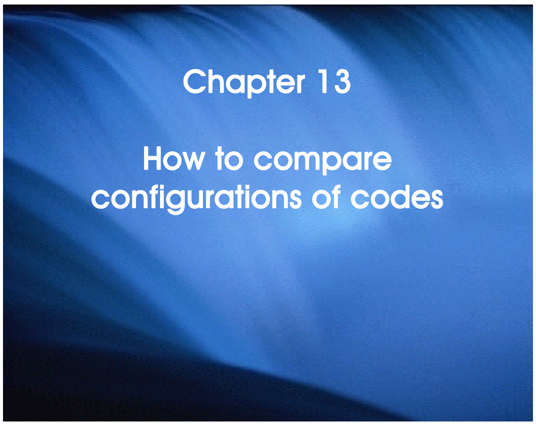


In addition to the option to test hypotheses about linkages between coding categories, the procedures for the logical minimization of configurations of meaning are a further special feature of AQUAD. The basic concepts of this sort of systematized qualitative meta-analysis or single-case comparison are based on the work of Charles Ragin (Ragin, 1987).

Here we summarize how the module *"Implicants"* transforms case-specific configurations of meaning into truth values of a binary logic (i.e., a particular characteristic is given/is not given), and then combines these truth values according to the rules of Boolean algebra. In this process, one of the characteristics (or conditions) is used as the criterion for the comparison. Comparing all those cases in which this criterion is "true" (or "false") results in a reduction of these configurations to the main implicants of this criterion.

In the following, we describe the steps and options when using the component *"Implicants."*

13.1 How to write data tables

AQUAD allows the researcher to perform a logical minimization of configurations of conditions in several studies or cases directly, using quantitative and/or qualitative data. The researcher can construct a table of data (*"Create a data table"*), edit data tables, or print them. Qualitative data, for instance "meaning A marked distinctly here" (i.e.,"true"), can be directly entered into a table of truth values. However, it may be more convenient to represent even such qualitative data by means of natural numbers, for instance, by "9" representing "true". Analogically you would enter "meaning A marked weakly here" as "1" or as "false." AQUAD provides both alternatives.

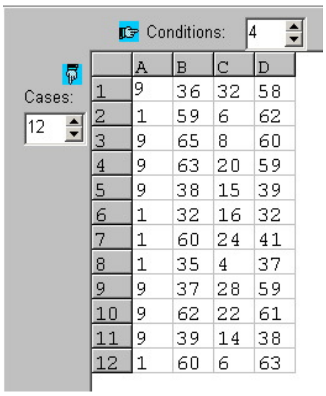
Here we describe a mixed form. In order to illustrate the steps of the whole procedure, we will refer to the fictitious example of a meta-analysis: In this example, the relation between school achievement and class size was investigated in 35 studies. Our data shall include qualitative values (A/a: large/small class) and quantitative scores (B/b: ability level in the class above/below average; C/c: duration of the experiment relatively long/short; D/d: achievement high/low). As distinguished from the display of truth values, we change configuration no. 5 a little in order to demonstrate a variant of the possible results. In addition, we do not enter all the results of all the 35 studies for space reasons; we only enter a selection from the data. Each of the eight observed configurations of conditions appears at least once in this selection. With real data we would not bother with differentiating these patterns of configurations. Instead, we would just enter the scores or markings of the conditions from all 35 studies without sorting them ourselves, and let the computer do the reduction to patterns of different configurations. Now, here are the various data possible in this study:

A: Size of class according to the information "small" or "large" in the study reports
9 = small class ("true") / 1 = large class ("false")
B: Results (standard scores) of an ability test (arith. mean of individual scores in a classroom)
C: Time (duration in weeks)
D: Results (standard scores) of an achievement test (arith. mean)

The first steps need no explanation: You choose the menu option “*Implicants*" and select from the sub-menu "*Create a data table*."

The two hands in the upper left corner direct your attention to the two parameters of your data table, which you have to determine first:

- *Number of conditions*: In its current version, the program is prepared to process between two and twelve conditions (including the criterion condition). The parameter "number of conditions" defines the number of columns of the data table. The program could take more conditions into account, but an extension of its capacity does not seem to make much sense. Think of the complexity of the results that has to be expected in this case (and the difficulties to interpret them)! In our case, achievement (condition D) serves as the criterion for comparisons, the configurations of the remaining characteristics A (size of class), B (average ability), and C (duration of observation) are examined as “conditions" of criterion D.



	A	B	C	D
1	9	36	32	58
2	1	59	6	62
3	9	65	8	60
4	9	63	20	59
5	9	38	15	39
6	1	32	16	32
7	1	60	24	41
8	1	35	4	37
9	9	37	28	59
10	9	62	22	61
11	9	39	14	38
12	1	60	6	63

In our case, we type the number “4" into the first entry field or click on the upper arrow in the spin button until "4" is reached.

- *Number of cases*: At this point you have to define how many findings (in our case: number of studies; usually we enter here the number of data texts) you are going to enter into the table of data. In other words, you specify the number of rows in the table. The only limit is that you need at least three cases for a meaningful comparison.

In the example we enter the number 12, because we want to use only a selection of 12 of the 35 available studies, due to reasons of space.

The entry grid is enlarged automatically according to the number of columns and rows you determine. So you can start immediately to fill in the cells with your data. Remember, in our fictitious example we use both qualitative data (cond. A) and quantitative data (cond. B, C, and D). By clicking on the "*OK*" button you terminate the entry of data determining the structure of your table.

You find these data on the CD of your AQUAD copy. The data table is named "school.adt." Just copy it into the ..\cod sub-directory on your hard disk, if you want to experiment with these data. You will then find this file as one of two data tables listed in the file box appearing on your screen.

Just a comment as regards the meaning of the numbers in this table: We assume that we do not have more exact information about the participating classrooms than whether it is a small or a large class (condition A). For later transformation into truth values we enter great numbers for characteristics which are to be treated as "true", and we enter small numbers for characteristics to be treated as "false." Since we expect a correlation of small classes and high achievement, we attribute the number 9 to small classes (deliberate decision!), and we attach "1" to "large classes."

For the other conditions metric scores are available (B: aptitude scores; C: duration of the experiment; D: achievement scores). Those scores are entered into the table as they are. Later, the program will transform them into truth values.

It is recommended to transform all conditions into numbers, even if you have to deal exclusively with qualitative conditions that were represented originally by means of expressions of natural language (like "much," "rarely," "often," etc.). After that, you enter these numbers into a table of data (as described above).

In the example above, condition A was treated like this. In other cases we could, for instance, put the number 9 into the defined column of the data table, if we have to qualify a statement like "condition ... is given," or "person ... is assertive." In case of the reverse interpretation "condition .. is not given" or "person ... is not assertive" we could enter the number 1. You may choose almost any scores you prefer. It is only important that during the transformation of the distribution, standard values which are above or below the cut-off (see below) are set up, and that they then are substituted accordingly with capital ("true") respectively small ("false") letters.

By the way, there is a short-cut from frequency tables to data tables for logical minimization. You may apply the option "*Count codes*" from the "*Retrieval*" sub-menu to create a frequency table of those codes, which represent relevant conditions for some criterion code in your study. The criterion code has to be counted together with the other codes. The resulting frequency table will be saved under any name which you enter. Just select this file again, when you activate the option "*Data table from list of frequencies*" in the sub-menu "*Implicants*".

13.2 How to transform scores into truth values

On the way from the data table to a table of truth values which we need for the logical minimization we have now to transform different types of data into the simple information "true" or "false." This is the decisive step. In order to facilitate the interpretation of the different results of the minimization process, AQUAD does not use binary digits (and the corresponding algorithms). In a term like *1001* or in the result *01**, it would be necessary each time to infer the meaning of every particular truth value from its position within the term. Instead, AQUAD uses letters as symbols for the conditions. A capital letter signifies *true*, a small one *false*.

In our example, the following configuration of conditions
A: small class ("true")
B: with high ability ("true")
C: in which only after a few weeks of the study ("false")
D: low average achievement has been found ("false")
would not be indicated by the term 1100, but by the sequence of letters Abcd.

How do we get from a table of data to terms of truth values like the ones in our example? We select either the option *"Convert data table into truth table"* in the sub-menu "*Implicants*" or we transform the original data ourselves into truth values and select "*Create a truth table*". In the latter case, the procedure is the same as for writing data tables, however, instead of numbers you have to fill in capital letters ("true") and small letters ("false") into the table's cells.

In the usual case, when you have a data table to begin with, AQUAD employs the following transformation strategy: For each of the conditions the scores in the table are first standardized (over all the cases), that is, they are transformed into standard scores with M=100, SD=10 . Then every z-score in this intermediate table is transformed into a capital letter or a small letter according to a particular criterion for *cut-off*. The default value for this cut-off criterion is

Cut-off = 50

which means that the lower 50 % of all scores in a condition are transformed into the truth value "false" and symbolized by small letters. Correspondingly, the upper 50 % of scores are reduced to the truth value "true" and symbolized by capital letters.

Of course, AQUAD allows that you change the cut-off as your research question demands. At the bottom of the window for transformation of data you see a small box displaying (in red figures) the default cut-off value. Click on the spin button and change this value (in steps of 5 %). Remember: the higher the cut-off, the more of your data are cut off as "false" (for example, in case of "70" showing in this box, the 70 % of lower data in your sample are taken as false, only the highest 30 % are accepted as "true"). Changes to the cut-off are valid only within the table for which you changed the cut-off criteria. That is, if you load a table at some later point of your analysis again, your particular cut-off settings will be employed. However, if you start to enter data for a new data table, the default cut-off value will be used – unless you adapt it to the demands of your study.

Now we are ready to start the transformation process. You select the data table to be transformed into a table of truth values from a selection window, you set or accept the cut-off value and after click on the "*OK*" button. Here is the resulting table of truth values:

Conditions

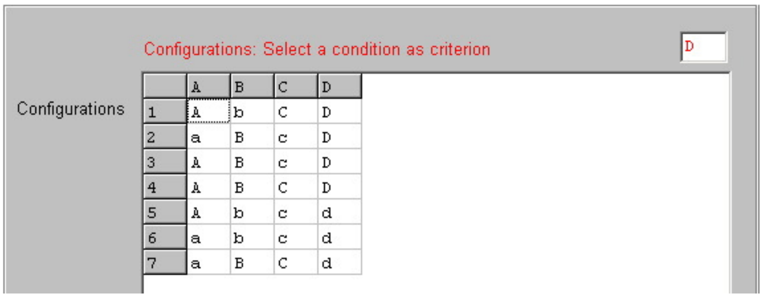
Cases	A	B	C	D
1	A	b	C	D
2	a	B	c	D
3	A	B	c	D
4	A	B	C	D
5	A	b	c	d
6	a	b	c	d
7	a	B	C	d
8	a	b	c	d
9	A	b	C	D
10	A	B	C	D
11	A	b	c	d
12	a	B	c	D

13.3 How to examine implicants of "positive" and "negative" criteria

Having created truth values we finally can examine the "implicants." The sub-menu demands a decision between implicants for cases in which a critical condition is positive, i.e., "true" and cases in which a critical condition is negative, i.e., "false." As we will see, both examinations complement each other very meaningfully. For the moment, we select "*Analysis: positive criterion*."

After selecting the name of the table of truth values, which we want to have minimized, the table is loaded and displayed on the screen. Now we have to select one of its conditions (columns!) as the criterion; then AQUAD will select from all truth values in our table only those combinations for which the critical condition (our criterion) is "true" – given we selected "*Analysis: positive criterion*." We select the criterion condition by clicking into its column header.

By the way: You may wonder why there are no longer 12 cases in they table shown below, but only 7 combinations. AQUAD reduces all redundancies from the table. That is, from cases with identical truth values only one representant is left in the final table for logical minimization:



	A	B	C	D
1	A	b	C	D
2	a	B	c	D
3	A	B	c	D
4	A	B	C	D
5	A	b	c	d
6	a	b	c	d
7	a	B	C	d

In our case we select the condition labeled "D" as criterion. That is, we are looking for those configurations of conditions which may play a role in effecting above average academic achievement (criterion "D") together with the size of a class. Or formulated differently: In our example, we choose the condition "D" as the criterion, because we want to search among the various conditions for all those that play a prominent role (together with the class "size") in cases in which we observe high academic achievement.

The fact that the criterion for the minimization must always be defined shows a further special feature of AQUAD. You need not decide from the very beginning which characteristic shall be the criterion and shall therefore be entered (into the last column), when you construct a data table (or a table of truth values). This would only make sense in connection with search strategies that define independent and dependent variables. For many questions within the domain of qualitative research, however, such presumptions about causal relations of conditions are an exception. AQUAD leaves it to you to select any given category (code, characteristic, meaning) from the pool of categories, and then to search for the typical configurations of the other characteristics which appear together with the value "true" of this category (defined as criterion). Thus, Boolean minimization has primarily heuristic functions in AQUAD. Now, here is the result of our examination of configurations (see screen shot on the next page):

In our example the minimization provides the main implicants

Bc, AC and AB

for the criterion "D". That is, high achievement was observed in classrooms

- with high aptitude level (B) *and* a relatively short period of observation (c) (Bc represents the logical relation B *and* c); or
- with low numbers of students (A) *and* long periods of observation (C); or
- with low numbers of students (A) *and* high aptitude level (B).

These implicants could be further reduced to the *essential* implicants AC and Bc. This means that in this study high achievement is observed in all those cases in which the classes are small *and* the observation lasted over a long time (AC), *or* in which the ability level of the students was high *and* the observational time was short. In the first configuration it is the ability, in the second one it is the class size that does not play an important role.

We do not get information only about configurations of conditions, here for criterion "D", but also information about groups or clusters of comparable cases. As this example also demonstrates, the main implicants often are redundant, that is, they determine overlapping groups of cases. There are cases which belong to two different configurations, namely cases 3, 4, and 10.

```
Boolean minimization - file: Examp.att
Criterion: Condition 4 / TRUE



Implicant/s
     Bc
     AC
     AB
CASES:

3 Implicant/s
---> 1. implicant: Bc - cases:
   2   3  12
---> 2. implicant: AC - cases:
   1   4   9  10
---> 3. implicant: AB - cases:
   3   4  10

Implicant Bc: 3 cases
Implicant AC: 4 cases
Implicant AB: 3 cases
```

Now, what about the option *"Negative criterion"*? As you will assume correctly, the only difference consists in the fact that AQUAD chooses in this case those combinations of conditions for minimization in which the criterion is "false". As a result, we get the "negative conditions" of the criterion, i.e., those implicants that are related to the logical value "false" of the criterion condition.

In our example, low school achievement (d) can be observed in big classes with an average level of ability (ab), or with an average ability and a long duration of the study (bC), or in big classes with a long duration of the study (aC).

13.4 What else can you do with implicants

From the preceding examples and the general descriptions in chapters 1 and 5 you know that logical minimization is used in AQUAD mostly to *compare* the results of qualitative analyses. In particular, you can compare linkages of meaning or configurations of categories

- when you study a larger number of single cases or
- when you want to meta-analyze qualitative studies.

Commonalities and differences of cases/studies became clearly visible. During the final steps, when we want to *summarize or group findings*, to differentiate among types of texts or speakers, the process of logical minimization seems to be indispensable.

In efforts to find causal relations beyond the boundaries of case-specific conditions valid for local causality, we have to identify one category across our cases as the effect we are interested in, i.e., as the effect for which we would like to learn more about its possible causes. For instance in the already mentioned study by Marcelo (1991), the researcher became more and more interested in finding reasons for some beginning teachers' problems with classroom discipline. In the logical formulation "if ... then ..." of empirical causality, the effect category defines the "then"-part. Stated concretely, the analysis was focused on the problem "If some yet unkown things happen, then beginning teachers are confronted with discipline problems." What we want to know is the content of the "if"-part, i.e., those groups or configurations of categories that cause the critical effect. Since this if-then linkage is known as the logical relationship of "implication," we also say that the propositions within the if- part imply or implicate the proposition determining the then-part, and we call these causal propositions the effect's implicants.

To illustrate his approach, we will again take examples from Marcelo's (1991) study of beginning teachers' experiences. As was just mentioned, the author found that these teachers talked most often about discipline problems in their classrooms, although not all of them mentioned this problem. Looking for critical differences between teachers, which might also explain their classroom problems, the analysis concentrated on six categories:

A self,
B teacher-student-relations,
C teaching methods,
D discipline problems,
E student motivation, and
F classroom climate.

An analysis of configurations for condition D (discipline problems) as criterion resulted in three groups of implicants:

D = ABC + ACEF + abcef

From this reduction we learn that we can distinguish between three groups among those beginning teachers, who talk much about discipline problems (D). An interpretation of these groupings seems to be highly relevant for the organization of in-service training of teachers:

- *Configuration ABC*: A first group is characterized by the configuration ABC, i.e., these teachers reflect about themselves, teacher-student-relations, and teaching methods - but not about student motivation and classroom climate.
- *Configuration ACEF*: A second group, characterized by the configuration ACEF talks about self, teaching methods, student motivation and social climate - but does not seem to reflect on teacher-student-relations.
- *Configuration abcef*: The third group, typified by the configuration abcef mentions discipline problems often in their interviews, but none of the other central categories!

This application of the analysis of implicants renders clusters of cases. For theoretical and methodological reasons as well as for practical reasons we may wish to switch from the wide angle view of general findings of different configurations of conditions for a critical category to a close-up view of single cases. In other words, we may be interested in reading once more, but now concentrating on particular codes, the interview transcriptions of all those teachers that belong to one of the sub-groups experiencing discipline problems. If you study the listing of cases in the result output, you will get much stimulation for permanent comparison also on this level of analysis, opening the road from the heights of abstraction back to the lowland of case-specific formulations.

Besides support for summarizing the findings of a study, logical minimization already offers important *heuristic functions during early stages of analysis*. By analyzing the implicants or configurations of conditions for particular criterion categories we may get valuable heuristic hints how to elaborate our interpretive approach. Let us assume a study with 50-60 interviews. And let us assume additionally we had developed five important categories of interpretation during the interpretation of the first transcriptions. We name these categories here simply A, B, C, D, and E. These categories stimulated interesting, but unfortunately controversial assumptions about central messages in our data texts. Probably you would not like to continue your efforts of interpreting and coding text after text when you are in doubt about your analytic approach – until you detect after coding all of your interviews that you missed a decisive feature from the beginning!

Instead, you could take your codings of the first ten or twelve interviews, determine a particularly important category first as the "positive" criterion, then as the "negative" criterion of logical minimization and have AQUAD find the implicants of this criterion. Assuming, condition A is critical, we run the option "*Implicants*" first for all those cases, where an issue A was mentioned as very important for the speakers; i.e., we take A as "true"in these interviews. Thus we will know those configurations of conditions B, C, D, and E that go together (maybe: cause) the state "true" of condition A. The resulting configurations could be:

BD + BC + bcd.

Afterwards we activate the option "*Negative criterion*" to detect configurations of conditions B, C, D, and E in interviews where the criterion A was *never* mentioned or was characterized as *unimportant*. That is, in these interviews criterion A appears as "false". Here we find the configurations

BD + cde.

Obviously there is a contradiction. The configuration BD is found as a configuration of conditions for statements under the critical condition A = true as well as for statements under the condition a = false. After a relatively short time of interpreting only about a dozen of our 60 interview texts we would thus get valuable heuristic advice how to differentiate our coding system. Probably we missed including evaluative aspects when we applied the categories B and D. Let us assume as an example that we are dealing with interview texts about student teachers experiences during a practicum in classrooms. We coded, for instance, statements about their observations of classroom interactions between teachers and students, but we missed including in our codes whether a student teacher experienced a particular interaction as successful/positive or as unsuccessful/negative. Thus, codings referring to category B or D would be employed in most interview texts, regardless of the truth value of A. If we now take into account whether an observation of interactions was evaluated positively and therefore probably consistent with condition A or whether an interaction was evaluated negatively and therefore maybe totally inconsistent with condition A (but consistent with a), we will be able to dissolve the contradiction in a short time. We see, as a heuristic tool, configuration analysis may facilitate the task of generating adequate categories even if only a few texts are analyzed.

Finally, we should think of *meta-analytic approaches* opened by logical minimization. A meta-analysis does not have to be quantitive in nature, as Glass, McGaw & Smith (1981) state as "not deniable." Depending on the nature of data, qualitative or quantitative meta-analyses are possible. Both approaches must not differ in the strictness and the systematicness of the comparison. With an instrument like AQUAD this demand can be fulfilled.

However, the sources of errors for comparisons of studies as summarized by Jackson (1980) in a disillusioning way, cannot be eliminated, even with the support of a computer. As emphasized above, it is the researcher, who controls the analysis and not the computer: the computer is only a useful tool. If only a very small percentage of those authors, who establish their work on summaries of other studies discuss these findings critically, then the tool is useless. With the support of a computer, however, already the original authors should become aware of the fact that they only picked and chose specific configurations of conditions from other researchers' studies or case analyses, or that they overlooked contradictory configurations. Jackson's (1980) charge that most of the comparisons are done a lot less strictly at the moment becomes particularly severe, if we consider the availability of software like AQUAD.

13.5 Functions of implicants in the process of theory building

How should researchers conceive of implicants as results of configuration analysis? Do they serve as evidence to proof or to reject underlying theories, the blueprints for reconstructing other people's views of the world, or to establish theories emerging in the process of qualitative analysis? The answer is a maybe puzzling "neither ... nor." As here is no space for elaborate methodological considerations, Ragin's (1987) explanations of the dialogue of evidence and ideas in Boolean configuration analysis may be interesting for further reading:

> The Boolean approach to qualitative comparison ... is a middle road between two extremes, variable-oriented and case-oriented approaches – it is a middle road between generality and complexity. It allows investigators both to digest many cases and to assess causal complexity (Ragin, 1987, p. 168).