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The use of degrees of certainty to evaluate knowledge

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Abstract

In patients with chronic diseases education should improve knowledge about the disease and increase certainty in knowledge. We present here a technique to measure changes in certainty after an educational intervention. For this purpose, before and after a course, patients answer a questionnaire in which answers are accompanied by an estimate of the degree of certainty. Answers are then assigned to areas of knowledge defined a priori: mastered (certainty ≥90%, correctness ≥90%), hazardous (certainty ≥90%, correctness ≤50%), uncertain (certainty ≤50%, correctness ≥90%) and residual. Finally differences in the distribution of answers among different areas are analysed statistically. Using this technique in a group of patients with type I diabetes who followed a course on insulin use, we found significant changes in the distribution of answers among different areas of knowledge. Thus changes in certainty can be analysed quantitatively and used to evaluate better the effect of therapeutic education.

Keywords: Knowledge evaluation; Degree of certainty; Group certainty topography; Type I diabetes

1. Introduction

The goal of educating a patient with a chronic disease is to help him to acquire and maintain over time both knowledge and those abilities that are most useful for harmonising his/her life needs with the constraints of a disease [1]. Education can affect knowledge, practical abilities, technical skills, attitudes, habits, intentions and decisions and appropriate assessment tools should be used to investigate changes in each of these domains [2].

The effect of education most frequently analysed is the effect on knowledge [2,3] which includes declarative and procedural knowledge [4–6]. Declarative knowledge is based purely on theory, it includes theoretical assioms, main rules and examples (i.e. to know his own glycaemic index) and does not by itself guarantee that it will be put into practice. Procedural knowledge concerns the way things have to be done (i.e. how to adapt insulin dose) and has a higher probability of being used when knowledge is put into action in a real context.

The most frequently adopted method for analysing the effect of education on knowledge takes advantage of questionnaires where the right answers are chosen from multiple choices or between just two possibilities (true/false questions) [7–10]. These tests are easy to apply, score objectively and interpret. Furthermore, since patients are not required to construct an answer, differences due to cultural background are minimised [2].

Tests are usually administered before and after the education and the results are then compared [2]. This approach, however, has a major drawback: the degree to which patients are sure about their knowledge (degree of certainty) remains undefined, consequently metacognitive knowledge does not come into play [11–14].

To better characterise knowledge, testees can be invited to add to each answer an estimate of their degree of certainty. So far the degree of certainty has been used to analyse the quality of knowledge of university students or professionals, but has rarely been used with patients. It is however clear that patients hesitate to use correct knowledge about which

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they feel unsure, while are ready to use wrong notions held for true with a high degree of certainty [15–25]. For this reason, educational programmes should be designed not only to increase correct knowledge, but also to make a better match between certainty and correctness. The aim of this paper was to develop an appropriate technique to describe and measure changes in the degree of certainty.

Leclercq et al. [26] have shown that patient's ability to estimate coherently and realistically his own knowledge can be evaluated by correlating the degree of certainty (expressed on a percent scale) with the percent of correct answers. In the case of a perfectly coherent estimate of one's own knowledge, percentages of certainty and percentage of correct answers should fall on a straight line when plotted on a two-dimension graph, whatever their absolute values. Patients are called realistic when the absolute values of those two variables coincide, falling on the line of identity (the graph diagonal) which is called the "line of perfect realism". According to these authors points lying above this line represent underestimation of one's competence, while points lying below it represent overestimation [27]. This type of analysis is concerned with coherence and realism of individual subjects.

In this report, we introduce a new approach to analyse changes in the degree of certainty of groups of subjects. To this end, before and after an educational intervention, patients answer a questionnaire in which answers are accompanied by a subjective estimate of the degree of certainty. Answers are then assigned to different areas of knowledge identified a priori from combinations between certainty and correctness and differences in distribution are analysed statistically. The areas of knowledge considered in this paper are: mastered knowledge (high degree of correctness combined with a high degree of certainty), hazardous knowledge (low degree of correctness combined with a high degree of certainty), uncertain knowledge (high degree of correctness combined with a low degree of certainty) and residual knowledge (total − [mastered + dangerous + uncertain]).

Using this approach in a group of patients with type I diabetes who followed a course on the use of insulin, we show that changes in the degree of certainty can be evaluated quantitatively.

2. Materials and methods

2.1. Patients

We enrolled 40 consecutive patients with type 1 diabetes that were seen over two weeks at our outpatient clinic and who accepted to take the course. Among the patients enrolled one did not come the first day of the course and was excluded from the study. Thus, 39 patients with type 1 diabetes (18 male, 21 female) took part on the course.

Mean age was 28.7 ± 0.1 years (range: 19–43 years), the duration of diabetes was 13.2 ± 1.3 years (range: 0.3–36 years), serum levels of HbA1c were $8.16 \pm 0.2\%$.

Six patients (15%) were treated with continuous subcutaneous insulin infusion (CSII), 33 (85%) with four daily insulin injections (MDI). Eleven (28%) had a primary school degree, twenty-five (64%) had a secondary school degree, three (8%) a university degree. All of them had been formally introduced to insulin use, usually on an individual basis, at the time of diagnosis and then recalled on the correct use of insulin during subsequent ambulatory visits. The preliminary level of education was not considered important for the present study, since we wanted to analyse differences in quality of knowledge due to education.

To follow the course patients were divided in four groups of 9 or 10 people.

The program was based on a systemic educational approach, including assessment of educational needs about insulin use (educational diagnosis), definition of specific goals, development of session procedure and program.

The program was discussed in advance with the patients, in order to obtain a greater degree of motivation and to try to respond to their needs as well as possible.

2.2. The course

The course, consisting of three meetings lasting 2.5 h, was held at weekly intervals and was attended by the patients, two doctors and an educationist. The theme was insulin use. The course included theoretical information, analysis of cases depicting real situations in everyday life, practical exercises and simulations. The patients were expected to participate directly and their health beliefs, habits and representations were systematically collected.

During the first meeting, patients were taught about the role of insulin, different types of insulin, preparation of insulin mixtures, insulin administration, insulin storage. At the end of the meeting, the person in charge of formal education commented on topics of special interest to the patients.

During the second meeting, the following items were discussed: desirable blood glucose levels, how to identify the insulin administration responsible of a given blood glucose value and how to change insulin dosage on the basis of blood glucose levels.

During the third meeting, patients were taught how to identify the causes of hyper- and hypoglycaemia, how to interpret glycosuria and ketonuria, and how to modify insulin dosing in response to emergencies like infectious diseases, increased physical activity or other stressing conditions.

2.3. The questionnaire

The effect of the course on knowledge was analysed with the help of a questionnaie containing 50 questions that

Area	Items	True	False	How much sure are you about your answer?							I don't know
				2% absolutely not sure	10% not sure	25% little sure	50% more or less sure	75% enough sure	90% sure	98% very sure	
1	The region of the body were insulin is absorbed most slowly are the thighs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	A hypoglycaemic episode can be provoked by an unexpected increase of physical activity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	The continuous presence in the urine of glucose and keton bodies is alarming	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	The glycaemic target changes according to the number of daily insulin injections	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Blood glucose values before dinner are influenced by the amount of insulin administered at noon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	If blood glucose levels are high before a meal patients should inject an additional dose of insulin	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Fig. 1. Example of questions exploring declarative knowledge.

Suppose your glycaemic target is 80-160 mg/dl, and this is your record with your notes:

DATA	Breakfast			Lunch			Dinner			Notes
	glycaemia	acetonuria	glycosuria	glycaemia	acetonuria	glycosuria	glycaemia	acetonuria	glycosuria	
Monday	120			190		+	140		+	Sore throat and fever
Tuesday	166			200		+	110		+	Sore throat and fever
Wednesday	185			195			95			
Thursday	205		+	225		+			++	Sore throat and fever

The appropriate action is to maintain unchanged the insulin dose and change the diet.

ANSWER		How much are you sure about your answer?							
True	False	2% absolutely not sure	10% not sure	25% little sure	50% more or less sure	75% enough sure	90% sure	98% very sure	I don't know
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Fig. 2. Example of one question exploring procedural knowledge.

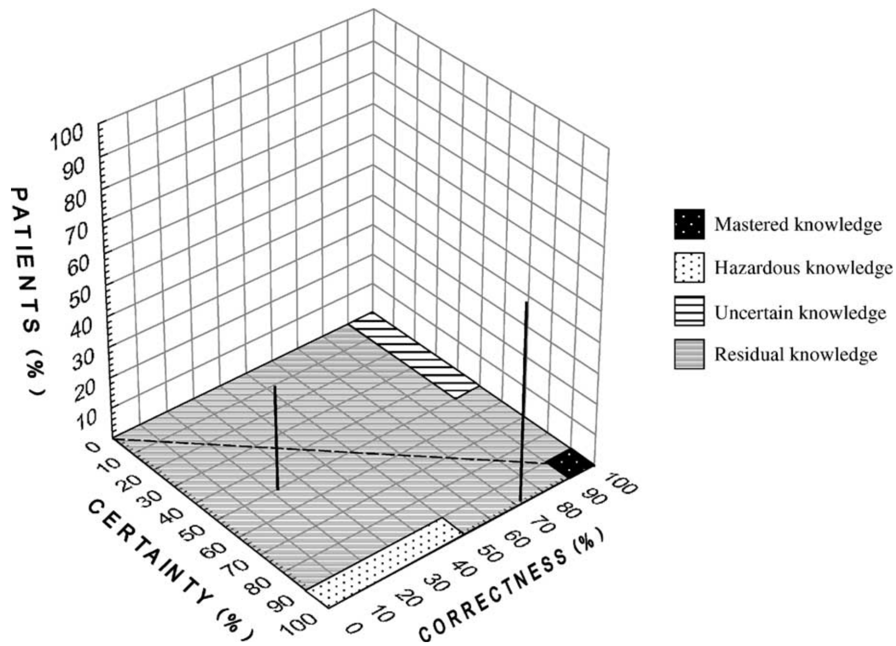

Fig. 3. Group certainty topography: plot obtained by combining degrees of certainty (*X*-axis), % of correct answers given with each degree of correctness (*Y*-axis) and number of patients (*Z*-axis). Different areas of knowledge are located on the *X–Y* plane. The dashed line on the *X–Y* plane represents perfect realism. The vertical lines represent an example of the distribution of answers given to one question. Note that certainty has discrete values, while correctness and number of patients have continuous values.

explored both declarative (39 questions) and procedural knowledge (11 questions).

Questions exploring declarative knowledge analysed patients' knowledge in six areas: (1) insulin action and mechanism of absorption (six questions); (2) causes of hypo and hyperglycaemia (seven questions); (3) acetonuria and glycosuria (six questions); (4) desirable blood glucose values (five questions); (5) length of action of different types of insulin and the relationship between insulin administration and blood glucose levels (seven questions); (6) how to change insulin dosing (eight questions) (Fig. 1).

Questions about procedural knowledge covered hypothetical situations in which insulin administration had to be changed on the basis of blood glucose levels (five questions), physical activity (three questions), fasting, infections diseases, hyperglycaemic crisis (one question each) (Fig. 2).

The questionnaire was checked for accuracy and appropriateness by five independent diabetologists. Explanation and administration of the questionnaire, took approximately 50 min, depending on age, scholarship, length of disease, etc. For all questions, patients could choose between three possible answers: true, false, I don't know.

2.4. Group certainty topography

Along with the answer to the question proposed, patients were asked to indicate their degree of certainty using a 7 degrees scale ranging from total doubt (2%) to complete certainty (98%) (Figs. 1 and 2). The numerical values for each degree of certainty were accompanied by a qualitative description (verbal instructions): totally unsure (2%), not sure (10%), moderately sure (25%), more or less sure (50%), sure (75%), strongly sure (90%), perfectly sure (98%) [14,18,26,28]. "I don't know" had no degree of certainty. In this scale, the precision is greater at the extremes than in the middle, according to Leclercq's demonstration that human perception has a logarithmic distribution at the extremes of the scale and is limited to 7 degrees [26–28].

From the combination between degree of certainty and correctness, each answer was then assigned to one of different areas of knowledge identified a priori. The areas we identified were: the area of mastered knowledge (answers given with at least 90% certainty and correct in at least 90% of cases), the area of hazardous knowledge (answers given with at least 90% certainty but correct in less than 50% of cases), the area of uncertain knowledge (answers given with less than 50% certainty but correct in over 90% of cases) and the area of residual knowledge obtained by subtracting the previous areas to the total area of knowledge. We assumed that mastered knowledge represents the best type of knowledge and that residual knowledge is preferable to hazardous or uncertain knowledge since it is closer to perfect realism. Results were presented in tabular form or as a three-dimensional plot, where the *X*-axis represents the chosen degrees of certainty (2, 10, 25, 50, 75, 90, 98%), the *Y*-axis represents the % of correct answers associated with each degree of certainty and the *Z*-axis represents the % of patients that were in that *X–Y* position for the question considered (Fig. 3).

An example will illustrate how such a graphical presentation was made. To one question 25 patients out of 39 (64.1%) answered with 98% degrees of certainty, but only 18 answers out of 25 (72.0%) were correct. The remaining 14 patients (35.9%) answered with 50% certainty, but only three answers out of 14 (21.4%) were correct. Thus on a graph like the one presented in Fig. 3, two vertical lines would have been drawn: one with eight 64.1, centred on the cell identified by $X = 98$ and $Y = 72$ and another with eight 35.9 centred on the cell identified by $X = 50$ and $Y = 21.4$.

Since the plot is a raised map concerning answers of a group of people to several questions we called it ''group certainty topography''.

Only questions to which patients gave a correct or wrong answer were considered for analysis. Questions to which patients answered ''I don't know'' were not considered, since no % of correct answers can be associated with them.

2.5. Analysis of wrong answers

Besides analysing answers according to the ''group certainty topography'', we also counted, before and after the course, the number of wrong answers given with 2–50% degrees of certainty and 75–98% degrees of certainty.

2.6. Statistical analysis

Pearson's χ^2 was used to analyse the effect of education on the frequency of correct or wrong answers or the frequency of questions to which the patients answered ''I don't know''.

The χ^2 was used to study the effect of education on changes in the frequency with which answers fell into different areas of knowledge. 5% was the level of significance accepted.

3. Results

3.1. Group certainty topography

In our group of patients, knowledge improved after the course. In fact after the course, the number of correct answers increased from 76.0% of total to 90.0% ($P < 0.0001$) and the number of questions to which the patients answered ''I don't know'' decreased from 5.3 to 0.4% ($P < 0.0001$).

Besides increasing knowledge, the course also influenced the degree of certainty. This is evident from an inspection of Fig. 4, which shows that after the course correct answers increased, accumulating into the area of mastered knowledge, while answers falling into all other areas of knowledge decreased. The change in the distribution of answers was highly significant (Table 1, $P < 0.0001$). Interestingly there were differences in the way changes in each area of knowledge contributed to the final result. In fact the greatest contribution to the formation of the χ^2-value came from the increase of answers falling into the area of mastered knowledge and from the decrease of answers falling into the areas of residual and uncertain knowledge (Table 1). The decrease of answers falling into the area of hazardous knowledge gave the smallest contribution to the formation of the χ^2-value (Table 1).

Table 1
Effect of education on the distribution of correct answers among different areas of knowledge and contribution of each area to the formation of the χ^2-value

Time with respect to course	Area of knowledge				
	Mastered	Hazardous	Uncertain	Residual	Total
Before course	726 (49)	44 (3)	118 (8)	592 (40)	1480 (100)
After course	1358 (77)	32 (2)	22 (1)	349 (20)	1761 (100)
χ^2	44.97	2.09	39.06	51.51	137.63*

The critical value of χ^2 with 3 d.f. is 7.81. Numbers in parentheses are % of total.
* $P < 0.0001$.

3.2. Analysis of wrong answers

From the analysis of wrong answers, it appears that the absolute number of wrong answers decreased, but the fraction of wrong answers given with a high degree of certainty actually increased (Table 2, $P < 0.0001$).

4. Discussion

This work presents a novel way to analyse the effect of education on the degree of certainty about knowledge in groups of patients. According to our approach, before and after education, patients answer a questionnaire in which answers are accompanied by a subjective estimate of the degree of certainty. From the combination of certainty and correctness, answers are attributed to different areas of knowledge defined a priori. Differences in the distribution of answers given before and after education are then analysed statistically.

A crucial aspect of our approach is that patients are expected to choose between different degrees of certainty, an act that could be affected by factors like human or personal capacity to self estimate, personal variations according to content or previous attitude towards risk

Table 2
Effect of education on degree of certainty associated with wrong answers

Time with respect to course	Number of wrong answers	
	2–50% degree of certainty	75–98% degree of certainty
Before	87 (23.8)	279 (76.2)
After	15 (8.3)	165 (91.7)

Values in parentheses represent % of wrong answers, $P < 0.0001$ by χ^2 analysis.

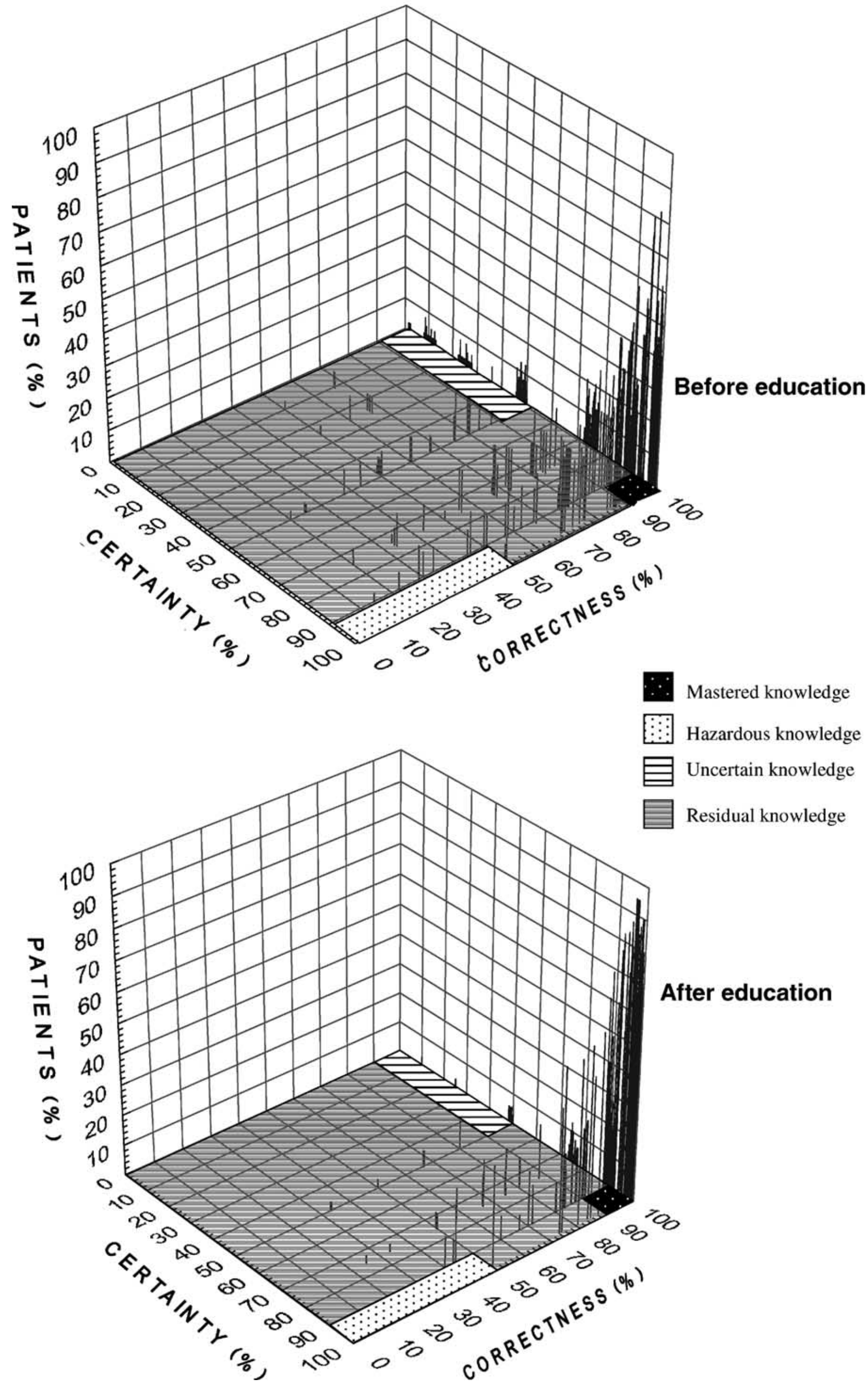

Fig. 4. Effect of education on "group certainty topography". The figure presents the distribution of answers before and after the course on insulin use. To ease identification of different answers, vertical lines originating from the same point on the horizontal plane were displaced laterally.

[15]. These factors, however, should cancel out since the questionnaire is administered to the same person before and after education.

Another important point is that patients need to be trained well in the use of various degrees of certainty before starting the study. In our experience, patients found little difficulty in using certainty degrees and the time needed to become proficient at this was, on average, 20 min. Investigators and practitioners, however, need to know that this will take extra time.

In the example presented, we identified four areas of knowledge (mastered, hazardous, uncertain and residual) whose boundaries were chosen on the basis of our personal perception and of published evidence [29,30]. The areas chosen, however, could have been different. We could have used a different number of areas or chosen different area

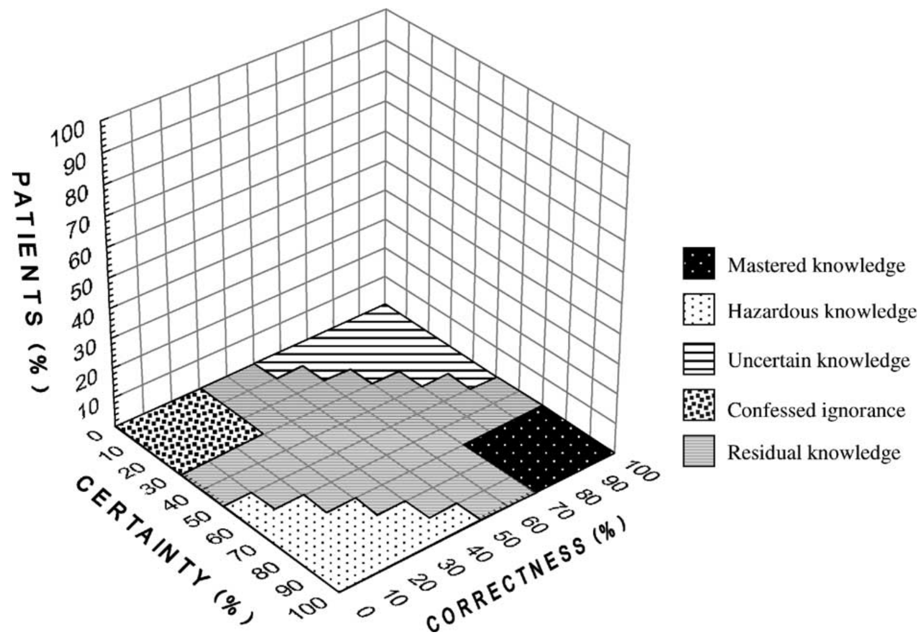

Fig. 5. Group certainty topography: changing profile and number of the different areas of knowledge.

profiles (Fig. 5). For example, we could have introduced an area collecting answers given with low degrees of certainty and low degrees of correctness (the "area of confessed ignorance") (Fig. 5), or we could have combined the answers falling into the areas of "confessed ignorance" with "I don't know" answers. For the purpose of the present investigation, we combined the area of confessed ignorance with that of residual knowledge, since both reflect a sort of realistic evaluation by patients about the state of their knowledge.

The present technique was devised to statistically analyse the effect of education on the degree of certainty in knowledge in groups of patients and in fact did show that a course on insulin use induced significant changes in the distribution of answers between different areas of knowledge. The changes seemed to concern some areas more than others. In fact changes in mastered, uncertain and residual knowledge were surely significant, while the change in hazardous knowledge was of uncertain significance [31]. It should be noted, however, that the area of hazardous knowledge contained a very small number of answers and, from this sole fact, can be expected to contribute less than other areas to the formation of the χ^2-value. Thus, when defining the different areas of knowledge, researchers should consider the number of answers expected to fall into these areas.

For the sake of statistic evaluation a tabular presentation of results could be adequate (Table 1). We feel, however, that the presentation of data as a raised map could help educators, trainers, doctors and nurses to understand better the level knowledge of their patients as a population and to modify their way of teaching, training and educating accordingly. For example from inspection of Fig. 4 it appears that at pre-test there was an element of underestimation that has largely, but not completely disappeared at the post test. It is also clear that a pictorial presentation may help greatly in the description of different areas of knowledge (Fig. 4). In our experience, results presented as a raised map can be understood by a lay audience. Some of our patients liked the idea that education helps to "clean up" areas of "bad knowledge".

The present approach does not exclude other types of analysis on the degree of certainty considering both individuals and groups of patients. Individually the degree of certainty could be examined by the spectral analysis recently introduced by Leclercq et al. [30]. Dealing with groups of patients, additional information could come by counting answers to which patients answered "I don't know" and from the analysis of changes in the degree of certainty associated with wrong answers. In our population of patients, the fraction of wrong answers given with a high degree of certainty actually increased after the course (Table 2). Thus "group certainty topography" should be considered as an additional tool to analyse the effects of education on the degree of certainty in knowledge.

4.1. Conclusion

Group certainty topography could help health professionals and educators to analyse quantitatively the effects of education on the certainty patients have about their own knowledge and to change the strategy of the educational effort, accordingly. Furthermore the pictorial presentation of results could help educators and patients to "see" the effects of education.

The technique appeared to work well with a group of patients who followed a course on insulin use, but it needs to be tested in the same setting, by comparing different sorts of training, and in other settings (different diseases, different numbers of patients, different areas of knowledge, different levels of basal knowledge).

4.2. Practice implications

Changes in knowledge after a course can be very complex and each type of change may require a specific educational effort. Thus for knowledge that is correct both before and after a course it may be enough to preserve it with periodic meetings. On the other hand, knowledge that is wrong before and after a course should require a stronger educational effort, especially if it is held with a high degree of certainty. In this case, the traditional educational approach might not be sufficient and patients could need to be addressed on an individual basis. Finally, wrong knowledge that becomes correct or correct knowledge that becomes wrong, both with a low degree of certainty, could be managed with recurrent meetings. Along this way of reasoning, patients that after a course persist in giving a wrong answer, but do so with a lower degree of confidence, should be told that the quality of their knowledge has improved.

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