The ternary graph as a questionnaire – a new approach to Quality of Life assessment?

Introduction

The role of questionnaires in Quality of Life (QoL) research is commonplace and well established. [1] Questionnaires of vastly differing degrees of complexity exist in all walks of life. We have become aware of the degree to which patients (and others) become exhausted by completing often dull, standardised questionnaires.

Using a multi-disciplinary approach interacting across widely different disciplines and incorporating both patient and clinician perspective, we have developed a prototype interactive tool which we believe can be adapted to replace many forms of questionnaire. Our clinical model was that of a maxillofacial surgery patient.

Questionnaires resemble an algorithm, language based, through which the user is guided in steps. A simple computer algorithm will only ever do what it was programmed to do and a simple computer algorithm allows no spontaneous digressions, often precluding unforeseen discoveries. This top-down architecture equally applies to the design and use of questionnaires, where a more active user engagement may often be highly desirable.

Others [2] have commented on the integration of IT and HR-QoL with the intention of benefitting patient, carer and clinician:
'*Through the better use of IT, it is possible that these advances could lead to improved information, more informed choice based on HR-QoL, more effective doctor-patient communication, less frequent appointments, multiprofessional input, more cost-efficient targeted earlier intervention, and a realistic expectation between patient and health-care professional set within the health context of the individual.*'

Here we introduce an alternative to conventional questionnaires. Our tool can provide quantifiable output similar to the scales used in questionnaires (if wanted) as well as qualitative output, it is interactive and intuitive to use and it needs a high degree of user involvement. The design is extremely flexible and adaptable for a wide range of applications. We wish to share this tool with others to use it freely and to develop it for their own areas.

Materials / Methods

The underlying mathematical properties of equilateral triangles, allowing the quantitative compositional analysis of ternary mixtures is given in Appendix A [help-selfhelp-ternary-graphs-maths.pdf]. Appendix A gives a brief description of two common compositional analyses of ternary graphs as well as the full description of the general case of an equilateral triangle placed in a two-dimensional Cartesian coordinate system (as used in our code).
Our source code is deposited in the GitHub repository at https://github.com/laurenkt/magic-triangle. A demonstration version of our interactive tool can be accessed and run at https://laurenkt.github.io/magic-triangle/.

Discussion

The mathematical properties of an equilateral triangle underpin the working of our interactive self-assessment tool. Take an equilateral triangle and label each corner A, B, C as shown in Figure 1.

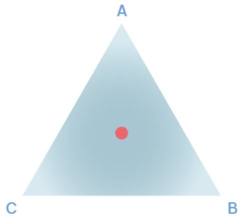

Figure 1 An equilateral triangle where the corners each represent one of the three components A, B, C and A + B +C = 100 %.

If A, B, C represent three components of a mixture A + B + C adding up to 100 percent, then each point in the triangle uniquely represents a particular percentage composition of the mixture. For example, the corner of the triangle labelled C would represent a mixture composed of 100 percent C, the centre of the triangle (as shown in Figure 1) would represent a mixture made up of 1/3 A + 1/3 B + 1/3 C.

A, B, C can be just about anything and the quantifiable way in which an equilateral triangle (a ternary graph) represents the composition of a ternary mixture explains why ternary graphs are widely applied in so many different areas. So far, to the best of our knowledge, quantitative graphical representations such as ternary graphs have not yet been exploited in a clinical or wider medical context for any assessment purpose.

Application areas include anthropology where, for instance, C. Lévi-Strauss used ternary graphs, known as the culinary triangles, labelled raw – cooked – rotted to characterise the culture and development of food and cooking. This was in relation to civilised (cooked) and primitive eating habits, or unchanged (raw) as opposed to changed foods (cooked / culture and rotted / nature). [3] Economics commonly make use of graphical representations, one example being A. C. Clarke's project-management trilemma [4] that in a production triangle labelled fast – good – cheap only two of the components can be simultaneously non-zero.
Chemistry, metallurgy, engineering, materials and earth sciences all make frequent use of ternary (and similar) graphs for the quantitative characterisation and description of mixtures. Here such graphs are often called phase diagrams. [5] Applications of phase diagrams range from mixtures of liquids summarising information about how to separate them, to representing properties of alloys made of three different metals, to compositions of sand and other soils as a function of geographical location. In biology ternary graphs are sometimes known as de Finetti diagrams [6] and, for example, are used to map population genetics. In psychology a theory called 'triangular theory of love' (intimacy – passion – commitment) was suggested by R. Sternberg. [7]

What all of these diverse applications of ternary graphs have in common is that it is sufficient to characterise and quantify the relative (percentage) composition of a ternary mixture. For our application of ternary graphs as an assessment tool we will need an additional step in order to provide a measure of an absolute scale for a particular set of A, B, C: any particular configuration of A, B, C may represent a consideration of some minor, or some major overall severity (see Figure 4; below).

With a more focussed view to the design of a ternary-graph based assessment tool for HN patients, the first task is to collate a set of descriptors to label the ternary graphs. This set of descriptor terms has to provide a comprehensive overview and picture of any concerns HN patients may have at any given point in time, in a straightforward and 'clutter-free' manner.

We start with a set of seven major descriptor terms as shown in Figure 2.

Figure 2 The seven top-level descriptor terms.

Several aspects become immediately obvious. First, all of these terms require some further refinement in order to give a proper description of the users' priorities. This could either be an introspective consideration, or be necessary to provide the clinician with all the necessary information about acute needs or need for referrals. For some terms one further level of refinement will be sufficient for clarification, other terms may require a third level, or even more levels, of refinement. The map of descriptive terms and their flow and hierarchies are summarised in Figure 3.

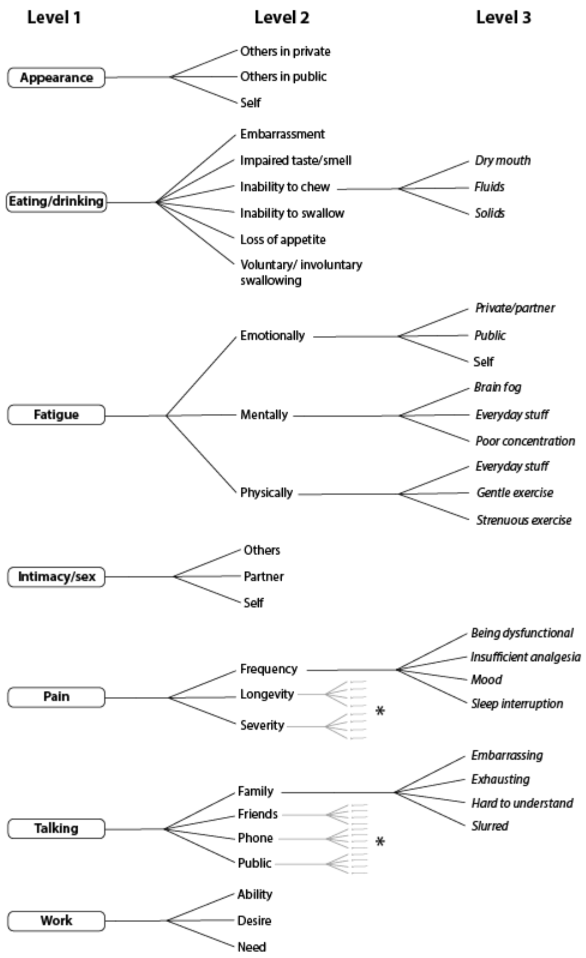

Figure 3 Map and flow chart of descriptor terms specific for self-assessment of HN patients. * indicates that the descriptor terms to extend all level 2 terms to level 3 are identical.

Starting with a set of seven descriptor terms at the top level and asking users to choose three priorities in a given run allows for many combinatorial options at the top level. Combining these multiple options with multiple further refinement levels provides a huge combinatorics space. Simply based on this principle, our tool allows for nearly unlimited ways for users to personalise their self-assessment approach while ensuring that they only have to consider what is relevant to them and ignore everything else.

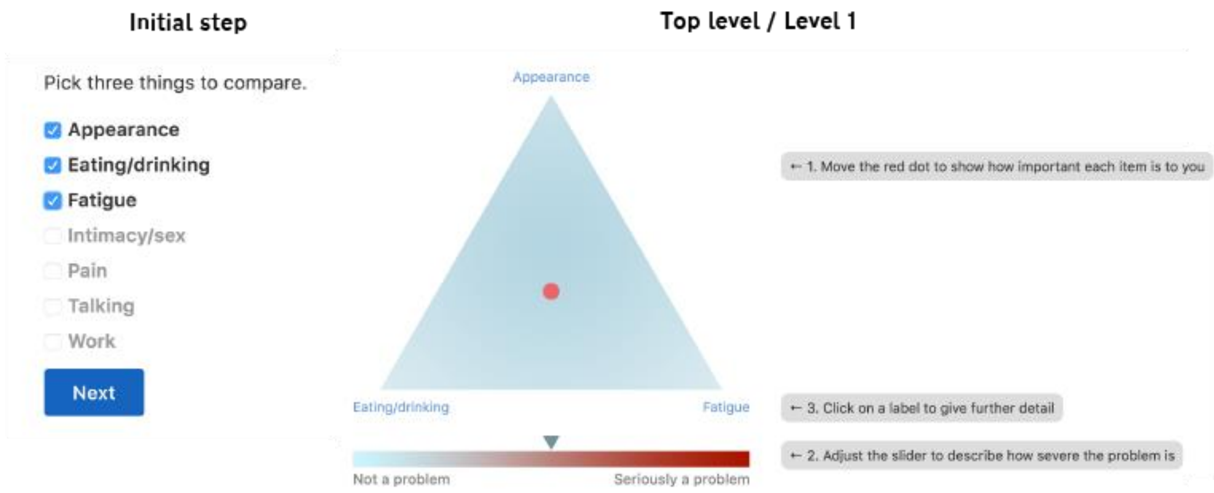

Figure 4 The initial step and top level ternary graph, including the slider and initial prompts to start the tool.

Figure 4 shows screenshots of the assessment tool at the top level. Initially the user is asked to choose three options of the top-level set of descriptors and to place the cursor in the position in the triangle that best reflects how they perceive the relative role and impact of these three options. In order to complete this step, the user needs to adjust the position of the arrow on a slider below the triangle. The slider scale looks qualitative but is calibrated internally on a scale of 1 to 10 (or 0 to 100 percent) and is essentially a '10 cm visual analogue scale', [8] thus allowing the user to state the overall severity of impact by the chosen three descriptor terms.

The graphical design of our assessment tool based on equilateral triangles is deliberately 'adult' and abstract. This should be the least confusing way to navigating this (or similar) tools also for less computer-literate users. [9]

Furthermore, our tool addresses people with ‘adult’ problems. A sparse and abstract design avoids any unacceptable trivialisation of personal suffering.

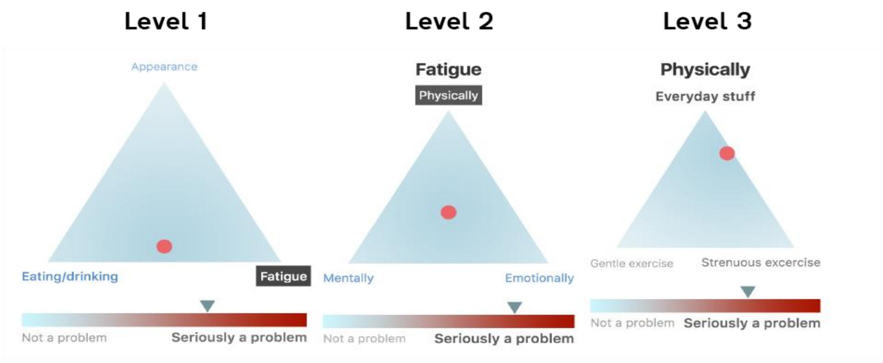

Figure 5 The consecutive steps of refined assessment in three levels.

Figure 5 extends the assessment to two further levels of refinement for an illustrative example of descriptor terms. In the final step the user can choose to repeat an overall assessment run, or to exit the application. On exiting the application, a percentage numerical summary of the session result is given (see Figure 6).

Output

1

LEVEL 1

Appearance	33%
Eating/drinking	33%
Fatigue	33%
Overall severity	**68%**

LEVEL 2

Fatigue

Physically	32%
Mentally	35%
Emotionally	33%
Overall severity	**74%**

LEVEL 3

Physically

Everyday stuff	82%
Gentle exercise	0%
Strenuous excercise	18%
Overall severity	**69%**

Figure 6 The final output screen, numerically summarising the session results.

On a less technical note, the design of the ternary graph tool is such that it supports the user to think in a broader, more holistic context – by collapsing three options/descriptors/topics into one representation.

Our graphical assessment tool is not to be seen completely independently from questionnaires and their roles in QoL research and, most importantly, the empowerment of patients. At this stage, we speculate that bottom-up, ‘pick your own’, much less verbally based assessment tools such as the ternary graph may well yield patient feedback different from that obtained from conventional questionnaires.

We encourage readers to try the assessment tool (https://laurenkt.github.io/magic-triangle/) or use the source code (https://github.com/laurenkt/magic-triangle) to adapt the tool for other applications. In either case, feedback and discussion about this new self-assessment approach - in the spirit of open source-code projects - would be appreciated.

References

1 http://www.handle-on-qol.com/Index.aspx

2 Rogers SN. Improving quality-of-life questionnaires in head and neck cancer. Expert Review of Quality of Life in Cancer Care 2016; 1: 61-71.

3 Lévi-Strauss C. Mythologies I: Le Cru et le Cuit. 1st ed. Paris: Plon, 1964. English translation: Lévi-Strauss C. Mythologies I: The Raw and the Cooked (Weightman J, Weighthman D translators) New York: Harper and Row Publishers, 1969.

4 Clarke AC. The Ghost from the Grand Banks. 1st ed. London: Gollancz, 1990.

5 Hillert M. Phase Equilibria, Phase Diagrams and Phase Transformations: Their Thermodynamic Basis. 2nd ed. Cambridge: Cambridge University Press, 2007.

6 Edwards AWF. Foundations of Mathematical Genetics. 2nd ed. Cambridge: Cambridge University Press, 2000.

7 Sternberg RA. Triangular Theory of Love. Psychological Review 1986; 93: 119-135.

8 Price DD, McGrath PA, Rafii A, Buckingham B. The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. Pain 1983; 17:45-56.

9 An award-winning example of a well-designed, user-needs defined website is the gov.uk website; https://www.gov.uk/design-principles.