the settings in the areas ‘Method’ and ‘Stimulus-Presentation’ are identical for narrowband and broadband stimuli. Please refer to the corresponding paragraphs of the last chapter.

6 Demo mode

The measurement application ‘Categorical Loudness Scaling’ can be started in demo mode from the start dialog of the ‘Oldenburg Measurement Applications’. The demo mode will be displayed on the settings dialog and the measurement dialog.

Besides the general limitations of the demo mode described in the manual of the start dialog, some more limitations apply when running the loudness scaling in demo mode. In the following these additional limitations are described. **Attention:** It is essential to note the information on the calibration in demo mode in the manual of the start dialog.

In narrowband measurements only two fixed frequencies are available. Unlike the regular signals these signals are no scientific evaluated signals. These signals are simple narrowband noise signals in the specified range (without a well defined bandwidth).

In broadband measurements only one broadband noise signal is available. This signal is a bandpass limited noise signal without a well defined frequency response (no reference noise).

Besides these limitations all settings can be adjusted in the same way as in the full licensed mode to a large extent. **Attention:** the demo mode of the ‘Categorical Loudness Scaling’ is intended to be used for the demonstration of the method only. Due to the special signals used in the demo mode, the demo calibration and the additional restrictions the measurement results obtained in demo mode must not be compared to other results and must not be interpreted as regular measurement results of a regular loudness scaling experiment.

7 The measurement dialog

After the successful creation of a new measurement or after the selection of a stored measurement the measurement dialog is displayed. The following figure (Figure 7) exemplary shows the measurement dialog for a new narrowband headphone measurement for separate sides left and right:

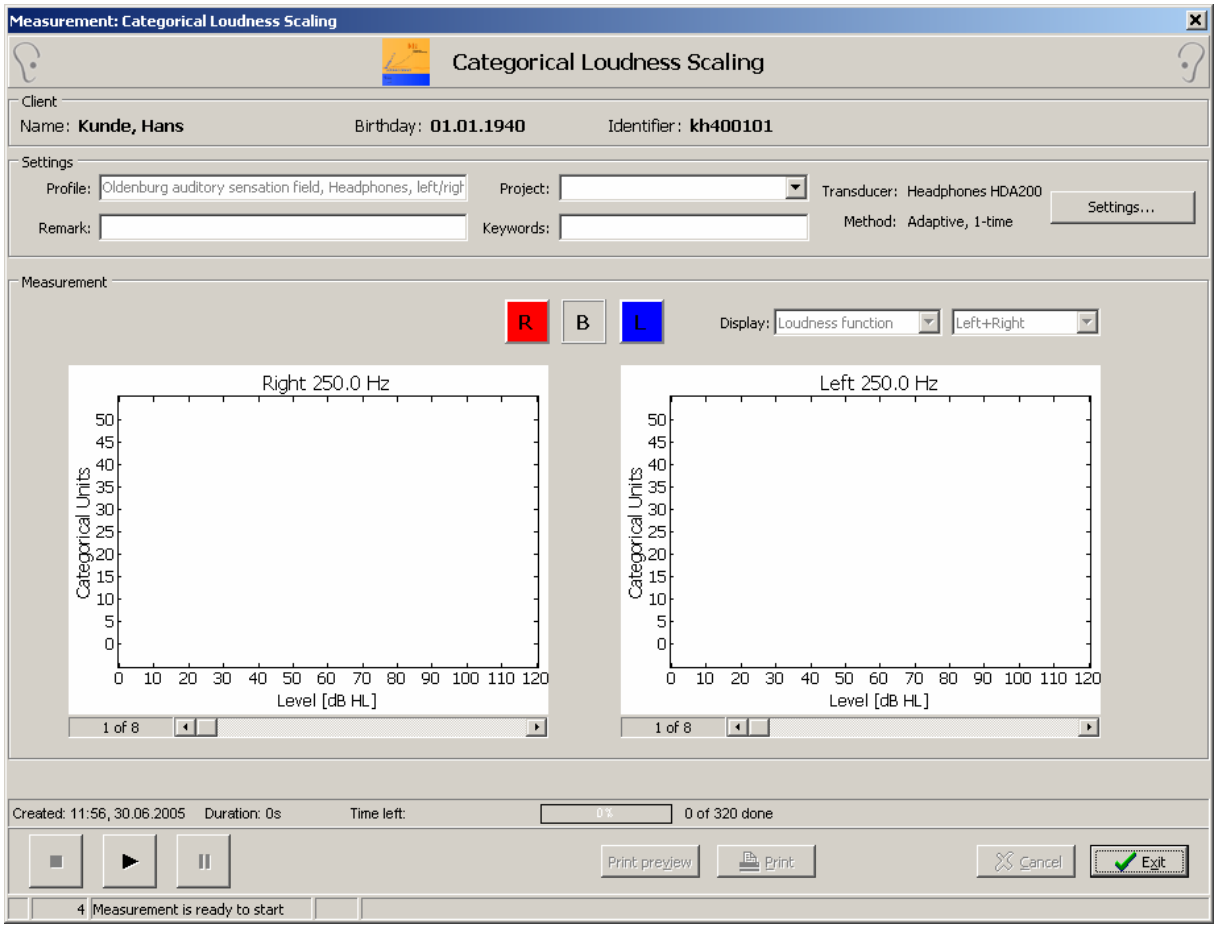


Figure 7

7.1 Common functions

The measurement dialog consists of three functional areas. The upper area contains client data and common settings (Figure 8). The lower area contains information about the status and progress of the actual measurement and measurement procedure control elements (Figure 9). The middle area contains measurement specific data and thus the contents depend on the application and the measurement configuration. In the following the common functions and labels in the upper and lower area of the measurement dialog are described.

The area 'Client' in the upper part of the measurement dialog (Figure 8) contains the actual client data. The region 'Settings' below contains the name of the actual measurement profile at the left. You can enter an optional remark into the edit field 'Remark' below.

You can assign the actual measurement to any project by from the user defined project list by selecting it in the field 'Project'. Projects can be added by adding them to the project list (see paragraph 'Project list' in the documentation of the start dialog). You can enter arbitrary keywords into the field 'Keywords'. You can search for these keywords in the database if the database query supports the field 'keywords'.

At the right the transducer type and transducer name is shown. Depending on the application, the measurement profile and the configuration you can click 'Settings…' to call the measurement settings dialog again. There you may change one ore more parameters of the measurement. Only measurements in the stopped state can be changed.

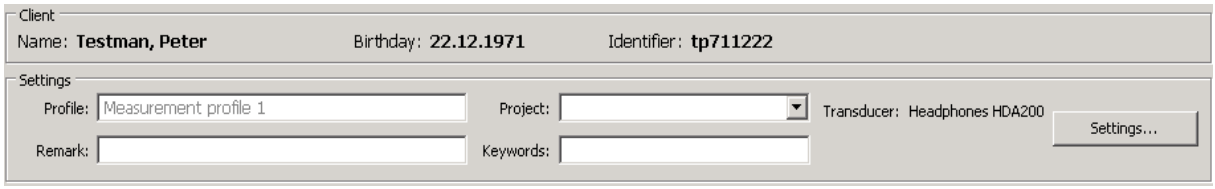


Figure 8

The lower area of the measurement dialog contains all measurement control elements and measurement progress data (Figure 9):

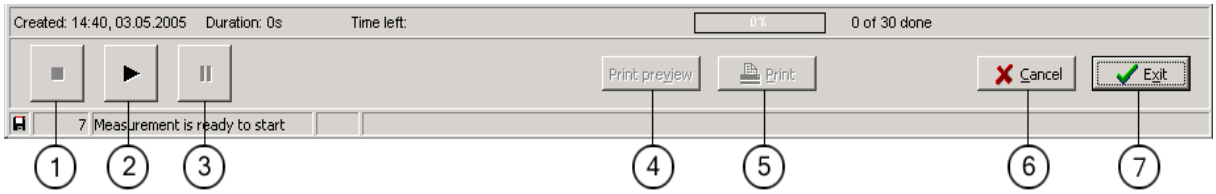


Figure 9

①	Stop	The measurement is stopped and can be restarted using the start button. Depending on the measurement type some or all measurement data will be rejected.
②	Start	The measurement is started or resumed after a break.
③	Pause	The measurement is set to paused state and can be resumed by clicking Pause again.
④	Print preview	The print preview dialog is shown (see below).
⑤	Print	The actual measurement is printed.
⑥	Cancel	The actual measurement is cancelled (data and/or changes are rejected).
⑦	Exit	Exits the actual measurement. Data and/or changes are stored.

Depending on the application, configuration and measurement state one or more buttons or functions may be disabled. For example a measurement can only be started *or* stopped, print preview and printing is only enabled if measurement data are present. Some measurement applications may not support all listed controls.

The measurement progress is shown above the buttons. During the measurement you can see (from left to right): time and date of measurement creation, actual net measurement duration, estimated remaining time, number of measured trials and total number of trials for this measurement. The latter is shown as text and with a progress bar. Please note that the total number of trials may be just a rough estimate in measurements using adaptive procedures and may change during the measurement. The estimation of the remaining time depends on the number of trials and therefore may change during the measurement too. For completed measurements the following information is shown (left to right): time and date of measurement creation, net measurement duration, time and date of measurement completion.

Below the buttons some information about the measurement status are shown in the status bar. At the left the floppy symbol may indicate that data have been changed. The next two fields show the global status where the first field contains a clock showing the time elapsed in the actual measurement state. The last two fields contain application specific information, where the first contains a clock showing the time elapsed since the last state change.

7.2 Extensions to the common functions

In the upper area of the ('Settings') some additional information concerning the measuring method are displayed below the type and name of the transducer. In this case the method type 'Adaptive' or 'Constant' and the number of stimulus presentations ('1-time' or '2-times') is displayed.

7.3 Executing a loudness scaling experiment

After starting a new or incomplete measurement using the start button a starting request is displayed on the screen or the response ox respectively (Figure 10):

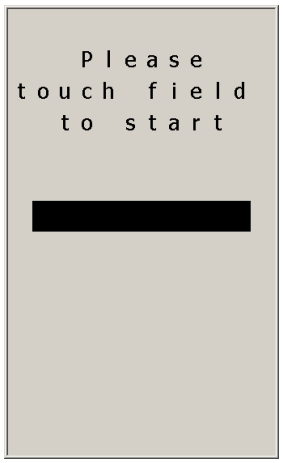


Figure 10

If the user (client) has clicked the field the categorical scale is displayed on the screen/response box. (Figure 11):

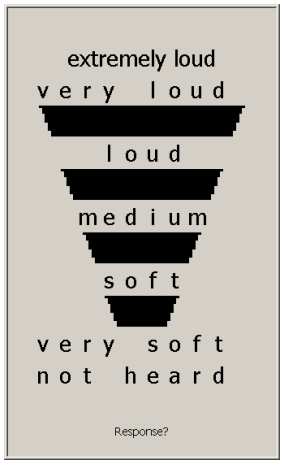


Figure 11

The scale is described in paragraph 11. After the displaying the scale the first signal is presented and the software waits for the response of the client. At the right of the status bar of the measurement dialog the name of the actual signal is displayed. During the signal presentation 'Signal' will be displayed with small letters below the categorical scale. If the software is waiting for the users response 'Response?' is displayed accordingly. In older versions of the software an 'X' was displayed in the lower right corner of the scale that was removed during the signal presentation (this was used to give some orientation to the client when signals are inaudible).

When the client selects a category by clicking on it the corresponding answer is displayed inverted (Figure 12):

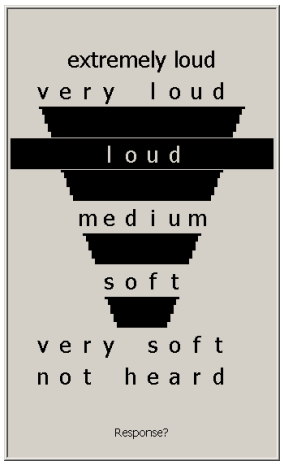


Figure 12

This inverted display remains untouched for a short time. Within this time period the client may revise his answer by selecting another category. At the moment the inverted display is cleared, the answer for this trial is stored. The next signal is presented and the software waits for the next answer. These steps are repeated until the measurement is complete or stopped manually.

If an adaptive measurement is stopped or cancelled manually all measurement data of loudness functions that are not complete are discarded because the adaptive level control does not store any incomplete loudness functions. If you just want to suspend the measurement for a small break use the 'pause' button. In this case the waiting for an answer is cancelled. After resuming the measurement by clicking the pause button again, the last presentation is repeated.

7.4 Display of loudness functions

In the center area 'Measurement' of the measurement dialog the results of complete or incomplete measurements are displayed. The loudness functions for all frequencies or signals respectively are displayed if either the measurement is new, or no measurement data are available for a narrowband auditory sensation field or 'Loudness function' is selected manually from the top right drop down list. The loudness function for one frequency/signal for each side will be displayed at a time. If more than one frequency/signal is available for the particular measurement you can scroll through the loudness functions using the scroll bar below each chart. The loudness functions are empty for new measurements. During a measurement the results and loudness functions are updated permanently. However, the display switches to the actual frequency/signal automatically. Therefore not all available data are visible at the same time.

Figure 13 exemplarily shows the display of the loudness functions for a complete narrowband headphone, left and right side measured separately:

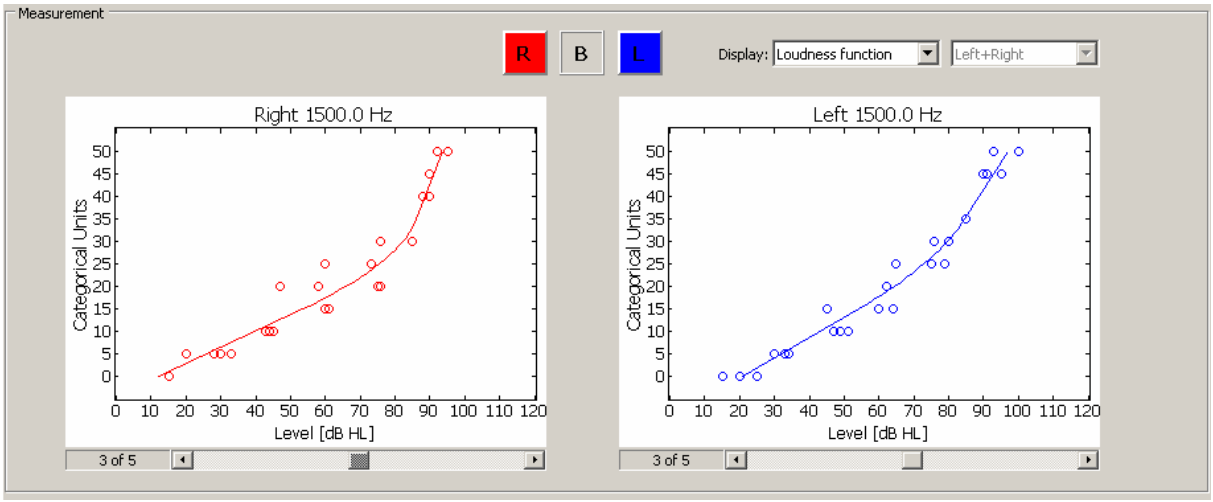
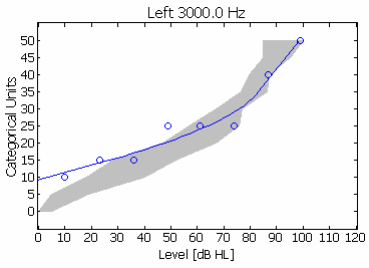


Figure 13

At the top the included sides are highlighted with colors in the middle of the dialog (here: left and right). Using the drop down list next to 'Display:' you can manually switch between the display of the loudness functions and the display of the auditory sensation field (see below). The loudness functions are shown in the charts below. The categorical loudness (Categorical Unit = CU) is plotted as a function of the presentation level. The scale is described in paragraph 11. Each circle corresponds to one measured trial, i.e. correspond to the answer of the client at the given presentation level on the level axis. The line corresponds to the fit function that was calculated (fitted) for the particular loudness function (only visible for frequencies/signals that were measured completely). This so called 'fitting function' may vary with the selected fitting model (see description of the context menu below). If reference data (mean values for normal hearing persons) are available for the actual configuration (method) they will be displayed as gray region (see figure at the right, not available for all measurement configurations). A level range around the mean value is displayed for each loudness value. This range may vary depending on the configuration (confidence interval, percentile).



A loudness function can be edited using the context menu (a right mouse click on a loudness function invokes the context menu, Figure 14).

In the following all menu items of the context menu are described:

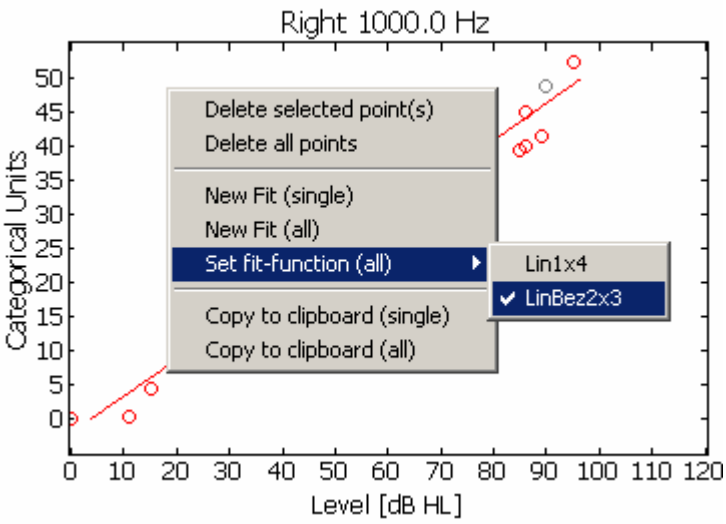


Figure 14

1. 'Delete selected point(s)'

   If a measurement is complete, i.e. if <u>all</u> loudness functions were completely measured, then particular data points may be cleared subsequently. This is useful to delete particular mavericks (e.g. caused by wrong answers of the client given by mistake). **Attention:** The particular data point will be deleted irrevocably. No additional trials will be measured. The fitting curve will be adjusted according to the remaining data.

   Select the data point to be deleted by a left mouse click. A selected point will be displayed in gray (see Figure 14). The menu item 'Delete selected point(s)' can only be selected if at least one point is selected.

2. 'Delete all points'

   If too many data points were measured incorrect you can delete all points using this menu item. **Attention:** All data points will be deleted irrevocably. In this case the corresponding loudness function will be empty and will be interpreted as 'not measured yet'. The measurement as a whole will therefore change its state to 'incomplete' and may be restarted. The formerly cleared loudness function will be measured again. If you want to remove a loudness function from a measurement without measuring it again, the corresponding frequency has to be removed in the dialog for changing the settings (see paragraph 5.1.1). In this case the corresponding loudness function will not be displayed any more. The measurement data will not be cleared and after selecting the frequency again in the settings dialog that data will be shown again.

3. 'New Fit (single)'

Selecting this menu item will cause a recalculation of the corresponding fitting function using the actual fitting model. Usually it is not necessary to call this function. However, for older measurements this may cause a change in the fit loudness function, if the mathematical fitting model has changed meanwhile. **Attention:** A recalculation of the fitting curve is irreversible and will be stored permanently.

4. 'New Fit (all)'

   Same as 'New Fit (single)', but the recalculation is performed for all loudness functions.

5. 'Set fit-function (all)'

   This submenu shows the actually selected mathematical fitting model used for the calculation of the fitting curves with a check mark. If you change the fitting model all loudness functions will be recalculated.

6. 'Copy to clipboard (single)'

   By selecting this menu item the parameters of the loudness function are copied to the clipboard as text line. The line has the following format:

   `ID "DATE START - END" "REMARK" SIDE "FITFUNCTION" NUMBER FREQUENCY PARAMETER`

   where:

   `ID` = identifier of the actual client.

   `DATE` = Date of measurement creation.

   `START` = Time of measurement creation.

   `ENDE` = Time of measurement completion.

   `REMARK`= Remark entered for this measurement.

   `SIDE` = Measured side = Links, Rechts, Binaural (German only: Links: left, Rechts: right, Binaural: binaural).

   `FITFUNCTION` = Name of the fit function used for the calculation of the fitting curves.

   `NUMBER` = Number of parameters used for the fitting function.

   `FREQUENCY` = Frequency (for narrowband measurements) or signal number (for broadband measurements).

   `PARAMETER` = the number `NUMBER` of fitting parameter (number and meaning of parameters depend on the fitting function used for the fit).

   These specifications are given without warranty. The export format is subject to alteration without notice.

7. 'Copy to clipboard (all)'

   Same as 'Copy to clipboard (single)' but the parameters of all loudness functions are copied. A text line will be created for each side (left, right, binaural). At the end of the line the data combination `FREQUENCY PARAMETER` will be appended for each frequency/signal (see above).

7.5 Display of auditory sensation fields

If a measurement containing data for narrowband auditory sensation field, i.e. at least two completely measured frequencies, the display (upper right drop down list) is automatically switched to 'Auditory sensation field' (the display can be switched manually at any time). If the display is switched to 'Auditory sensation field' the so called 'auditory sensation field' is shown.

Figure 15 exemplarily shows the display of an auditory sensation field for a complete narrowband headphone, left and right side measured separately:

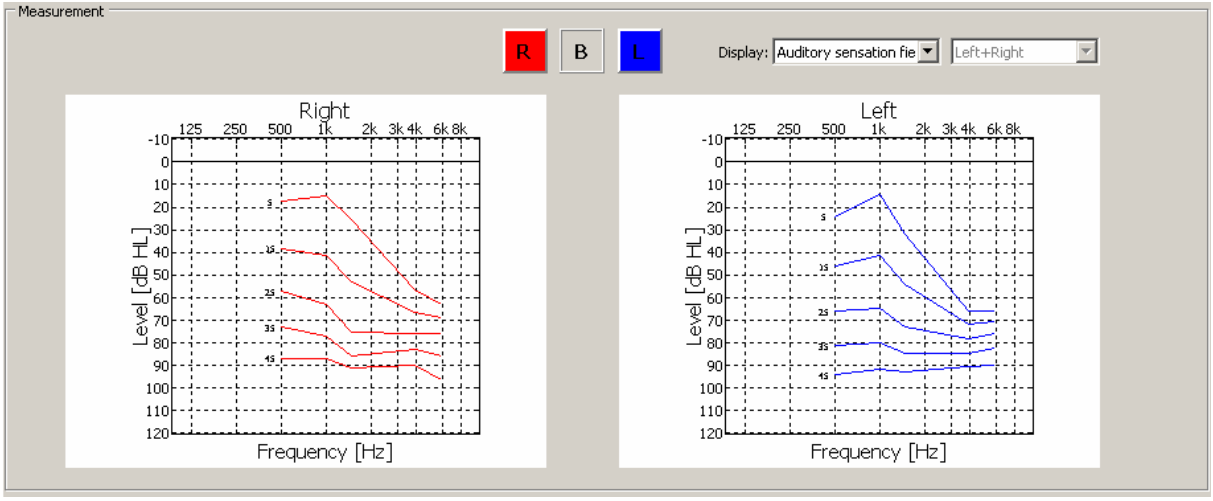


Figure 15

Equal loudness contours are for the categories 'very soft' (5 CU), 'soft' (15 CU), 'medium' (25 CU) , 'loud' (35 CU) and 'very loud' (45 CU) are plotted as a function of frequency. The corresponding CU value is plotted at the left of each curve. The scale is described in paragraph 11. The curves are plotting similar to an audiogram, i.e. higher levels are plotted at the bottom of the chart.

The auditory sensation fields can be edited using the context menu as described above for the loudness functions. However, the menu items concerning singe loudness functions are disabled.

7.6 Saving

If the data of a measurement have changed, e. g. by changing some settings or measuring loudness functions, a floppy symbol . is shown in the lower left corner of the measurement dialog. Then you can quit the measurement dialog by clicking 'Exit' or 'Cancel'. In the first case the measurement is stored with all settings and measurement data, clicking 'Cancel' discards all changes, the measurement is not stored again.

7.7 Print preview and printing

If you click button ⑦ 'Print' (see above) the standard printer configuration dialog is shown. If you click button ⑥ 'Print preview' a dialog with a print preview containing some controls for the configuration of the printout (*Figure 16*):

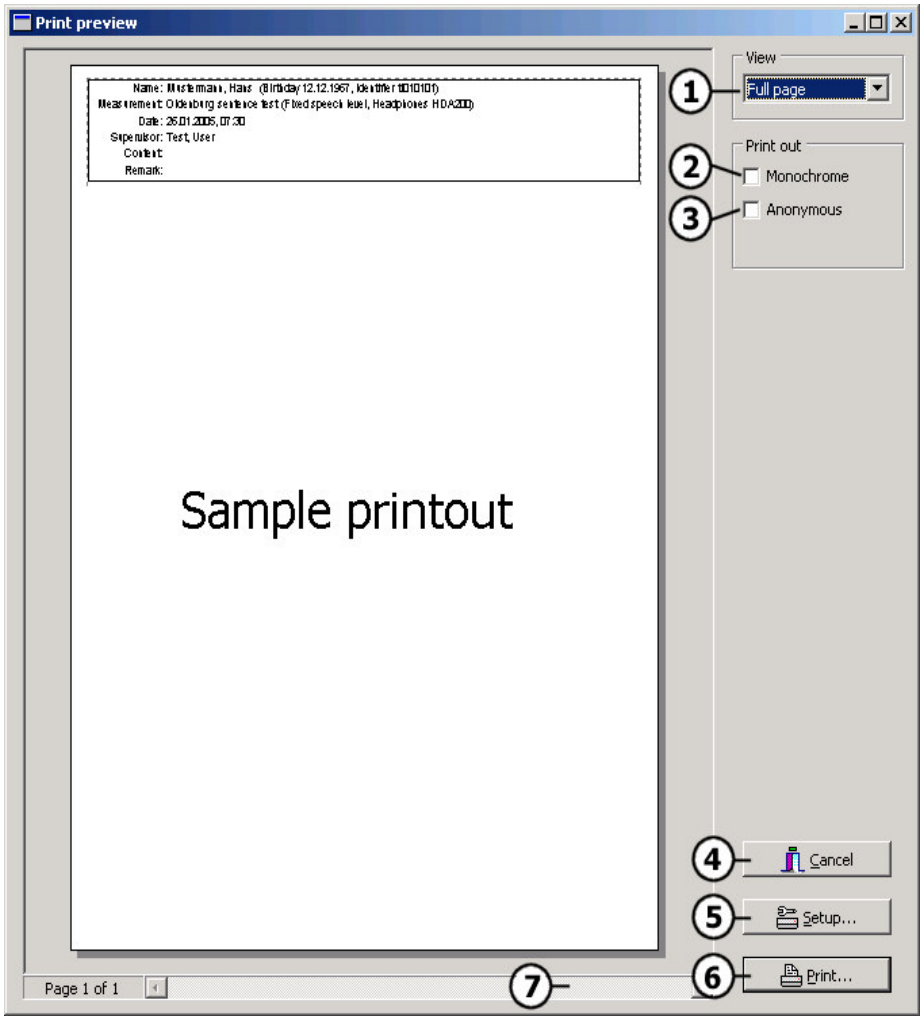


Figure 16

The dialog contains the following controls:

①	View	Select the desired zoom for the print preview. This setting has no effect on the printout.
②	Monochrome	Select here if you want to print monochrome or colored. The default setting depends on the installed printer model.
③	Anonymous	If you check this option the names of the investigator and the client are hidden, only the client identifier is printed.
④	Cancel	Exits the print preview.
⑤	Setup...	Calls the standard printer configuration dialog. For details refer to the Windows manual and the documentation of your printer.
⑥	Print...	The standard print dialog is called. For details refer to the Windows manual.
⑦	Scrollbars	Use the scrollbars to navigate through the pages if the printout contains more than one page.

For some measurement applications an additional checkbox ‘Track’ may appear below „③ Anonymous“. Use this option to toggle the visibility of the measurement track on the printout.

7.8 Exporting and calculating loudness functions

In paragraph 7.4 above the procedure how to copy parameters of a loudness function to the clipboard was described (menu items ‘Copy (all)’ and ‘Copy (all)’). From these parameters or the text copied to the clipboard respectively the corresponding loudness functions can be calculated. An example for the calculation of the loudness functions from these data using a MATLAB® script is listed below (no warranty, export format and calculation procedures are subject to changes without any notice):

```
function PlotCuOfLevelSample(exportdata)
%
% Examples:
% PlotCuOfLevelSample('xy "1.1.2001" "" Rechts "LinBez2x3" 4 1500.0 81.29 0.361 2.018 0')
% PlotCuOfLevelSample('xy "1.1.2001" "" Rechts "Lin1x4" 4 1500.0 0.63963 0 25.41549 103.586')
close;
hold on;

signaltype = SignalTypeOfString(exportdata);
fittype = FitTypeOfString(exportdata);
params = [ str2num(ParameterOfString(exportdata, 1)) ...
           str2num(ParameterOfString(exportdata, 2)) ...
           str2num(ParameterOfString(exportdata, 3)) ...
           str2num(ParameterOfString(exportdata, 4)) ];

x = (-20:120);
y = CUOfLevel(x, fittype, params);

plot(x, y, 'b-');
title(signaltype);
hold off;
return

function fittype = FitTypeOfString(string)
   [s,f,t] = regexp(string, '"([a-z_A-Z0-9 \t\r\n\f\-.:]*)"');
   fittype = string(t{length(t)}(1):t{length(t)}(2));
return

function signaltype = SignalTypeOfString(string)
   [s,f,t] = regexp(string, '"([a-z_A-Z0-9 \t\r\n\f\-.:]*)"');
   signaltype = intField(string( 2+t{length(t)}(2) : length(string) ), 2);
return

function parameter = ParameterOfString(string, index)
   [s,f,t] = regexp(string, '"([a-z_A-Z0-9 \t\r\n\f\-.:]*)"');
   parameter = intField(string( 2+t{length(t)}(2) : length(string) ), index+2);
return

function field = intField(string, index)
   field = '';
   [s,f] = regexp(string, '[a-z_A-Z0-9\-.:]*');
   if index<=length(s) & index<=length(f),
      field = string(s(index):f(index));
   end
return

function cu = CUOfLevel(levels, fittype, params)
   cu = zeros(1, length(levels));
   for i=1:length(levels),
      x = levels(i);
      if strcmpi(fittype, 'LinBez2x3')
         Lcut = params(1);
         m_lo = params(2);
         m_hi = params(3);
         if x<Lcut, m = m_lo; else m = m_hi; end
         y = x2y_lin(x, Lcut, 25, m);
         if y>15 & y<35,
            C = [y2x_lin(15, Lcut, 25, m_lo) Lcut y2x_lin(35, Lcut, 25, m_hi); 15 25 35];
            y = BezierX2YFor3ControlPoints1(x, C);
         end
```

```
      else % fittype 'Lin1x4'
         Slope = params(1);
         Offset = params(2);
         Schwelle = params(3);
         USchwelle = params(4);
         if x<=(Schwelle+Offset/Slope)
            y = Offset;
         elseif x>=USchwelle
            y = (USchwelle-Schwelle)*Slope;
         else
            y = (x-Schwelle)*Slope;
         end
      end
      cu(i) = y;
   end
   cu = (cu<0)*0 + (cu>=0 & cu<=50).*cu + (cu>50)*50;
return

function y = x2y_lin(x, x0, y0, m)
   y = y0 + m*(x-x0);
return

function x = y2x_lin(y, x0, y0, m)
   x = (y-y0)/m + x0;
return

function y = BezierX2YFor3ControlPoints1(x, C)
   % calculate t of x
   t = NaN;
   a = C(1,1)-2*C(1,2)+C(1,3);
   b = 2*C(1,2)-2*C(1,1);
   c = C(1,1);
   if a ~= 0
      t1 = -b/(2*a) + 0.5*sqrt((b/a)^2 - 4*(c-x)/a);
      t2 = -b/(2*a) - 0.5*sqrt((b/a)^2 - 4*(c-x)/a);
      t = min([tfilter(t1) tfilter(t2)]);
   elseif b ~= 0
      t = (x-c)/b;
   end
   % calculate y of t
   y = NaN;
   if t>=0 & t<=1
      y = (C(2,1)-2*C(2,2)+C(2,3))*t.^2 + (2*C(2,2)-2*C(2,1))*t + C(2,1);
   end
return

function tout = tfilter(tin)
   tout = 999;
   if isreal(tin) & tin>=0 & tin<=1, tout = tin; end;
return
```

8 Profiles

In the following all available measurement profiles, i.e. variants or pre-defined settings respectively, for the 'Categorical Loudness Scaling' are listed with a short description.

8.1 Oldenburg auditory sensation field, Headphones, left/right

Loudness scaling using narrowband noise signals at standard frequencies ('Oldenburg auditory sensation field'). Presentation on left/right channel separately using headphones.

8.2 Oldenburg auditory sensation field, Headphones binaural

Loudness scaling using narrowband noise signals at standard frequencies ('Oldenburg auditory sensation field'). Presentation binaural (diotic) using headphones.

8.3 Oldenburg auditory sensation field, Freefield, left

Loudness scaling using narrowband noise signals at standard frequencies ('Oldenburg auditory sensation field'). Presentation on left freefield channel.

8.4 Oldenburg auditory sensation field, Freefield, right

Loudness scaling using narrowband noise signals at standard frequencies ('Oldenburg auditory sensation field'). Presentation on right freefield channel.

8.5 Broadband, Headphones, left/right

Loudness scaling using one broadband signal. Presentation on left/right channel separately using headphones.

8.6 Broadband, Headphones, binaural

Loudness scaling using one broadband signal. Presentation binaural (diotic) using headphones.

8.7 Broadband, Freefield, left

Loudness scaling using one broadband signal. Presentation on left freefield channel.

8.8 Broadband, Freefield, right

Loudness scaling using one broadband signal. Presentation on right freefield channel.

9 Literature

For additional information on the categorical loudness scaling please refer to:

Kollmeier, B. (Ed.) (1997). „Hörflächenskalierung – Grundlagen und Anwendung der kategorialen Lautheitsskalierung für Hördiagnostik und Hörgeräte-Versorgung“. median-verlag. ISBN 3-922766-26-9.

10 Signals

In the following the available signals for the ‘Categorical Loudness Scaling’ are listed with a short description.

User defined broadband signals can be installed in addition to the standard broadband signals. This procedure is described in paragraph 12.1.

10.1 Narrowband

For the narrowband loudness scaling so called low-noise-noise signals with a third octave bandwidth around the specified center frequency are used.

10.2 Ol-Rauschen

One section of the speech shaped noise from the Oldenburg sentence test.

10.3 Gö-Rauschen

One section of the speech shaped noise from the Göttingen sentence test.

11 The categorical loudness scale

During the ‘Categorical Loudness Scaling’ the client is asked for the loudness in certain categories for different presentation levels. The scale used for these categories is shown below:

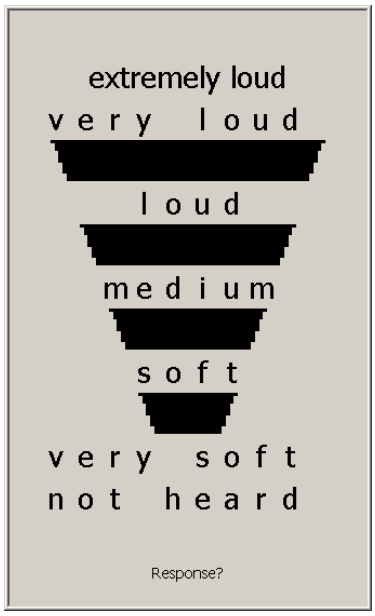


Figure 17

The scale consists of seven main categories named ‘not heard’, ‘very soft’, ‘soft’, medium’, ‘loud’, ‘very loud’ and ‘extremely loud’ and of four intermediate categories shown as wedge-shaped bars. These eleven categories are converted to categorical units = CU. The conversion is shown in the following table:

Categorical number	Categorical text	CU
1	not heard	0
2	very soft	5
3		10
4	soft	15
5		20
6	medium	25
7		30
8	loud	35
9		40
10	very loud	45
11	extremely loud	50

12 Additional functions

The measurement application ‘Categorical Loudness Scaling’ adds additional menu items to the menu of the start dialog. These menu items can be selected form the menu ‘Measurements/Categorical Loudness Scaling’.

The actual version supports the function (menu item):

12.1 Install broadband signal...

With this function a user defined broadband signal for use in broadband loudness scaling experiments can be installed for freefield and headphones (eventually two different signals). **Attention:** A unique signal identifier is assigned to the installed signal on this system (computer). This identifier is only available on the computer where it was originally installed. Therefore

measurement data measured with this signal may not be usable on other computers, even if the same signal is installed on the other computer, because the identifiers may be different.

Please note: if no standard calibration reference (standard noise) should be used an additional reference signal has to be installed using the menu item 'Measurements/Calibration/Install broadband calibration reference' before running this installation procedure for loudness scaling. Only the calibration reference will be really calibrated, the signal to be installed for loudness scaling will refer to that calibration reference. The installation of a broadband calibration reference is described in the manual of the calibration. When using signals that are equalized for particular headphones, an additional calibration reference for every headphone or headphone equalization respectively hast to be installed. Furthermore the newly installed calibration references have to be calibrated first. Only after these steps are performed you may finally install a broadband signal for use with the categorical loudness scaling. **Attention:** When using signals that are equalized for a particular headphone, it is necessary for the accurate operation of the 'Oldenburg Measurement Applications', that the type of the headphone is part of the identifier of the calibration reference. For example, if the user defined calibration reference should be named 'MYSIGNAL' and if the corresponding signal was equalized for the headphone HDA200, then the identifier entered during the installation process of the calibration reference must be MYSIGNAL_hda200 (including the underscore before the headphone type).

If a broadband signal should be installed for use with headphones, it is necessary to install the corresponding signal for freefield presentation first (without any headphone equalization). Only then the headphone signal can be installed (even if no equalized signal is used for the headphone because the freefield signal is internally used).

After selecting the menu item 'Install broadband signal…' the following dialog is displayed (Figure 18):

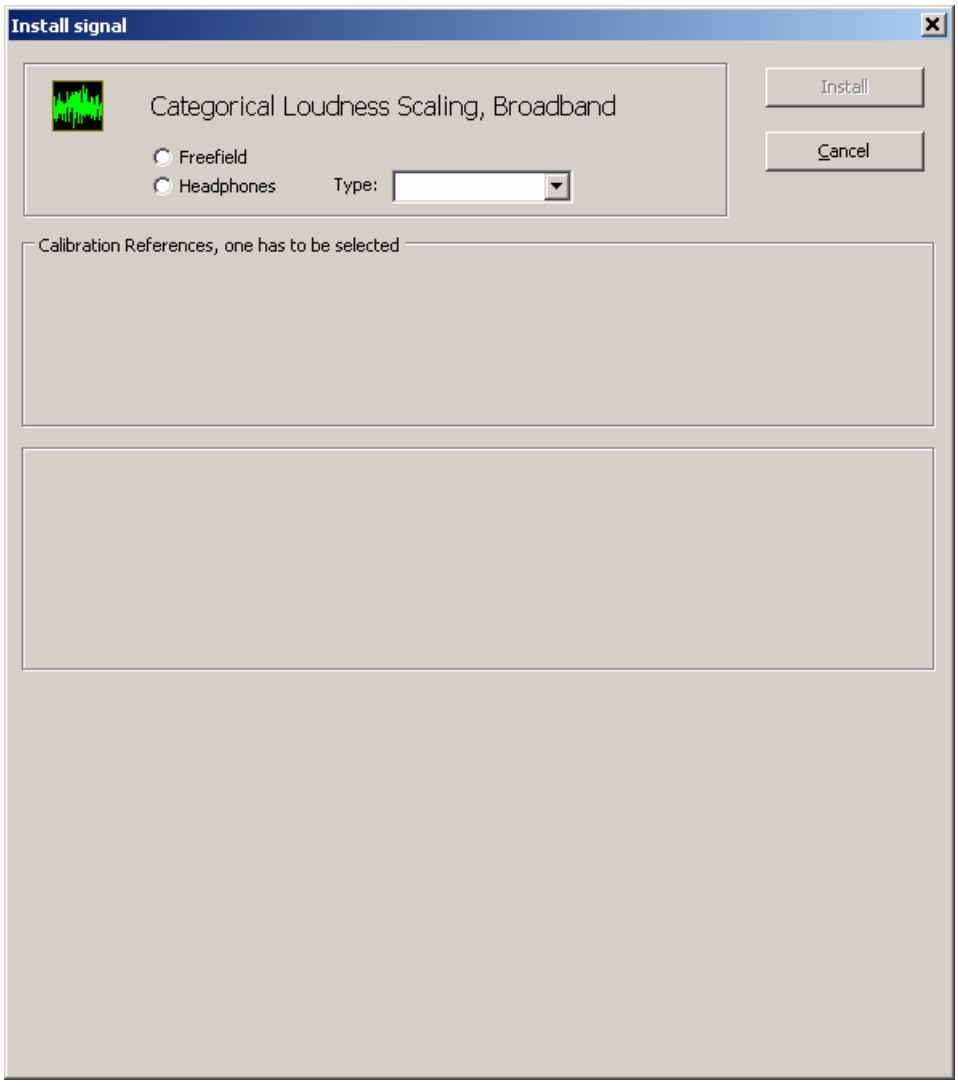


Figure 18

First the transducer type has to be selected by clicking 'Freefield' or 'headphone'. If 'Headphone' was selected, the headphone type (e. g. 'HDA200').has to be selected. This can be achieved by selecting one headphone from the drop down list or by entering a custom name into the field 'Type'. The headphone type will be stored but no further tests will be performed. Particularly the accurate correlation between a headphone type and the corresponding headphone equalization of signals has to be regarded.

Since a freefield signal has to be installed in every case, the following description starts with the installation of freefield signals followed by the installation of headphone signals.

12.1.1 Freefield signal

After selecting 'Freefield' all freefield calibration references, that are actually calibrated for the current audiometer, are listed (field 'Calibration References, one has to be selected'). However, after installing the signal it can be used with all audiometers (but only, if the corresponding calibration reference is calibrated for that audiometer). Below this list an overview on all freefield signals is shown, that are already available for loudness scaling ('Freefield signals already installed'). First one of the listed calibration references has to be selected. This calibration reference will be used in measurements for the signal to be installed. If the freefield signal (.WAV file) to be installed is identical or corresponds to one of the existing standard calibration references the corresponding reference may be selected here. However, usually a separate calibration has to be installed due to differences in the power spectrum of different signals (see above, for the installation of calibration references it is mandatory to read the manual of the calibration).

The selected calibration reference can not be changed subsequently. Please note that changes to the calibration of the calibration reference will result in a corresponding change of the output level of the installed freefield signal. After selecting the calibration reference the fields for the input of signal parameters are shown (Figure 19):

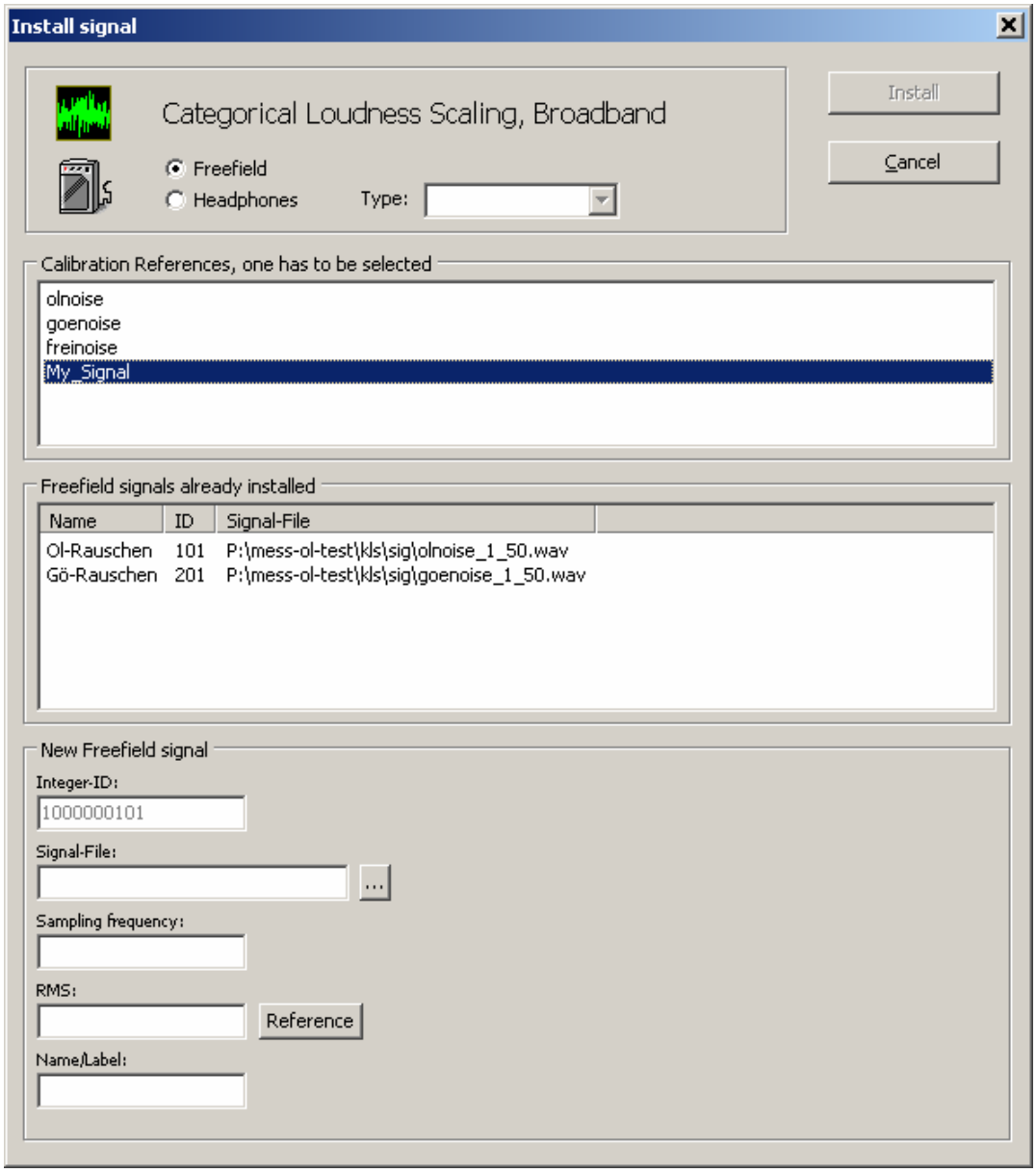


Figure 19

The so called 'Integer-ID' (internally called 'Modus') assigned by the software automatically. This identifier is unique on the system (computer) and is permanently mapped to a specific signal. Therefore it is not possible to exchange measurement data using user defined signals between different computers or display or resume such measurements on other computers than the computer where they were originally created.

In the field 'Signal-File' the full filename (including the path) may be entered manually or you may select an existing file from the disk by clicking the '...' button. Please note that the existence of a file is not checked here. However, in later measurements the file has to be present and valid.

Enter the sampling frequency of the wave file into the corresponding field. If an existing file was entered in the field 'Signal-File', this value will be set automatically; otherwise it has to be entered manually. Please note that only stereo wave files with a sampling frequency of 44100 Hz are supported as a rule.

The RMS value in dB full scale has to be entered into the corresponding field. This value may differ from the calculated RMS value of the file itself, but has to be set correctly in relation to the

selected calibration reference. If the same RMS value is entered here as the RMS value of the calibration reference, then the identical amplification will be applied to the signal as would be applied to the calibration reference at same levels. This should be the normal case. By pressing the button 'Reference' the RMS value assigned to the calibration reference can be copied to the RMS field. If the signal was created with different amplitude the RMS value has to be adjusted according to this difference (smaller RMS values will result in higher amplifications and vice versa).

Finally a unique (preferably short) name has to be entered into the field 'Name/Label'. If the selected name is already in use by another signal a corresponding hint will be displayed and another name has to be chosen. This name will be shown in later measurements on the measurement dialog and on the printout in the corresponding charts. Therefore they should be reasonable short, but should include all important signal properties, e. g. eventually applied headphone equalization.

After entering all requested signal parameters the button 'Install' may be pressed. After successfully finishing the installation procedure the newly installed freefield signal can be selected for broadband loudness scaling experiments and can be selected in the corresponding dialog.

The signal parameters are checked when the button 'Install' is pressed and corresponding hints or error messages may be displayed, for example if the chosen 'Name/Label' is already in use. If the selected signal file (WAV file) is already installed with a different name a warning will be displayed. However, after a confirmation the signal may be installed again (using another name/label).

12.1.2 Headphone signal

After selecting 'Headphone' and the selection or input of the desired headphone type respectively, all headphone calibration references, that are actually calibrated for the current headphone of the current audiometer, are listed (field 'Calibration References, one has to be selected'). The installation of a headphone signal is only valid for the current headphone of the current audiometer and must be installed for different headphones and/or audiometers separately. First one of the listed calibration references has to be selected. This calibration reference will be used in measurements for the signal to be installed. If the freefield signal (.WAV file) to be installed is identical or corresponds to one of the existing standard calibration references the corresponding reference may be selected here. However, usually a separate calibration has to be installed due to differences in the power spectrum of different signals (see above, for the installation of calibration references it is mandatory to read the manual of the calibration). For the installation of this calibration reference, please refer to 'Freefield signal' above).

Attention: it is mandatory to select the correct calibration reference for the particular headphone. Before a broadband headphone signal can be installed, the freefield signal and the corresponding calibration reference must be installed (see above). Afterwards a calibration reference for the headphone has to be installed (if a separate reference has to be used). Only after this the broadband headphone signal can be installed for use in loudness scaling experiments as described here.

In the area 'Freefield signals already installed' all freefield signals are listed, that are already available for loudness scaling. The freefield signal that corresponds to the headphone signal to be installed has to be selected. Therefore the freefield signal must already be installed at this moment (see above 'Freefield signal'). The specification of the freefield signal is mandatory, therefore for each headphone signal a corresponding freefield signal has to be installed.

After selecting the calibration reference and the freefield signal the fields for the input of signal parameters for the new headphone signal are shown (Figure 20). Furthermore already installed headphone signals that are assigned to the same freefield signals are listed at the right.:

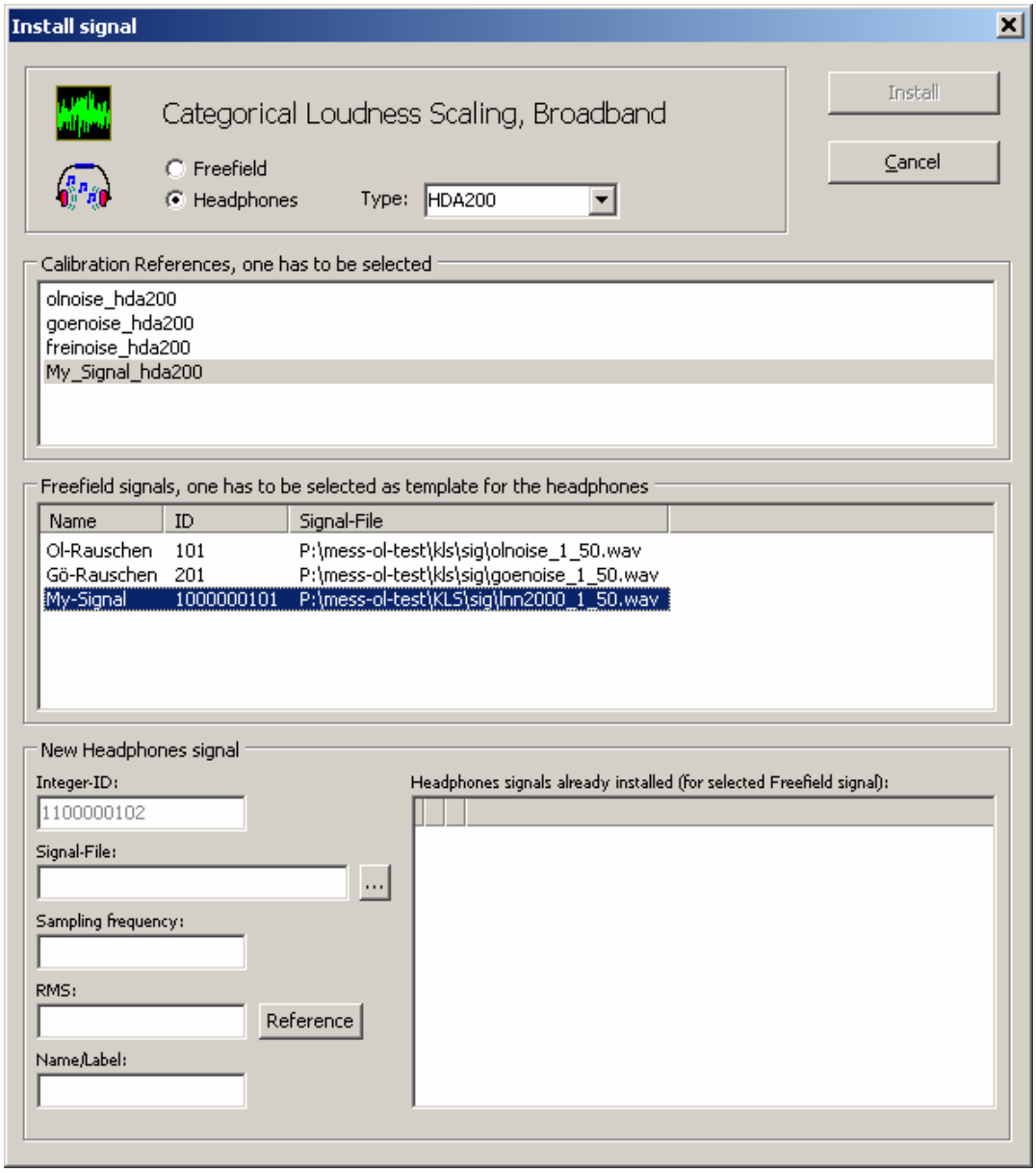


Figure 20

The parameters (area 'New Headphones signal') have to be adjusted in the same way as described above in the paragraph 'Freefield signal'.

After entering all requested signal parameters the button 'Install' may be pressed. After successfully finishing the installation procedure the newly installed headphone signal can be selected for broadband loudness scaling experiments and can be selected in the corresponding dialog.