STSM Report

Flower plotting tinnitus subtypes

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The STSM was carried out from August 18 to 25, 2016 at the Karolinska Institute Stockholm. The guest (Winfried Schlee) and the STSM host (Christopher Cederroth) have many plans for future collaborations on several research projects and one grant proposal. A major step for this collaboration will be the joint publication of the STSM results as described below.

Introduction

Tinnitus is a common phantom perception and is characterised by the perception of sounds in their physical absence. This condition is experienced by about 10-15% of the population (Gallus et al., 2015) and can be incapacitating in 10 to 20% of these cases, interfering with sleep and concentration, affecting productivity at work, increasing the likelihood of accessing disability pension, and can even lead to suicide (Dobie, 2003; Heller, 2003). Even if many people habituate over time and even if tinnitus distress can be reduced by psychotherapeutic interventions, tinnitus is a chronic condition and there are still no therapies available that reliably reduce tinnitus loudness (Langguth et al., 2013).

Tinnitus is a chronic complex disorder and a major challenge for tinnitus research and also for clinical management of tinnitus is its heterogeneity (Elgoyhen et al., 2015). Multiple causes for tinnitus have been identified (www.tinnitusresearch.org/en/projects/flowchart_en.php) and the proper diagnosis of tinnitus – as well as proper management – has to rely on input from specialists of various medical disciplines. Moreover the tinnitus-related handicap varies from patient to patient (Kuk et al., 1990). Whereas some patients suffer mainly from sleeping problems (Schecklmann et al., 2015), others are primarily handicapped by impaired cognitive function (Tegg-Quinn et al., 2016; Trevis et al., 2016) or communication abilities (Gilles et al., 2016). This variability is reflected by a large variety of different measurements for quantifying the different aspects of tinnitus in individuals (Hall et al., 2016). One approach that has been suggested to account for this variability is the use of multiple measurement tools for quantifying the different aspects of tinnitus (Langguth et al., 2007). Even if most of these measurements correlate with each other, they assess slightly different aspects of an individual's tinnitus (Milerová et al., 2013; Zeman et al., 2012). However, a challenge related to the use of multiple measurement tools, is the visualization of the data. Information from multiple assessment tools needs to be integrated and aggregated in a way that is understandable for all disciplines and practical for the clinical context. In this paper we want to concentrate on this challenge and suggest a new way of aggregated representation of an individual's tinnitus data as a so-called "tinnitus flower plot".

Hypothesis

We propose that such an aggregated representation of the various aspects of tinnitus should meet the following requirements:

1) The data representation should be easy to understand and the information of the figure can be grasped visually.
2) The data representation should be understandable across all medical disciplines. No prior knowledge about cut-off scores and ranges of the scores should be needed.
3) The data representation should be able to integrate and aggregate scores from multiple medical domains and various measurements.
4) The data representation should be able to display longitudinal data. Changes over time, e.g. as a response of clinical treatment, should be displayed and important changes easily detectable by the clinicians.

We suggest here the “tinnitus flower plot” (see figure 1) to be a visualization instrument for clinical data that meets the here defined requirements and can be useful for the daily clinical work. The requirements will be discussed in detail.

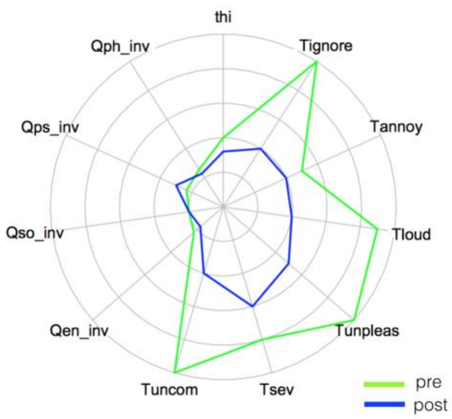

Fig 1. Example “tinnitus flower plot” for an individual tinnitus patient with a clear treatment benefit.

Sample description

For the purpose of the study, we selected a group of tinnitus patients from the Tinnitus Research Initiative database (www.tinnitus-database.de) (Landgrebe et al., 2010)that participated in any clinical treatment study at the University Hospital Regensburg and have completed the Tinnitus Handicap Inventory (THI), the Tinnitus Severity Questionnaire and the WHO quality of life (WHO-QOL) questionnaire before and after the treatment. An additional inclusion criterion was that patients have rated the clinical outcome with the Clinical Global Impression (CGI) scale on a 7-point Likert scale. These questionnaires were selected as they are the measurement tools that have been most frequently used in the Tinnitus Research Initiative database (Landgrebe et al., 2010). A number of 584 tinnitus patients were included in the analysis. The mean age of the group was 53.3 years (SD 12.2) with an average tinnitus duration of 8.4 years (SD 8.87). 36.7% of the included patients were female. The patients were classified to different groups based on the CGI (table 1). Since the group of patients with a CGI rating of 7 is relatively small (n=3), this group was excluded for the following analysis.

Table 1. Patient categorization according to CGI rating

CGI group	**CGI rating**	**n**
1	very much better	18
2	much better	66
3	minimally better	131
4	no change	255
5	minimally worse	77
6	much worse	24
7	very much worse	3

Development of the graphical method

Ad requirement 1: Selection of the plot type.

The flower plot is a graphical method that allows to display multivariate data on a two-dimensional plane. A line is drawn, which connects the different axis and circumscribes the surface of the flower plot. With increasing values on the axis, the surface increases and can be interpreted as an aggregated measure of the multiple variables that are displayed in the plot. We hypothesize, that this surface is a graphical entity that can be easily evaluated by the observer and can be understood intuitively.

Ad requirement 2: Transformation of the values.

All scores were normalized according the range of the possible scores. A value of 1 therefore represents the maximum possible score. The WHO-QOL instrument measures the quality of life on four different domains with a maximum score of 20 on each domain, representing the best possible quality of life. For the purpose of this graphical illustration, the WHO-QOL scores were inversed prior to normalization to ensure consistency across all measures. A low value on this inversed score thus represents a low rating of the respective quality of life domain. These inversions and normalizations have been performed in order to allow all observers - without specialized knowledge of the measurement instruments – to visually judge upon the data.

Ad requirement 3: Selecting the order of the axes.
It is inherent in the method of the flower plot that the surface of the figure depends on the order of the axes. It is therefore conceivable that certain axes orders are more sensitive for displaying clinical changes than others. With the restriction that values from the same questionnaire (e.g. the four domains of the WHO QOL) should be displayed in neighbourhood to each other, we simulated the full set of possible permutations, which allows a number of 34’560 different outlines of the flower plot. For each of these flower outlines, the following steps were repeated:
- Flower plots for all tinnitus patients were created and the surface of the flower calculated
- Patients were grouped to the CGI groups (see table 1), the average flower surface was calculated for each CGI group to compute the mean distance between the CGI groups
- Patients were grouped to the CGI groups (see table 1) and the variance of the flower surface within each CGI group calculated

The results of these calculations are displayed in Figure 2a with the mean surface difference between CGI groups plotted on the abscissa and the mean surface variance within groups plotted on the ordinate. Goal of this step was to select a figure outline that minimizes the surface variance within CGI groups and maximizes the mean surface difference between CGI groups (marked with a red square). We selected this flower outline as the outline of choice throughout the following steps. In figure 2b we show the mean difference in flower surface before and after treatment for each CGI group using the selected flower outline: The CGI group “no change” showed on average no change in the flower surface, CGI groups with an improvement show an reduction while CGI groups with a worsening of the patient are characterized by an increase of the flower surface.

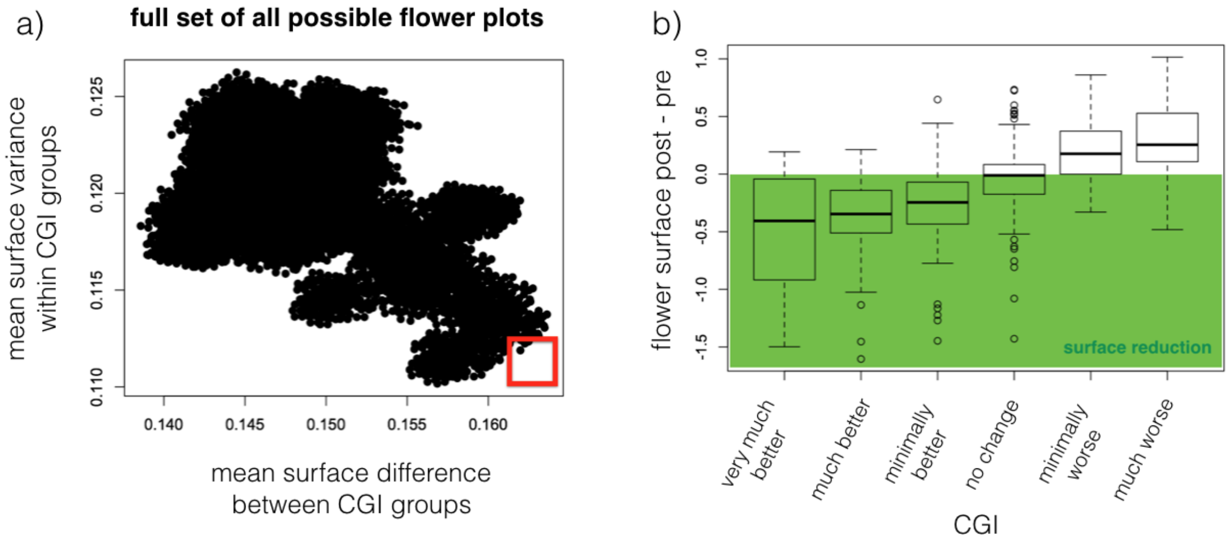

Figure 2. a) The full set of all possible flower plots with different flower outlines (i.e. different organization of axes) was simulated. The mean surface difference between CGI groups was calculated for all flower outlines (abscissa). The mean surface variance within CGI groups was calculated and plotted on the ordinate. The red square highlights the flower outline which optimizes for maximum difference between CGI groups and minimum variance within CGI groups. b) Flower surface differences (post-pre) are displayed for the optimal flower outline. The mean flower surface difference is shown for each CGI group. The CGI group "no change" showed on average no change in the flower surface, CGI groups with an improvement show an reduction while CGI groups with a worsening of the patient are characterized by an increase of the flower surface.

Ad requirement 4: Displaying longitudinal data.

Data of different time points are plotted by different flowers within the same plot. In the examples in figure 3, the measurements before treatment are shown in green while the measurements after the treatment are plotted in blue. As shown in these examples, changes over time can be displayed and observed by comparing the flower surfaces.

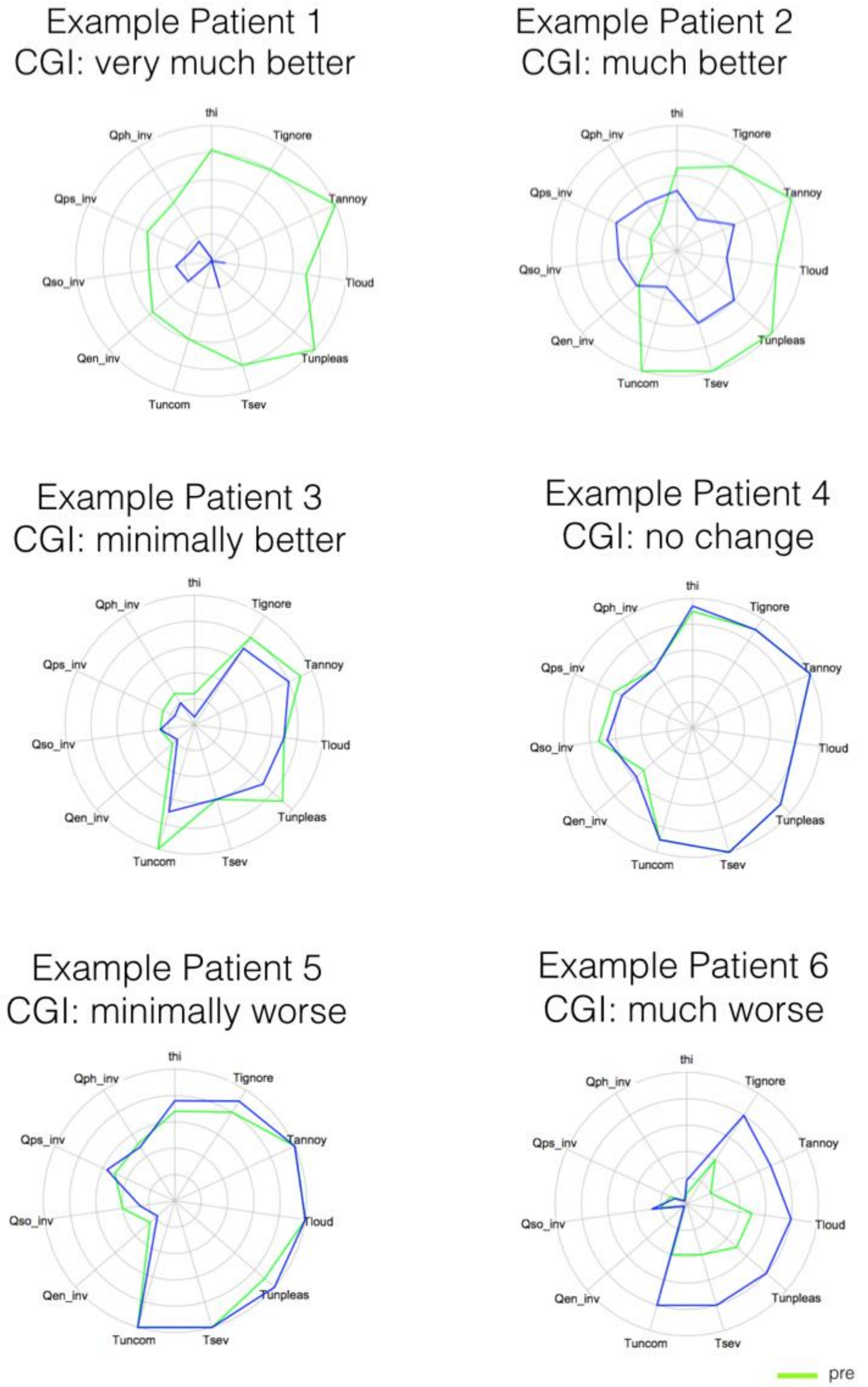

Figure 3. Example plots of tinnitus patients with different CGI ratings.

Discussion

This article describes the development of a comprehensive visualization tool for the management and assessment of chronic tinnitus patients. It selects a collection of relevant measurements for tinnitus assessment and integrates them in a flower plot for an easily comprehendible display of the clinical data.

The data representation is able to visualize both individual and group data and was developed to give a visual and understandable presentation for all medical disciplines - detailed knowledge of the measuring instruments is not needed. The flower plot representation is able to display changes over time to highlight treatment-induced changes.

To the best of our knowledge, this is the first attempt to design a comprehensive visualization of aggregated tinnitus measures over time. This work contributes to novel strategies for high quality care of chronic tinnitus patients and its implementation in the general clinical routine. Nevertheless, more work needs to be done. One component is the selection of measuring instruments that are used for the flower plot. For the purpose of this study we used a set of variables that has been collected on a large number of patients in the tinnitus database, namely the Tinnitus Handicap Inventory (THI), the six subscores of the Tinnitus severity scale as well as the 4 domains in the WHO quality of life measuring instrument. It has to mentioned here, that this selection of parameters was based on a pragmatic approach for the purpose of this development. The technique of the flower plot as it is described here is modular can be adapted to all other selections of parameters a well. There is currently a large European consortium of tinnitus experts, COMiT, organized within the TINNET COST Action (http://www.tinnet.tinnitusresearch.net/index.php/2015-10-29-10-22-16/wg-5-outcome-measurement) that is actively working on a selection of measuring instruments that are best suited to operationalize treatment change in chronic tinnitus patients. This selection can be used to further improve the flower plot. Special attention should also be paid to make the measuring instruments available to all clinicians in multiple languages. Furthermore, medical education should cover how to apply the instruments correctly and how to interpret the results.

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