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Ternary graph as a questionnaire: a new approach to assessment of quality of life?

R. Brown [a], L. Tomasello [b], D.A. Mitchell [c,d,*], A. Sebald [d,e], S. Stepney [d,f]

[a] 634, Kings College, Cambridge, CB2 1ST
[b] Department of Electronics, University of York, Heslington YO10 5DD, UK
[c] Maxillofacial Unit, Huddersfield Royal Infirmary, Lindley, Huddersfield HD3 3EA, UK
[d] York Centre for Complex Systems Analysis, University of York, Heslington YO10 5DD, UK
[e] Department of Chemistry, University of York, Heslington YO10 5DD, UK
[f] Department of Computer Science, University of York, Heslington YO10 5DD, UK

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Abstract

This study was prompted by awareness of the importance of research into quality of life (QoL) for patients with diseases of the head and neck, the important part questionnaires currently play in this field, and awareness of the “questionnaire fatigue” experienced by many patients. Our multidisciplinary research group raised coincidental awareness of the widespread use of ternary graphs in the sciences, social sciences, and humanities as a graphical tool for quantitative, semiquantitative, or purely graphical characteristics of ternary mixtures. We explored how the basic properties of ternary graphs could be translated into an interactive electronic tool as an alternative to conventional questionnaires. We have described how this was done, and offered open access to an interactive ternary-graph based (self) assessment tool, specifically designed for the needs of patients with conditions of the head and neck. Finally, have we made open-source code available for those who may wish to adapt or develop the tool for further applications.

Keywords: Questionnaires; Ternary graphs; Quality of Life; Assessment; Cancer; Mouth

Introduction

The role of questionnaires in research into quality of life (QoL) is commonplace and well- established,[1] and questionnaires of various degrees of complexity are used in all walks of life despite the fact that patients (and others) become exhausted by having to complete standardised, often dull, questionnaires.

We have used a multidisciplinary approach to interact across widely different disciplines, and incorporate both patients' and clinicians' perspectives, to develop a prototype interactive tool that we think can be adapted to replace many types of questionnaire. Our clinical model was that of a maxillofacial surgical patient. It is essential to understand that in this paper we have described the development of, and given access to, a simple interactive online tool. This tool now exists, but has not yet been used in any comparative QoL studies. This (and its use beyond maxillofacial surgery) is beyond the scope of a single publication.

* Corresponding author at: Maxillofacial Unit, Huddersfield Royal Infirmary, Lindley, Huddersfield HD3 3EA, UK.

E-mail addresses: rb732@cam.ac.uk (R. Brown), lt696@york.ac.uk (L. Tomasello), david.mitchell@cht.nhs.uk (D.A. Mitchell), angelika.sebald@york.ac.uk (A. Sebald), susan.stepney@york.ac.uk (S. Stepney).

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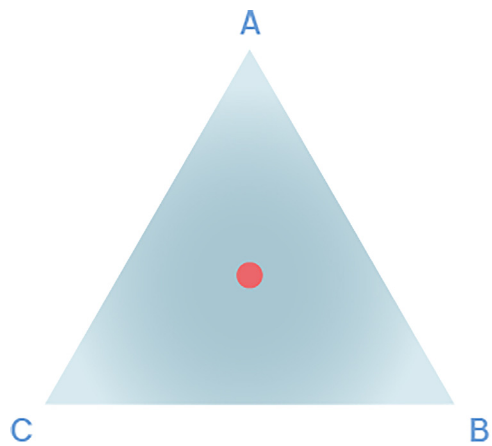

Fig. 1. An equilateral triangle where the corners each indicate one of the three components A, B, C and A + B +C = 100%.

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

Others[2] have commented on the integration of information technology (IT) and health-related QoL with the intention of benefitting patients, carers, and clinicians:

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 have introduced an alternative to conventional questionnaires. Our tool can provide quantifiable output that is 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 involvement by the user. The design is extremely flexible, and adaptable to a wide range of applications. We wish to share this tool for others to use freely and to develop it in their own areas. The basic prototype must now to be designed with a series of directly relevant, progressive terms, and validated using established standard techniques.

Materials and methods

The underlying mathematical properties of equilateral triangles that allow the quantitative compositional analysis of ternary mixtures is shown in Appendix A (**Supplementary data, online only**). This 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 has been deposited in the GitHub repository at https://github.com/laurenkt/magic-triangle,[3] and a demonstration version of our interactive tool can be accessed and run at https://laurenkt.github.io/magic-triangle/.[4]

The interactive tool was designed so that it runs on any standard web browser and on lower-end hardware. We have not yet implemented a version to run on tablet computers or other gadgets with touch screen technology. It would, however, be straightforward to adapt our tool for this kind of hardware.

The design of our code is such (https://github.com/laurenkt/magic-triangle)[4] that all metadata (for example, lists of all descriptor terms) are contained in one file and so to change these is straightforward.

Discussion

The working of our interactive self-assessment tool is underpinned by the mathematical properties of an equilateral triangle.

Take an equilateral triangle and label each corner A, B, C as shown in Fig. 1. If A, B, and C indicate three components of a mixture - A + B + C that adds up to 100% - then each point in the triangle uniquely indicates a particular percentage composition of the mixture (see Appendix A for an explanation of the underlying mathematics). For example, the corner of the triangle labelled C would indicate a mixture composed of 100% C, and the centre of the triangle would indicate a mixture made up of 1/3 A + 1/3 B + 1/3C.

A, B, and C can be just about anything, and the quantifiable way in which an equilateral triangle (a ternary graph) indicates 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 illustrations such as ternary graphs have not yet been exploited in a clinical or wider medical context for any sort of assessment.

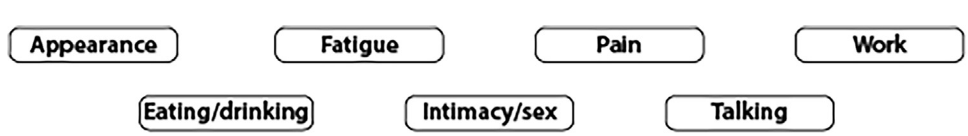

Fig. 2. The seven top-level descriptor terms.

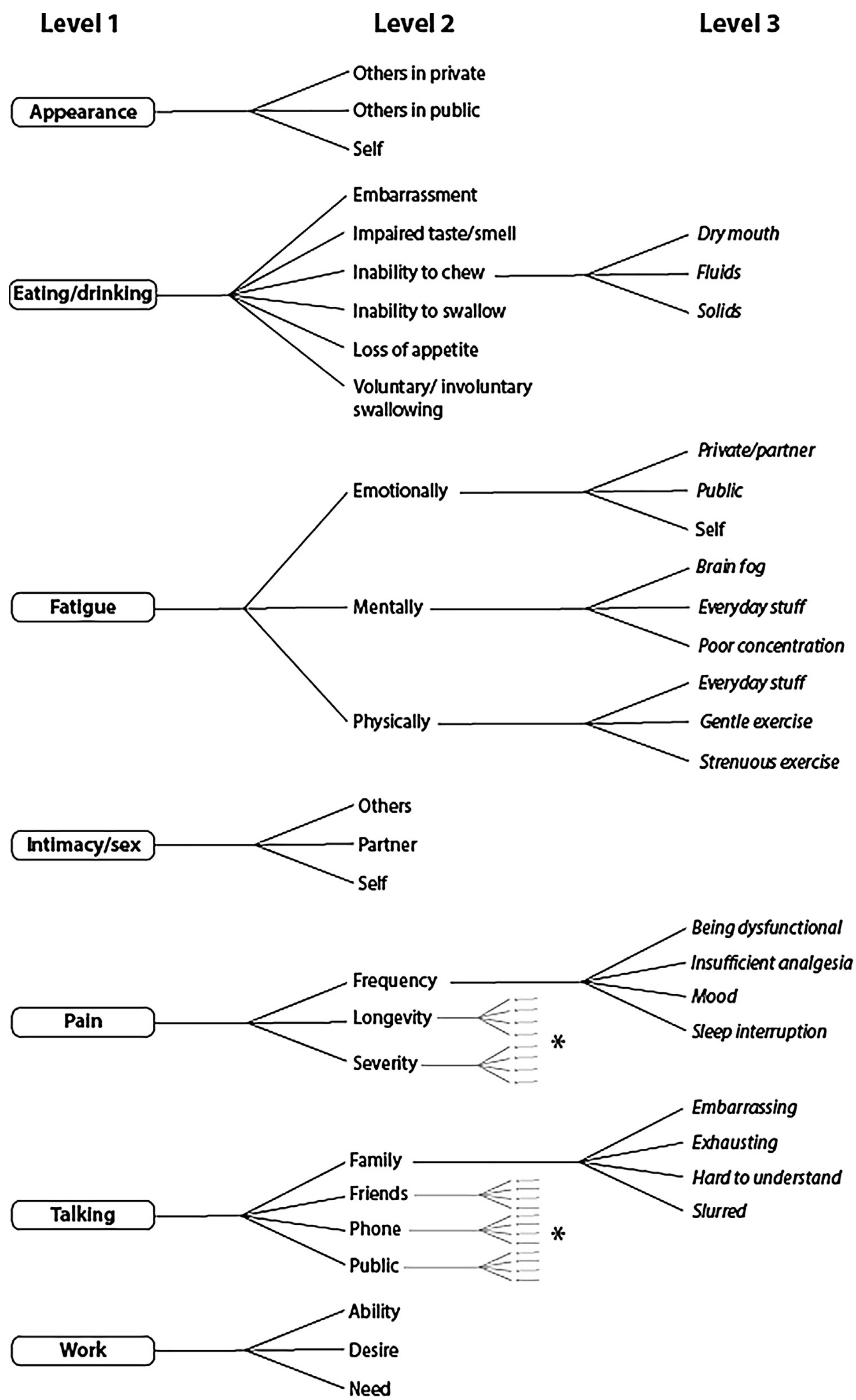

Fig. 3. Map and flow chart of descriptor terms specific for self-assessment of patients with head and neck disease. * Indicates that the descriptor terms, which extend all level 2 terms to level 3, are identical.

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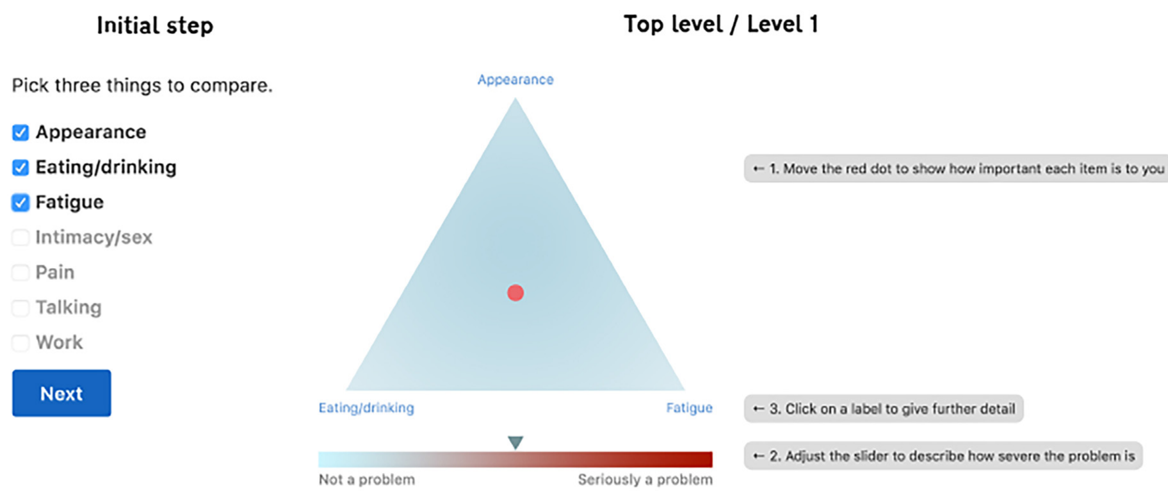

Fig. 4. The initial step and top level ternary graph, including the slider and initial prompts to start the tool.

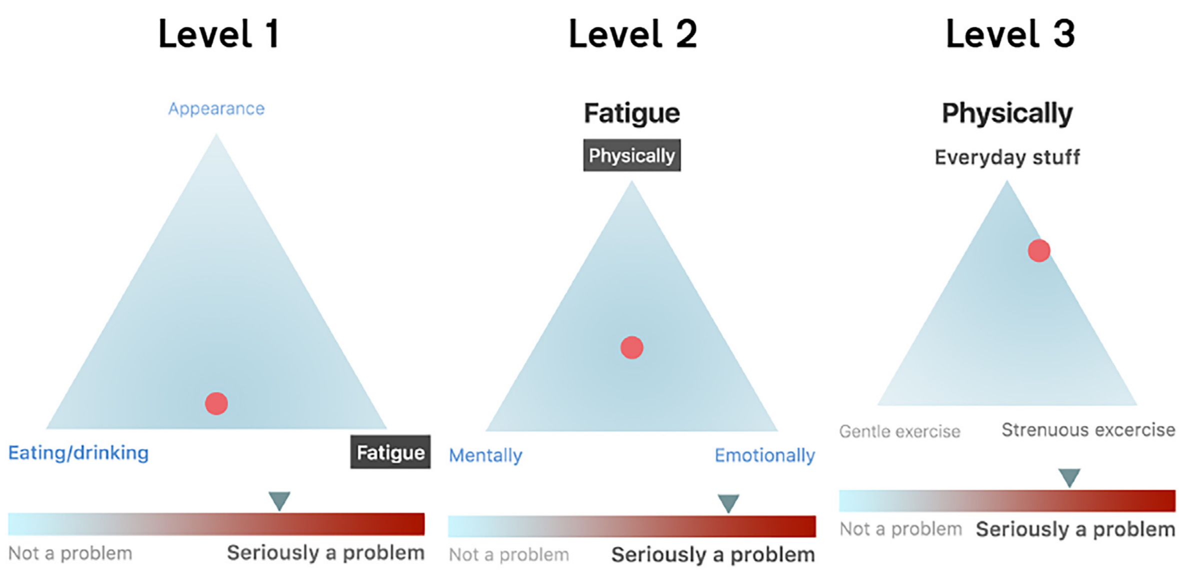

Fig. 5. The consecutive steps of refined assessment in three levels.

Areas of application include anthropology where, for instance, 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/natural).[5] Economics commonly make use of graphics, one example being Clarke's project-management trilemma[6] where, in a production triangle labelled fast – good – cheap, only two of the components can be simultaneously not zero.

Chemistry, metallurgy, engineering, materials, and earth sciences all make use of ternary (and similar) graphs for the quantitative characterisation and description of mixtures, and these graphs are often called "phase diagrams".[7] Applications of phase diagrams range from mixtures of liquids that summarise information about how to separate them, to properties of alloys made of three different metals, to compositions of sand and other soils as a function of geographical site. In biology, ternary graphs are sometimes known as de Finetti diagrams[8] and, for example, are used to map population genetics. In psychology a theory called the "triangular theory of love" (intimacy – passion – commitment) was suggested by Sternberg.[9]

What all 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 to provide a measure of an absolute scale for a particular set of A, B, and C: any particular configuration of A, B, and C may indicate a consideration of some minor, or major, overall severity.

To focus the view more on the design of a ternary-graph based assessment tool for maxillofacial surgical patients, our

Output

LEVEL 1		LEVEL 2 Fatigue		LEVEL 3 Physically	
Appearance	33%	Physically	32%	Everyday stuff	82%
Eating/drinking	33%	Mentally	35%	Gentle exercise	0%
Fatigue	33%	Emotionally	33%	Strenuous excercise	18%
Overall severity	**68%**	**Overall severity**	**74%**	**Overall severity**	**69%**

Fig. 6. The final output screen, which numerically summarises the results of the session.

first task was to collate a set of descriptors to label the ternary graphs. This set of terms must provide a comprehensive overview of any concerns that affected patients may have at any given time point, in a straightforward and clutter-free manner. We have started with a set of seven major descriptor terms (Fig. 2).

Several aspects immediately become obvious. First, all these terms require some further refinement to give a proper description of the users' priorities. This could either be an introspective consideration, or it could 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, and other terms may require a third level (or even more) (Fig. 3).

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 choices of combinations at the top level. If these multiple options are combined with multiple further levels of refinement, there is a huge space for combinatorics. As it is simply based on this principle, our tool allows for well nigh unlimited ways for users to personalise their self-assessment approach while they ensure that they have to consider only what is relevant to them, and ignore everything else.

Fig. 4 shows screenshots of the assessment tool (https://laurenkt.github.io/magic-triangle/) at the top level.[4] 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. 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 it is calibrated internally on a scale of 1 to 10 (or 0 to 100%), and is essentially a "10 cm visual analogue scale",[10] which allows 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 has been made deliberately "adult" and abstract, which should be the least confusing way to navigate this (or similar) tools that are also for less computer-literate users. An award-winning example of a well-designed, user-needs website is the UK government design principles one.[11]

Our tool also addresses people with "adult" problems. A sparse and abstract design avoids any unacceptable trivialisation of personal problems.

In Fig. 5 we have extended the assessment to two further levels of refinement for an 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 result is given (Fig. 6).

On a less technical note, the design of the ternary graph tool helps the user to think in a broader, more holistic context by collapsing three options/descriptors/topics into one indication.

Our graphical assessment tool is not completely independent of 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 feedback from patients that differs from that obtained from conventional questionnaires.

We encourage readers to try the assessment tool (https://laurenkt.github.io/magic-triangle/)[4] or use the source code (https://github.com/laurenkt/magic-triangle)[3] 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.

Conclusions

We have shared an idea and a prototype of a tool for a new approach to self-assessment. Our prototype addresses specific needs for maxillofacial surgical patients by giving the chosen set of descriptors. However, the approach is generic and can easily be adapted for other areas by simple changes of the descriptor terms (and possibly number of layers of refinement).

The graphical presentation of data and visualisation in general is a major topic in contemporary computer science. It is easy to see that there should be endless possibilities to design and implement further intuitive and quantifiable, graphically-led, interactive assessment tools.

Our "magic triangle" can serve as a self-assessment tool (repeatedly, over extended periods of time), for preparation in

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outpatient clinics and in research related to QoL. We suspect there are many other potential uses, and will investigate this further.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

This is a theoretical concept and computer-based construct, so no ethics approval is required. No patients were involved in any experimentation or investigation, although some took part in the construction of the software and the writing of the paper.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.bjoms.2017.04.011.

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