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The impact of information presentation on the efficiency of managerial decisions

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Hans Georg Gemünden

THE IMPACT OF INFORMATION PRESENTATION ON THE EFFICIENCY OF MANAGERIAL DECISIONS

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THE IMPACT OF INFORMATION PRESENTATION ON THE EFFICIENCY OF MANAGERIAL DECISIONS

1. THE PROBLEM

It is a basic premise of accounting that supplying managers with "good", problem-adequate, reliable, valid, actual, and material information will increase the efficiency of their decisions. However, production of such information is only a necessary, but not a sufficient condition for better decision-making. One also has to secure that this information is **used** properly. This is the research domain of behavioral accounting (and behavioral MIS/DSS-research). It posits that decision quality is not only affected by content and quality of information, but also by the way how it is communicated and perceived. Therefore one also has to analyze how variables like amount of information offered, aggregation level, communication medium, and presentation form affect decision quality.

One of these instruments, presentation form, will be analyzed in this paper. In particular, we test how tree-structured presentation formats affect information behavior and decision quality. Tree-structured presentation formats have been used in controlling for a long time, as the example of the well-known Du-Pont-Control-Tree documents. However, despite its widespread use, as far as we know, the efficiency impacts of this tool have not been tested systematically. We shall first review the empirical studies which have tested the impact of graphical decision aids and then present results from our own experimental work.

2. RESEARCH ON PRESENTATION FORMS

2.1. Scope of the Meta-Analysis

The influence of graphical aids has already been researched for quite a long time, but more intensive research on managerial applications has started only recently stimulated by the ongoing diffusion of PC's and standard-software for business graphics. (See DeSanctis (Computer Graphics 1984) and Benbasat/Dexter/Todd (Integration 1986) for reviews).

These experimental studies usually follow an S-O-R-paradigm. They manipulate an independent graphical stimulus S and observe which reactions R an intervening organism O produces. They are input/output-studies which treat information behavior as a "black box". More sophisticated designs consider interaction effects with task and personality variables.

We focus our meta-analysis on studies which have analyzed

* the impact of systematically manipulated graphical aids,
* on commercial efficiency variables (i.e. costs, profits, and decision-quality, particulary accuracy of diagnosis or forecasting),
* for management problems,
* in true experiments where participants have been assigned randomly to graphical conditions.

2.2. Results of the studies

Studies which analyze relevant efficiency measures[1)] have been performed for:

(1) charts vs. tables,

(2) schematic faces vs. tables, and

(3) multi- vs. mono-chromatic presentation formats.

Tasks, participants, graphical stimuli, efficiency measures, and results of these studies are presented in table 1.

Ad (1): Charts vs. Tables

Only one study (Dickson/DeSanctis/McBride (Computer Graphics 1986) second experiment) out of 13 which have tested tables vs. line or bar charts, shows a significantly higher efficiency for graphics. On the other hand one study documents superior performance for tables (Remus (Presentations 1984)). Reported or re-analyzed effect sizes usually lie below 5 % explained variance. (For re-analysis of effect-sizes see text-books on meta-analysis e.g. Hedges/Olkin (Statistical Methods 1985) or Fricke/Treinies (Metaanalyse 1985)). Besides, graphics usually did not significantly accelerate decision-making. These results stand in sharp contrast to standard-software vendor's arguments. (For similar conclusions see: Ives (Graphical User Interfaces 1982), and DeSanctis (Computer Graphics 1984)).

Ad (2): Schematic Faces vs. Tables

Schematic faces have been tested in three studies using a lens-model paradigm. Particpants were either given few pieces of numerical accounting information or a schematic face. They had to summarize these cues into a classificatory statement. Accuracy of classificatory judgment was used as efficiency measure. In all three studies participants with schematic faces performed significantly better, re-analyzed mean explained variance was about 5.6 %. While Moriarity found significantly faster processes with faces, Stock/Watson could not replicate this effect. If the results are combined it appears that schematic faces are able to increase efficiency because they improve decision-quality and do not slow down speed of decision-making. However, results are **biased:** By assigning better discriminating variables to inner face variables which are perceived more intensively (see Stock/Watson (Graphics 1984) 197p. for this assignment) analysts using

Table 1: Tasks, Subjects, Designs and Results of Experimental Studies Testing the Influence of Graphical Aids

- Charts vs. Tables -

Source	Task	Subject	Independent Variables	Efficiency	Results
Benbasat (Effects 1974)	business game, purchase and production	32 stud.	charts vs. graphics, other exp. cond.: decision aid, amount of information, exception reporting	cost performance	n.s. (re-analysis of table 1 corr.: -0.28, expl. var. 7.6 %), tend. sign. interact. with decision aid
Smith (Inquiry Techniques 1975)	business game, purchase and production	17 stud.	creation of additional tables or charts by the participants	1. cost performance 2. forecasting accuracy	1. n.s. (re-analysis p. 119: point-bis. corr.: 0,04) 2. n.s., (insuffic. information to est. effect size)
Lusk (Differential Peaking 1979)*	answering factual questions	300 stud.	2 tabular and 3 graphic report variants; cogn. style: group embedded figures test	number of correct answers	table sign. better, no signif. interaction with cognitive style
Davis (Information Presentation 1980)	business game, coordination of production and sales plans	96 stud.	chart vs. table; other exp. condition: raw data vs. statistically summarized data	cost performance	n.s. (insuff. inf. to estimate effect size)
Lucas/Nielsen (Presentation 1980)	business game, logistics	36 stud. 78 managers	chart vs. table	mean profit	n.s. (insuff. inf. to estimate effect size)
Lucas (Graphics 1981)	business game, inventory decision under uncertainty	97 managers	chart only vs table only vs. table and chart (see: Lucas, "table 4"); cogn. style: analytic vs. heuristic (Barkin-question.)	cost performance ("best simulation")	n.s. (insuff. inf. to estimate effect size), tend. sign. interaction with cognitive style
Ghani/Lusk (Information Represention 1982)	simple business game, production and logistics under uncertainty	49 stud.	2*2-design: 1. first table then chart, 2. first chart then table, 3. first table then table, 4. first chart then chart (all in colour)	1. profits 2. change of profits	1. n.s. 2. n.s. (insuff. inform. to estimate effect sizes)
Zmud/Blocher/Moffie (Color Graphic 1983)	simple task: evaluate risk of an invoice within 15 seconds	51 internal auditors	coloured bar-charts vs. mono-chromatic tables, other exp. condition: 5 vs. 9 cues	accuracy of risk class assignment	n.s. (re-analysis of "Table 3", expl. var. 0.01 %), sign. interaction: with 5 cues chart superior, with 9 cues table

Table 1 (cont.): Tasks, Subjects, Designs and Results of Experimental Studies Testing the Influence of Graphical Aids

- Charts vs. Tables (*continued*) -

Source	Task	Subject	Independent Variables	Efficiency	Results
Remus (Presentations 1984)	business game, coordination of production and sales plans	53 stud.	charts vs. tables	cost perform.: 1. actual costs 2. estimated cost, based on individ. regression 3. estimated cost, based on avaraged regression parameters	1. n.s., corr.: -0.02 2. n.s., corr.: -0.08 3. sign. lower costs for tables, corr.: -0.62 (Re-analysis: point-biserial correlations estimated from t-values of table 1,2,3)
Benbasat/ Dexter (Graphical Information Presentation 1985)	business game, allocation of promotional budget among three sales territories	35 stud.	2*2-design: chart vs. table, other exp. cond. mono- vs. multichromatic; cognitive style: group embedded figures test	profit	n.s. (insuff. inf. to est. effect size), no sign. interaction with colour or cogn. style
Benbasat/ Dexter/Todd (Graphical Information Presentation 1985)	business game, allocation of promotional budget among three sales territories	66 stud.	2*2-design: chart vs. table, other exp. cond. mono- vs. multichromatic; cognitive style: group embedded figures test	profit	n.s. (insuff. inf. to est. effect size), no sign. interaction with colour or cogn. style
Benbasat/ Dexter (Time Constraints 1985)	business game, allocation of promotional budget among three sales territories	65 stud.	3*2*2-design: a. only chart vs. only table vs. chart and table, b. mono- vs. multi-chromatic, c. 5 vs. 16 minutes time limit	profit	n.s. (re-analysis Chi-Square-Test with Tab. 2a),b) combined, tetrachoric corr.: -0.20), with 15-min.-cond. chart sign. worse, with 5-min.-cond. n.s.
Vent (Denkstrategien 1985)	complex economic game, energy supply of Western Germany, more than 150 instrumental variables	24 stud.	graphic vs. numeric inf.: a. during introduction to system b. for feed-back (2*2-design)	index over 17 critical variables, cost get 50 % weigh	a. graphic better, tend. sign., expl. var. 13.8 % b. n.s., expl. var. 7.8 % tend. sign. interact. expl. var. 12.9 % (re-analysis table 2)

Table 1 (cont.): Tasks, Subjects, Designs and Results of Experimental Studies Testing the Influence of Graphical Aids

- Charts vs. Tables (continued) -

Dickson/De Sanctis/Mc Bride (Computer Graphics 1986) 1. Exp.*	very much simplyfied fiancial statement analysis of a small firm	154 stud.	bar-chart with numerical information vs. table	1. "accuracy" correct answers to factual quest. 2. "decision quality" correct calculations	1. n.s., point-bis. corr.: 0.04 2. n.s., point-bis. corr.: 0.04 (re-analysis of "Table I")
Dickson/De Sanctis/Mc Bride (Computer Graphics 1986) 2. Exp.	business game, demand forecasting task	320 stud.	chart vs. graphic, different temporal development of demand: a) lin. falling, b) cyclical variations, small variance, c) cyclical variations, large variance	forecasting accuracy (absolute amount of relative deviation)	a) chart sign. better, corr.: 0.24 b) chart sign. better, corr.: 0.26 c) chart sign. better, corr.: 0.18 (re-analysis of "Table II" averaged pearson correlations)
Dickson/De Sanctis/Mc Bride (Computer Graphics 1986) 3. Exp.*	analysis of reports upon computer-graphics software packages	363 stud.	2x2x2-design: a) chart vs. table, b) single presentation of whole report vs. two presentations of two halfes, c) reports may be used or not to answer factual questions (recall vs. recognition)	correct answering of factual questions: 1. "message measure" 2. "traditional measure"	1. "message measure" main effect n.s., interaction effects n.s. 2. "traditional measure" main effect n.s., tend. sign interaction with presentation freq. (re-analysis of "Table VI" und "VII" expl. variances under 1 %)

- Schematic Faces vs. Tables -

Source	Task	Subject	Independent Variables	Efficiency	Results
Moriarity (Graphics 1979)	classification whether a firm will fail during next year or not	277 stud.	schematic faces a) without b) with explication, c) 10 selected data from income statement and balance sheet, d) 13 selected ratios in each condition information is given for 6 years before failure, 22 firms have to be classified	number of correctly classified firms	sign. main effect, (re-analysis of "Table 4": expl. var. 3.0 %), but only differences between a), b) vs. d) sign. i. e. only partial superiority of schematic faces

Table 1 (cont.): Tasks, Subjects, Designs and Results of Experimental Studies Testing the Influence of Graphical Aids

- Schematic Faces vs. Tables (continued) -

Moriarity (Graphics 1979)	classification whether a firm will fail during next year or not	20 managers	schematic faces with explanation vs. ratios, each inf. for 6 years before failure, 11 firms have to be classified	number of correctly classified firms	schematic faces sign. better (re-analysis of "Table 7", Chi-square-test, tetrachoric corr.: 0.25)
Stock/Watson (Graphics 1984)	classification whether a bond-rating will rise, fall, or stay constant next year	123 stud. 14 managers	schematic faces vs 6 ratios each information for 6 years before new rating, 21 firms have to be classified	number of correctly classified firms	schematic faces sign. better (re-analysis of F-values p. 199: expl. var.: 7.9 %), no sign. interaction students/managers

- Mono- vs. Multichromatic Presentation -

Source	Task	Subject	Independent Variables	Efficiency	Results
Benbasat/ Dexter (Graphical Information Presentation 1985)	business game, allocation of promotional budget among three sales territories	35 stud.	2*2-design: chart vs. table, other exp. cond. mono- vs. multichromatic; cognitive style: group embedded figures test	profit	colour sign. better, no sign. interaction with chart/table, sign. interaction w. cognitive style: field-dependent are stronger improved
Benbasat/ Dexter/Todd (Graphical Information Presentation 1985)	business game, allocation of promotional budget among three sales territories	66 stud.	2*2-design: chart vs. table, other exp. cond. mono- vs. multichromatic; cognitive style: group embedded figures test	profit	n.s. no significant interaction effects
Benbasat/ Dexter (Time Constraints 1985)	business game, allocation of promotional budget among three sales territories	65 stud.	3*2*2-design: a. only chart vs. only table vs. chart and table, b. mono- vs multi-chromatic, c. 5 vs. 15 minutes time limit	profit	colour sign. better, (re-analysis: Chi-square-test of table 3a),b) combined), no interaction test, but sign. improvement of colour only under 5-min.-cond.

*: study is only reported but not evaluated in the text, because it does not use an economic efficiency measure

faces get an **implicit weighing advantage.** To perform a fair test, the control group should have also got discriminatory weighs either in a verbal or in a numeric form. Besides, we have to critisize task validity of the lens-model studies: analysis of income-statement and balance sheets is more than adequately weighing some few pre-selected key-ratios.

Ad (3): Effects of Colour: Multi- vs. Monochromatic Presentation

In three recent business game experiments Benbasat, Dexter and Todd tested the influence of colour using mono- vs. multi-chromatic presentations for both, tables and charts. Two of their three experiments show significantly better performance for multi-chromatic coding. However, their carefully designed experiments show that the effects of colour depend on personality and task.

2.3. Defects of Current Research

Our review documents a large gap between claimed and real influence of graphical aids on efficiency of managerial decisions. However, many of the reviewed studies suffer from two defects: They do not specify when and why graphics are supposed to be superior, and they do not analyze empirically whether and **how** presentation influences information behavior. Therefore we do not know how to interpret contradictory findings and lacking evidence. Are there no influences

a) because graphics only support perception of information which is not critical for the quality of decision-making, or

b) because all humans have a comprehensive behavioral repertoire which allows them to use different presentation forms equifunctionally, or

c) because some humans perform better with one presentation form whereas others perform better with another, so that the average effect is small?

Choice between these competing explanations is important because it has

different implications. In the first case, perception support systems are only "hygiene factors" of an MIS/DSS which do not affect decision quality but may be helpful because they faciliate acceptance. In the second case, users could and should be trained to use their different behavioral possibilities, and in the third case, presentation form and personality should be matched by adapting both components.

Another shortcoming of current research on presentation forms is the SOR-paradigm. Participants **receive** different graphical stimuli and **re-act** on them. This paasive role contrasts to the active user who produces his own graphics suited to his individual information-needs quick and cheaply by means of a new technology. Current research ignores the fundamental changes in information behavior. It does neither consider non-use benefits which occur during the process of constructing a computer-graphic, nor does it recognize barriers and defects of standard-software packages which handicap potential user and favour mis-use of computer-graphics.

Researchers in the MIS/DSS field are well aware of lacking evidence and contradictory findings. They recommend a **contingency framework** which explicitly considers task- and personality-variables. E. g. Dickson/DeSanctis/-McBride (Computer Graphics 1986) and Benbasat/Dexter/Todd (Integration 1986) have performed series of experiments which systematically test such contingencies.

We should not expect that a contingency-paradigm could solve all our problems. E. g. our review show the following significant interactions:

* with a decision aid graphics have a larger impact than without a decision aid (Benbasat (Effects 1974)),

* "heuristics" are improved stronger through graphics than "analytics" (Lucas (Graphics 1981)),

* for simple tasks bar-charts give more accurate classifications, for complex tasks tables give better results (Zmud/Blocher/Moffie (Color Graphic 1983)),

* without time-pressure tables show better results (Benbasat/Dexter (Time Constraints 1985)),

* a change of presentation form deteriorates efficiency (Vent (Denkstrategien 1985)).

However, these significant interactions are confronted with contradictory **non**-significant interactions:

* no significant interactions for three (other) variables of information system and two personality variables (Benbasat (Effects 1974)),

* no significant interactions with a change of presentation form (Ghani/-Lusk (Information Representation 1982)),

* no significant interactions with cognitive style (Benbasat/Dexter (Graphical Information Representation 1985)),

* no significant interactions with colour (Benbasat/Dexter (Graphical Information Presentation 1985), Benbasat/Dexter/Todd (Graphical Information Presentation 1985)).

Thus, the contingency approach has two serious drawbacks:

1. There are many possible interaction effects with media, task and personal and organizational variables. To avoid ubiquitios **ex-post facto speculations** upon the reasons of a few "significant" interactions out of the large number of tested effects, one must outline **ex ante** the reasons for specific interactions and exclude the hypothetically irrelevant ones. This requires a strong theory, which actually does not exist.

2. Even if the few specific predictions cannot be falsified, the input-output-nature of the experiment does not allow to test whether and how the assumed intervening, but **not** observed and measured information processes have really produced the observed result.

2.4. An Extended Framework: The Kiel Experiments

To overcome these shortcomings we have chosen an **extended research framework** in a series of experiments which have been performed at the University of Kiel and several other German universities (**"Kieler Experimente"**).[2] The hallmark of this research approach is that we do not only manipulate an experimental cue, i. e. the format of information presentation, but that we also **trace the intervening information processing behavior.** Thus we can empirically control by means of path-analysis how presentation format has influenced efficiency via information behavior.

A second hallmark is to put the analysts into a **complex information environment** and give them a **natural task.** We do neither restrict the information offer to 5 or 7 informational cues, nor do we play gaming tasks. Participants analyse four real complex "Mis-Management"-cases (during two days). They are supplied with balance sheet and income statement informations (up to 512 items). We trace amount, content, structure and sequence of their information activities by means of very large information-display boards and detailed content analyses of their reports. These information items (about 250,000) are then combined to different scales.

2.5. Summary

There is a large gap between pretended and empirically confirmed efficiency effects of presentation format. Current research suffers from conceptual defects: it cannot explain why lacking evidence and contradictory findings occur. A contingency framework may clarify some relationships but it cannot give ultimate answers, and it creates additional problems. To overcome problems of current research we propose an extended framework. It starts from a theory which explicitly considers the intervening information processes, it uses several processual data gathering methods to trace this behavior, and it performs path-analyses to identify whether and how behavior and efficiency are influenced. Such a framework is not restricted to describe how people **re-act** on experimentally altered conditions. It can also be used to analyse how active users manage changes which they have

produced themselves.

In the following chapters we shall first outline our theoretical framework which explains how tree-structures are supposed to influence information-behavior and efficiency. Then we shall describe test design, operationalization of efficiency, and perform a classical input/output-analysis of main effects and interaction effects. Finally we shall perform a path analysis and discuss our findings.

Footnotes to chapter 2

1) Studies which use correct answers to factual questions as efficiency measures (e.g. Lusk (Differential Peaking 1979) are reported in our summarizing table but not considered in our evaluation.

2) Research on this project has been published in: a) books: Krehl (Informationsbedarf 1985), Knorr (Informationsnachfrage 1986), Fink (Kognitive Stile 1985), Gemünden (Informationsverhalten und Effizienz 1986), Petersen (Verlauf 1986); b) articles: Hauschildt/Rösler/Gemünden (Cash Flow 1984), Hauschildt (Graphische Unterstützung 1985), Hauschildt/Grenz/Gemünden (Erfolgsspaltung 1985); c) working papers: Hauschildt/Gemünden/-Knorr/Krehl (Kieler Experimente 1983), Krehl (Musteranalysen 1983), Krehl (Erheberhandbuch 1983), Gemünden/Petersen (Kieler Meßkonzept 1985).

3. DERIVATION OF HYPOTHESES

3.1. The Influence of Tree-Structured Presentation Forms on the Quality of Income Statement Analysis

Tree structures may improve decision-quality in four ways:

(1) by excluding irrelevant informations,

(2) by stimulating more intensive information processing,

(3) by supporting pattern formation and recognition,

(4) by supporting objectwise scheduling of information processing.

Ad (1): Excluding Irrelevant Informations

Tree-structures may show which branches contain relevant informations and which contain irrelevant ones. They signal which problem-segments an analyst can neglect and thus reduce his information-load.

This argument needs qualification. A branch in a search-tree can only be neglected as "irrelevant"

- if a **deterministic link** exists between a symptom shown at an intermediate level of the tree and a cause shown at a final node;

- if there is only **one** cause which the analyst has to detect, and

- if the **modelled** tree gives an adequate description of the "true" cause-effect relationship.

Such a situation may be given for a technical system where a "fault-tree" helps a "trouble-shooter" to find the unique cause which is responsible for the systems' malfunctioning. In this case there may exist only one solution which is either "true" or "false". The trouble-shooter can test his solution hypothesis immediately, and the test-result verifies or falsifies his hypothesis unambigously. (Cf. e. g. Rouse (Experimental Studies 1981) for experiments in such a task-environment). The information problem is generated by the fact that the tree becomes very complex. In this situation an "expert system" may help to find a feasible solution.

However, if we observe a **social** system, we usually have a complex interplay of **several** causes: the validity of one explanation does not exclude another hypothesis. Such multi-causal explanations are well documented. Just imagine a firm crisis caused by market deteriorations **and** managerial faults.

Second, accounting informations, especially in balance sheets and income statements, are highly **aggregated** and often **biased**. Therefore one can only **partially** verify or falsify hypotheses about cause-effect relationships.

Third, since the "true" cause-effect relationships are unclear, different trees can be modelled. The research from Fischoff/Slovic/Lichtenstein (Fault Trees 1978) documents that the **construction** of a fault tree has a strong influence on the generation and evaluation of hypotheses for different causes of failures. In particular, if one omits certain branches, the subjective probability of various sources of errors changes dramatically, for students as well as for experts.

To summarize: Tree-structures which are modelled to detect failures in a social system offer a priority-heuristic which branches a decision-maker should scan first, but they do not enable him to neglect other branches definitively. The information-load reducing potential of a tree-structure depends on the extent at which the premises of the concept are given.

Ad (2): Stimulating More Intensive Information Processing

Tree-structures offer a graphic representation of a systematic concept. They show which branches an analyst should canvass if he finds promising indicators. This stimulates deeper information processing, and more precise localization of potential causes of a crisis. On the other hand, if cause-effect-hypotheses have been falsified by the data processed by the analyst so far, tree-structures offer alternative hypotheses which can be tested by examining other branches of the tree. Thus, they support a wider search for potential problems and prevent analysts from a selective and biased problem perception (see Libby (Information Processing 1981) 102p.).

Ad (3): Pattern Formation and Recognition

There has been an intensive and ongoing debate concerning the "right" measure of a firm's performance. Modern German accounting theory realizes that this is the wrong question. There does not exist one ratio for all purposes. In particular, there does not exist one single indicator which shows the "true" gains or losses. Rather, one has to evaluate **patterns** of different sources of income, in order to qualify a general measure. E. g. a substantial overall profit which comes from the liquidation of a real estate with a low book value has a lower quality than a high profit which is explained by recurring operating profits from the main business.

A **tree-structure** emphasizes the **links** between different sources of income. It inspires analysts to **integrate** different elements into patterns. It also faciliates **recognition** of typical patterns signaling a crisis.

Ad (4): Supporting Objectwise Scheduling of Information Processing

The typical information processing sequence with tree-structure is objectwise. First one analyses the top-triangle of a tree-structure, and then decides which overlapping triangle should follow next. Figure 1 illustrates

this processing behavior.

Figure 1: Objectwise Information Processing in a Tree-Structure

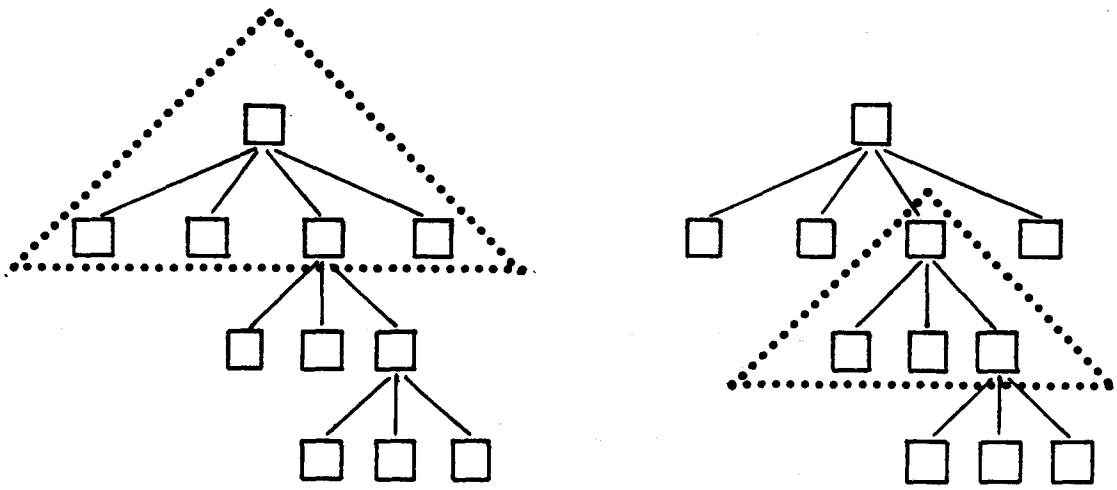


Figure 2: Acticitywise and Objectwise Information Processing

Step	Activitywise	Objectwise
1	A_1 at O_1	A_1 at O_1
2	A_1 at O_2	A_2 at O_1
3	A_1 at O_3	A_3 at O_1
4	A_2 at O_1	A_1 at O_2
5	A_2 at O_2	A_2 at O_2
6	A_2 at O_3	A_3 at O_2
7	A_3 at O_1	A_1 at O_3
8	A_3 at O_2	A_2 at O_3
9	A_3 at O_3	A_3 at O_3

Tables stimulate activitywise prcoessing: First data are gathered, then compiled on a record form, then ratios are calculated, and finally these informations are evaluated. The difference between an activitywise and an objectwise processing is that with a pure activitywise processing strategy one first gathers data for **all** objects, then compiles data for all objects etc., whereas with an objectwise processing, one performs all activities for one object after the other.

It is clear that the two processing strategies are ideal types which occur very seldom in reality. It is also clear that they are not necessarily linked with tabular and tree-structured presentation forms. Nethertheless do we expect that tree-structured presentation forms facilitate and stimulate objectwise processing of problem-adequate modules: behavior is influenced in the **direction** of objectwise processing.

What are the potential advantages of objectwise, modular processing? An objectwise processing allows the decision-maker to develop **intermediate** evaluations which **control** the sequence of information processing. Which information is processed next, depends on the evaluations and information **choices**, the analyst makes **during** the process, influenced by his case-specific knowledge, he has acquired at a given state of the process. Information-processing is not formular-oriented, i. e. the analyst is not forced to fill out all the blanks in tabular record, independent of his information-needs which he has developed during the process. Rather, his information-acquisition and processing is concept- and knowledge-driven. If a tree-structure is a conceptual model to structure information needs then objectwise processing is the instrument to use this model.

Another advantage of objectwise processing is that intermediate evaluations are stored as **chunks**. In order to come to a final evaluation, analysts only need to retrieve and integrate certain chunks, they do not have to re-integrate the whole information they have already processed. This reduces

cognitive strain. Besides, the chunks can be retrieved very quick, so they can easily be adjusted towards new pieces of information. (See Simon (Information Processing Models 1979) for this information-processing feature of experts).

Considering all arguments together, we conclude

A presentation in tree-structured form will lead to a higher quality of income-statement analysis than a presentation in tabular form.

3.2. Interactions with Experience

The positive influence of a tree-structured presentation form depends on the knowledge organization which the analysts have. If the analysts are already familiar with a systematic income statement decomposition, and thus have already developed a powerful "internal model", the visualization of this concept in form of an "external model" will probably not help them very much. If they are used to organize their income-statement information in another way, it is possible that they reject the model, because they would have to re-organize their knowledge-structure to use the new model.

Thus, we expect that the graphical perception support will have its highest effect for unexperienced analysts. With increasing familiarization with the concept the differences between presentation forms will become smaller.

The difference in quality of income statement analysis between tree-structured and tabular presentation forms will be highest for unexperienced analysts. It will become smaller with increasing experience.

4. EXPERIMENTAL DESIGN

4.1. Task

Participants play the role of a credit manager who has to prepare his chief for a negotiation with a client firm. Analysts are given balance sheet and income statement data and two contradictory background messages: A positive memo from their chief who has just visited the client firm, and a negative note from their colleague who has heard a bad rumour about this firm. Participants have to work out an expertise which substantiates their judgment on the firm's economic situation. They also have to develop a checklist of open questions which should be answered during the bargaining session.

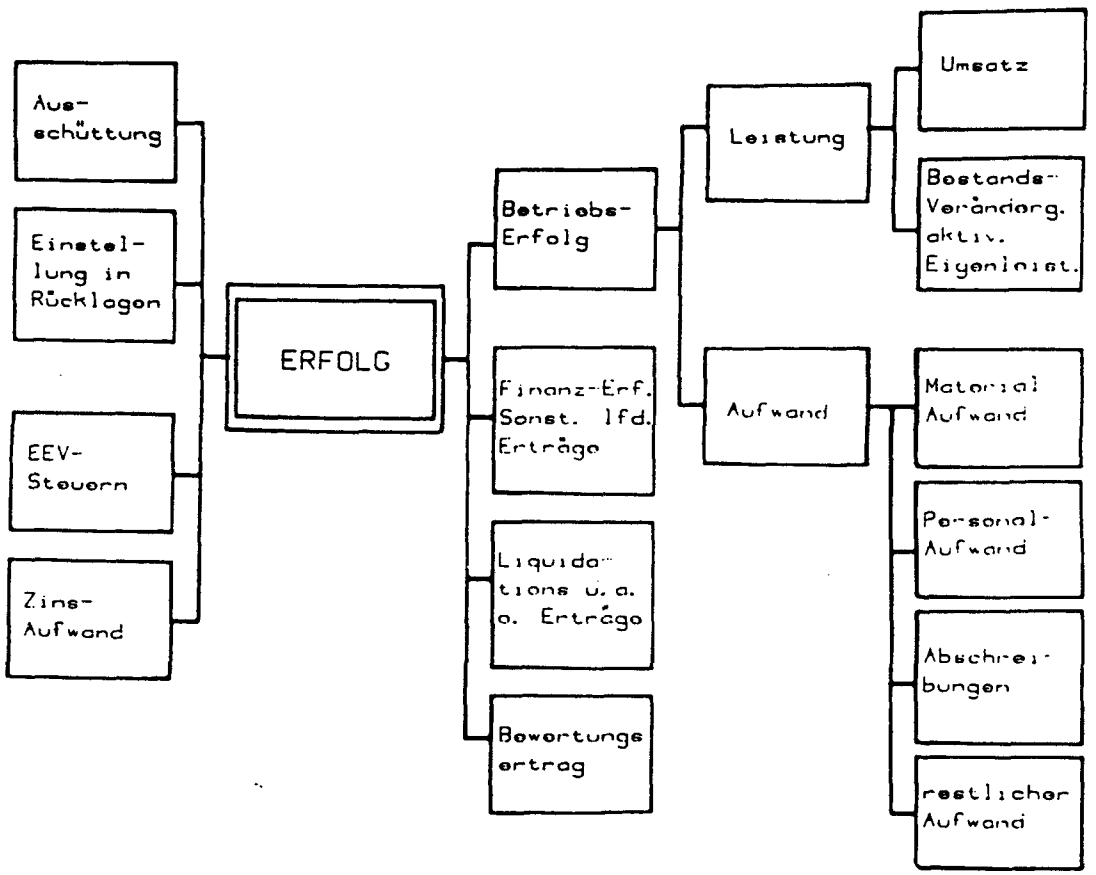
4.2. Information Environment and Presentation Format

Participants are offered the raw-data from balance sheet and income statements of German joint-stock companies, and aggegregated sums and differences of these data. Aggregated data and raw-data have the same content for all experimental groups. The only difference is the presentation format for the aggregate data: tree-structured format vs. tabular format. Figure 3 shows how presentation format was manipulated.

Data are offered for the actual and previous year of the client firm, and for the previous year of another firm which is working in the same industry and which has similar size. Altogether up to 512 data items are offered.

The information is presented in several large information-display-boards which are fixed on the walls of the experimental rooms. Data are printed on small information cards which are put in the pockets of the information-display-boards. Participants pick up the information cards they want and sign them with their initials and a serial number. So one can trace amount, content, and sequence of information acquisition.

Figure 3: Presentation Formats: Tree-Structure and Table



- *Umsatz*
- *Bestandsver. u. akt. Eigenleistg.*

LEISTUNG

- *Materialaufwand*
- *Personalaufwand*
- *Abschreibungen*
- *Restlicher Aufwand*

AUFWAND

Betriebserfolg

Finanzerfolg und sonstige Erträge

Liquidations- und a. o. Erträge

Bewertungsertrag

ERFOLG

Ausschüttung

Einstellung in Rücklagen

EEV - Steuern

Zins - Aufwand

The positive effect of tree structures depends on the quality of income statement decomposition which has been chosen in this experiment. Its predictive value has been tested with a sample of 70 German joint-stock companies against other decomposition variants (Hauschildt/Grenz/Gemünden (Erfolgsspaltung 1985)). The test documented its relative and absolute predictive value: All sources were necessary, the scheme performed better than its competitors, and the absolute classification accuracy was satisfactory: about 70 % of the firms were classified correctly. Evaluating this number the reader should acknowledge that we re-classify a journalist's "mismanagement"-judgment and not insolvency.

4.3. Participants

Participants are post-graduate business administration students majoring in accounting. We performed three experiments:

* Experiment A, University of Gießen, winter-term 1981/82, 34 students, median duration of study: 7.5 terms;

* Experiment B, University of Kiel, summer-term 1982, 33 students, median duration of study: 6.5 terms;

* Experiment C, University of Kiel, summer-term 1984, 36 students, median duration of study: 6.4 terms.

Information behavior of the student populations was compared with information behavior of lending officers in a field-study where thinking-aloud was applied (Weigel (Informationsverhalten 1980)). Quality of analysis was compared with the results from CPA-exams. For the same analyzed cases similar results emerged. Population validity seems to be fulfilled.

4.4. Organization

Participants have to analyze four different cases. After each case they get a detailed feed-back. Cases are analyzed in different experimental rooms, standardized feed-back is given in a central room. Both events take 90 minutes. Our next figure shows the time schedule of the experiments:

Friday morning	9.00 - 10.30	Analysis of the first case, exp. room
	10.45 - 12.15	Central feed-back session, central room
Friday afternoon	14.00 - 15.30	Analysis of the second case, exp. room
	15.45 - 17.15	Central feed-back session, central room
Saturday morning	9.00 - 10.30	Analysis of the third case, exp. room
	10.45 - 12.15	Central feed-back session, central room
Saturday afternoon	14.00 - 15.30	Analysis of the fourth case, exp. room
	15.45 - 17.15	Central feed-back session, central room

The following monday a fifth case is analyzed. The quality of this analysis is relevant for the certificate. The data from this case are used to validate the efficiency measures.

Several students worked in one experimental room which had its special presentation format, but each student had to work individually. Students were assigned randomly to the different rooms. Room assignment was the same for all four cases, but working places within a room were re-distributed randomly for each case. Potential room and working place influences on information behavior and quality of analysis were examined. They explained less than one percent of variance and were not statistically significant.

4.5. Comparisons of Different Experimental Conditions

Experimental groups differ in experience and presentation format. Students from the university of Gießen had the highest experience, because they were just before their final MBA-examination in accounting. Students from Kiel in 1982 had a medium experience, and students from Kiel in 1984 had the lowest knowledge in accounting, because the case-seminar was for most of them the first post-graduate course in accounting.

Experiment B (Kiel 82) is a mere replication of experiment A (Gießen 81/82). In both experiments half of the students were presented tree-structured forms, the other half got a tabular presentation. During the central feed-back session no visual aids were used. So we have a 2*2*4-Design (2 presentation formats, 2 experience levels, 4 cases), and can test the main effects of experience, presentation format, cases, and their interactions.

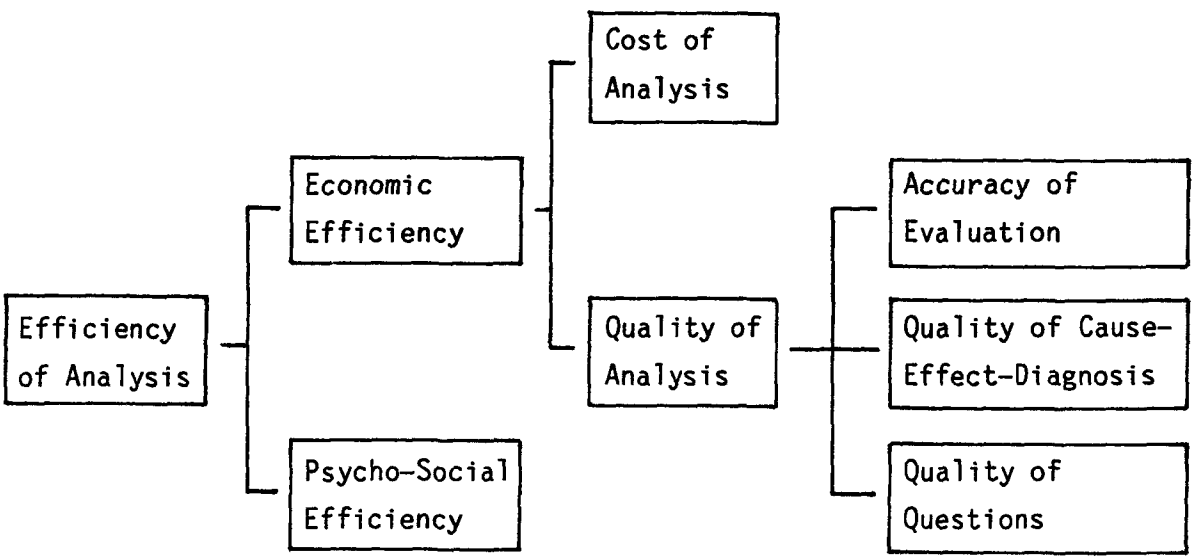
In Experiment C (Kiel 84) all participants got a tree-structured presentation format. In addition, tree-structures were used during the feed-back session to illustrate the concept of income statement decomposition. If we compare these participants with the analysts from the other experiments, two effects are confounded: the effect of an **additional** visual aid which is assumed to be positive, and the effect of a lower experience which is supposed to be negative. In order to estimate effect sizes, we have to make additional assumptions to estimate them. E. g. we can use the pooled difference between tree-structured and tabular presentation form from experiments A and B as a lower bound for the presentation format effect to estimate an upper bound for the experience effect Kiel 84 vs. 0.5 * (Gießen 81/82 + Kiel 82).

5. OPERATIONALIZATION OF EFFICIENCY

5.1. The Concept

Efficiency is a summarizing evaluation of the attainment of several efficiency dimensions. Basic efficiency dimensions are *economic efficiency* and psycho-social efficiency. Psycho-social efficiency is measured by satisfaction with result and course of the analysis. Economic efficiency can be evaluated by cost and informational revenues of the analysis. In our experiments all participants were given the same resources, information, and time budget. Therefore we concentrate our measurement on the quality of the analysis. Quality is divided again into three components: accuracy of evaluation, quality of cause-effect-diagnosis, and quality of questions. Figure 4 summarizes our concept.

Figure 4: Efficiency Dimensions



We will only use accuracy of evaluation to test the propositions. It is the central efficiency dimension and shows positive relations to the other dimensions as will be shown below.

5.2. The Operationalization of Accuracy of Evaluation

The efficiency dimension "accuracy of evaluation" measures the performance of an analyst to evaluate the important segments of a given case properly.

The measure considers three criteria:

(1) relevance of evaluated symptoms,

(2) instrumental quality of evaluation, and

(3) thoroughness, i. e. amount of evaluated symptoms.

These three components are linked by the following basic formula (as shown below, the actual formular is more complicated, since it considers several relevance weighs):

$$\text{Accuracy of Evaluation} = \sum_j R_j * A_j$$

j: Index for different categories of evaluations. There are 70 mutually excluding categories of income statement and balance sheet analysis evaluations.

R: Relevance of an evaluation

A: Adequacy of an evaluation, coded as a binary variable. It takes value 1 if an analyst makes an adequate evaluation of symptom belonging to a category i, and 0 otherwise.

5.2.1. Relevance of Evaluated Symptoms

Relevance of evaluated symptoms is not derived from our subjective judgment. Rather, we use three different sources in order to get an objective and valid weighing of the evaluations:

(1) Theoretical Weigh:

The first source are **experts:** We performed a systematic content analysis of 24 German monographs for income and financial statement analysis, and counted how many ratios they proposed for the 70 categories of analysis. Altogether 1,239 ratios were identified. The relevance weigh of an evaluation category j is measured by the share of proposed ratios falling into this category.

(2) Statistical Weigh:

The second source are balance sheets and income statements of the foremention matched sample of 70 German joint-stock companies. The relevance weigh is the percentage of firms classified correctly, using the median of a representative ratio for each category. To be precise, this test is performed for three different variants of ratios: a) for the inter-temporal comparison, the differences between actual and previous year's ratio values are used, b) for the pairwise inter-firm comparison the difference between the mis-managements firm's ratio and his matching partner is used c) for the general comparison, the difference between the ratio value and the general median of the sample is used. With these three variants, we take into account that different analysts which use different techniques of comparison make evaluations of different quality.

(3) Case-specific Weigh:

The third source are the ratio values of the cases to be analyzed. The more these values differ from the typical value of a population, the higher is their information value, and the more important is it to report such a deviation. To measure this aspect, we use the absolute size of z-standardized values of the ratios as weighs for case-specific relevance. z-standardized values are defined as deviations of case-specific values from mean ratio values, divided by the standard deviation of the ratio. Case-specific weighs were also derived for inter-temporal, pairwise inter-firm, and general (implicit) comparisons.

5.2.2. Instrumental Quality of Evaluations

Evaluations are classified as appropriate or inappropriate. An appropriate judgment must fulfill all the following requirements:

1. it has to be based on factually true premises,

2. its derivation has to be logically true,

3. its direction has to be pragmatically correct,

4. it has to be based on ratios which are constructed appropriately,

5. it has to consider size differences of compared objects adequately,

Factual and logical truth can be determined easily. E. g. if an analyst diagnoses that operating profits have risen where they in fact have fallen, it is very easy to detect an inappropriate evaluation. Whether an evaluation is pragmatically correct cannot always be decided. E. g. losses should generally be evaluated negatively, but a high share of revolving assets can mean many things. It cannot unambigously be evaluated as "good" or "bad". It is also difficult to evaluate the appropiateness of a ratio. We have always evaluated the appropriateness with respect to a specific goal which is assigned to each of the 70 evaluation categories. To secure a reliable classification large tables with different nominators and denominators where constructed, which indicate whether a ratio has to be evaluated as appropriate or not for a specific category.

5.2.3. Amount of Evaluated Aspects

If an analyst evaluates more categories appropriately he offers a better analysis. However, quality does not increase in a linear manner. We make allowance for this property by weighing the categories with different weighs, i. e. evaluating a few important categories appropriately can lead to a higher quality of analysis than analyzing many less important categories. To be precise, we use the following formula:

$$\text{Accuracy of Evaluation}_{i,l} = \frac{\sum_j \text{R-THEO}_j * A_{ijkl}}{3 * \sum_j \text{R-THEO}_j} + \frac{\sum_j \sum_k \text{R-STAT}_{jk} * A_{ijkl}}{3 * \sum_j \sum_k \text{R-STAT}_{jk}} + \frac{\sum_j \sum_k \text{R-CASE}_{jkl} * A_{ijkl}}{3 * \sum_j \sum_k \text{R-CASE}_{jkl}}$$

with:

i: Index for analysts (i=1,...,103)
j: Index for evaluation categories (j=1,...,70)
k: Index for comparison techniques (k=1,...,3)
l: Index for cases to be analyzed (l=1,...,4)

A_{ijkl}: Appropriateness of evaluation of analyst i for category j using comparison technique k for case l; boolean variable which takes value 1 if the evaluation is classified appropriate, and 0 otherwise.

R-THEO_j: Weigh for theoretical relevance of category j
R-STAT_{jk}: Weigh for statistical relevance of category j and comparison technique k
R-CASE_{jkl}: Weigh for casespecific relevance of category j and comparison technique k for case l

It should be noted that we do not expect overload effects of the adressee of the analysis, caused by "too many" evaluations. It seems plausible to exclude such effects for our measurement situation, because we study unskilled students which have only 90 minutes to gather a lot of information, to write it on a record, to calculate ratios, and to evaluate it. But for a more general application of our measurement approach, additional field-experiments with practitioners are required.

5.3. Reliability of Efficiency Measurement

5.3.1. Intercoder Agreement

All analyses (about 10,000 evaluations) were coded twice by two independent coders, so we can estimate reliability. We have coded **category** which is evaluated, **comparison technique**, and **appropriateness** of the judgment. Intercoder agreement is 0.81 for category, 0.87 for appropriateness, and 0.92 for comparison technique. Cohen's Kappa which eliminates accidental agreements is 0.80 for category, 0.71 for appropriateness, and 0.84 for comparison technique. These are high values which are better than those usually reported in behavioral accounting studies performing a content analysis of think-aloud-protocols. (Reported inter-coder agreements from such studies: Shields (Information Load 1978) p. 105: 0.71 - 0.78, Biggs/Mock (Auditor Decision 1983) p. 239: 0.75, Anderson (Process Tracing 1984) p. 163: 0.91, Biggs (Financial Analysts 1984) p. 315: 0.72); reported Cohen's Kappa: Biggs/Mock (Auditor Decision 1983) p. 239: 0.67, Anderson (Process Tracing 1984) p. 163: 0.66, Biggs (Financial Analysts 1984) p. 315: 0.67).

5.3.2. Generalizability

Our efficiency measure is generalizable if we can predict the performance for a case number n+1 by using the measures for n similar randomly drawn cases. To evaluate this property we have calculated Cronbach's Alpha for the efficiency measures which the students have attained for the four cases analyzed during the experiment. Cronbach's Alpha is 0.71. This is a rather good value, considering the fact, that we use only four items as predictors, and that our "items" are complex cases, and not answers to simple questions. If we include the examination case, a fifth case which was written under different conditions, Cronbach's Alpha rises to 0.75. This confirms the generalizability of our measure.

5.4. Validity of Efficiency Measurement

5.4.1. Content Validity

We derive content validity from the fact, that we have developed a quite exhaustive system of 70 mutually exclusive categories, to which nearly all evaluations can be assigned. The scheme is based on extensive literature search and several years of pretesting. We have also applied the coding scheme to analyses of CPA-exams with very few "other" category codings. A second, and very important aspect of content validity is the way how we have derived our relevance weighs (see above).

5.4.2. Criterion Validity

Criterion validity can be judged by using an outside criterion which should correlate positively with our measure. We expect that efficiency values should correlate positively with experience. This is true: student analysts show strong and significantly increasing values of accuracy for subsequent cases. Those students which had a higher previous knowledge have significantly higher accuracy values, and candidates for a CPA-exam perform better than unskilled students.

5.4.3. Construct Validity

Construct validity requires simultaneous testing of convergent, discriminant, and nomological validity. Since nomological validity can only be confirmed over a series of independent experiments, we restrict our test to convergent and discriminant validation. Convergent validity means that accuracy of evaluation should correlate positively and substantially with related theoretical constructs. Discriminant validity means that correlations with less related constructs should be lower. To test this, we use the following constructs and measures:

1. Other dimensions of quality of analysis (used to test convergent validity):

a. Quality of cause-effect diagnosis: Number of appropriate non-linear tests of hypotheses.

It is a hallmark of experts that they develop and test more and complexer hypotheses. This general hypothesis posited by Simon (Information Processing Models 1979) and others was confirmed for financial statement analysis by Bouwman (Expert vs. Novice 1982) and Anderson (Investment Decision 1982). We have similar findings. "Non-linear tests" mean that analysts go beyond simple level- or trend-statements, or mathematical decompositons of income-statements. Rather, they link several information items in a special way, which can not be expressed by a ratio. By their construction-law ratios are bounded to link only **two** things which are expressed as a nominator and denominator. To identify "non-linear tests" special coding categories were implemented.

b. Quality of questions: Number of appropriate questions

Since financial statement analysis are evaluated for the questions they provoke (Lev (Financial Statement Analysis 1974) p. 34), number and quality of developed questions were also evaluted.

2. Other constructs (used to test discriminatory validity):

a. Psycho-social efficiency: Satisfaction with the result and course of the analysis. Two rating scales which are averaged.

b. Evaluation tendency:

1. Tendency of summarizing judgment: readiness to accept the loan, expressed on rating scale.

2. Tendency of partial evaluations: For each evaluation a "positive", "negative" or "neutral" tendency was coded. The tendency of partial evalua-

tions indicator expresses the difference between all positive and negative evaluations as a share of all evaluations.

We expect positive intercorrelations between accuracy of evaluations, quality of cause-effect-diagnosis and quality of questions. An accurate evaluation is a good base for an indepth cause-effect-diagnosis. Symptoms which cannot be explained and hypotheses which cannot be tested will lead to open questions.

A higher quality of the analysis may induce a higher satisfaction but this correlation is expected to be lower because it depends on the individual level of aspiration.

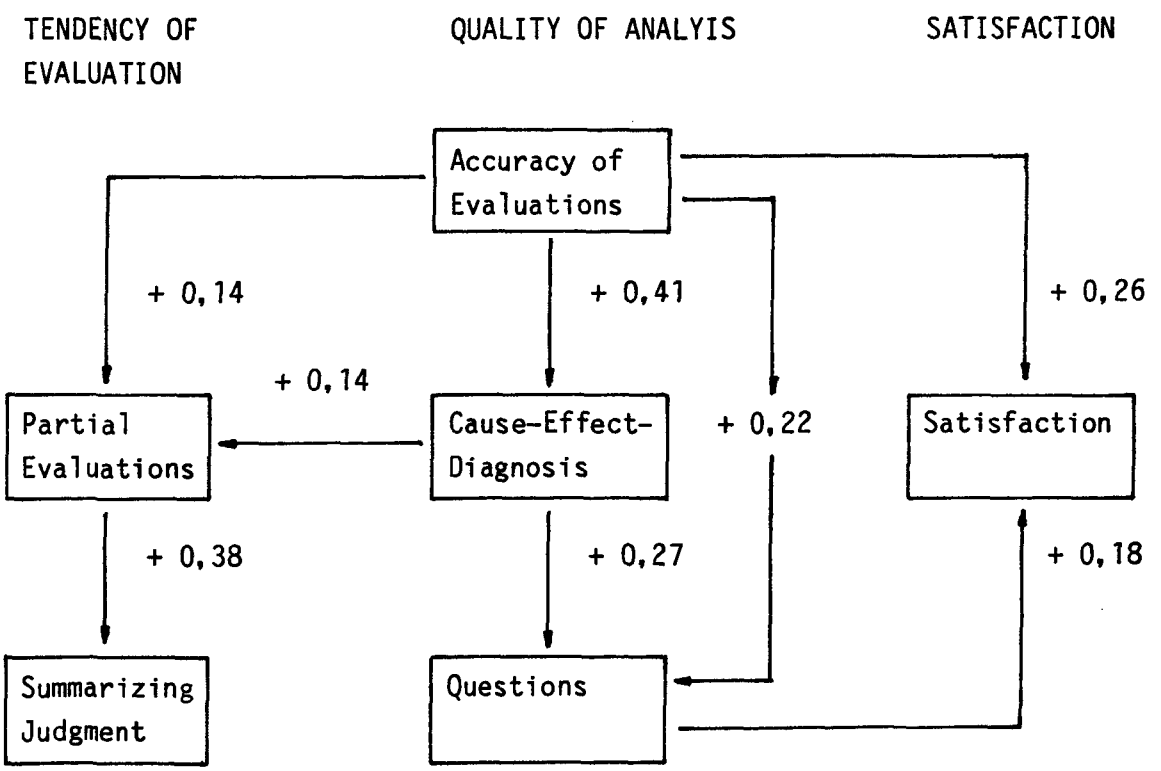
Besides, we expect that the evaluation tendency of a summarizing judgment and of partial evaluations will correlate positively.

The following correlation matrix confirms our expectations: Intra-construct are substantial, significant, and higher than inter-construct correlations. Our expectation are also confirmed by a path-analysis: Accuracy of evaluations is a central efficiency dimension which directly or indirectly influences all other efficiency dimensions.

Table 2: Correlation Matrix of Efficiency Indicators (412 analyses)

Constructs	Quality of Analysis			Evaluation Tendency		Satis-faction
Indicators	Accura-cy of Eval.	Cause-Effect-Diagn.	Qual. of Quest.	Tend. Summ. Jugment	Tend. Partial Eval.	Satisf. with Course
Cause-Effect-D.	0,410					
Qual. of Quest.	0,333	0,361				
Tend. Partial Ev.	0,205	0,205	0,135			
Tend. Summ. Judgm.	0,196	0,165	0,168	0,416		
Satisf. Course	0,257	0,065	0,237	0,038	0,083	
Satisf. Result	0,241	0,076	0,196	0,048	0,109	0,810

Figure 5: Path Analysis of Efficiency Indicators



6. THE EMPIRICAL RESULTS

6.1. Test of the Hypotheses

We have stated two hypotheses:

H_1 A presentation in tree-structured form will lead to a higher quality of income-statement analysis than a presentation in tabular form.

H_2 The difference in quality of income statement analysis between tree-structured and tabular presentation forms will be highest for unexperienced analysts. It will become smaller with increasing experience.

To test these hypotheses we perform a 2*2*4-analysis of variance with the data from **experiments A and B (Gießen 82 and Kiel 82).** The between-subject-factors are presentation form (tree-structure vs. tabular structure) and experience (lower Kiel level vs. higher Gießen level), the within-factor is learning with four levels (case no 1,2,3,4).

Table 3 shows the mean values of accuracy of evaluation of income statement analysis for our four experimental groups. We can see that the values for the tree-structures are higher in all cases. This main effect is significant (p=0,004) thus confirming H_1. The differences between both presentation formats are lower for the higher experienced analysts from Gießen. This interaction effect is only significant at the 10-%-level (p=0.092) thus confirming H_2 only partially. There is no significant main effect for experience (p=0.253).

The **trend** of the efficiency measures we shows a strong effect of learning (p=0,000), and a significant interaction between learning and experience (p=0.013): the Gießen analysts show a higher increase in efficiency, they start on a lower level and end on a higher level. Their lower starting level conflicts with our expectation that more experienced analysts should reach a higher quality from the beginning. The explanation for this finding is that the Gießen candidates were offered a new analytic tool by a profes-

sor from Kiel which changed their information behavior dramatically. Therefore they needed a longer time to accept and to apply this concept. In the long run they combined it with their previous knowledge and thus were able to reach a higher effiency.

Table 3: Mean Values of Accuracy of Evaluation of Income Statement Analysis for the Four Groups from Experiment A (Gießen 82) and B (Kiel 82)

Experimental Group	Case Number 1	2	3	4
Tabualar Format				
Gießen 82	7.6	10.6	17.1	16.3
Kiel 82	7.8	12.9	15.0	13.6
Average	7.7	11.8	16.0	15.0
Tree-structured Format				
Gießen 82	8.8	11.5	17.6	18.7
Kiel 82	12.2	16.5	21.0	18.1
Average	10.5	14.0	19.3	18.4

The difference between tabular and tree-structured presentation format does not change: there is no significant interaction-effect of presentation format and learning (p=0.906). This is somewhat contradictory to our hypothesis H_2 which posits that effects of presentation form will decrease with increasing experience.

In **experiment C (Kiel 84)** tree-structures were used during experimental working sessions in classrooms **and** during the central feedback session. Therefore we can analyze the additional effect of explicitly explaining the tree structure-concept. Table 4 shows our findings.

Table 4: Mean Values of Accuracy of Evaluation of Income Statement Analysis for Experiment C (Kiel 84)

Experimental Group	Case Number 1	2	3	4
Tree-structured Format only in Classrooms				
Average Gießen/Kiel 82	10.5	14.0	19.3	18.4
Tree-structured Format also for Feedback-Session				
Kiel 84	6.0	12.5	16.7	18.5

The experiment confirms the strong learning effect (p=0.000). We can also see that the groups from Gießen and Kiel 82 perform significantly better (p=0,024). This is caused by the very low initial level of the rather unexperienced Kiel 84 analysts. However, getting explained the tree-concept explicitly, these students experience very strong learning effects so that they end at the same level. The interaction-effect of experimental group and learning is significant (p=0.050).

To summarize: Tree-structured presentation formats can improve accuracy of evaluation of income statements. The development of this effect depends on previous knowledge and explicit graphical explanation of the concept:

* **Analysts who have to unlearn another concept take longer time to perform better with tree-structures.**

* **Analysts who get explained the tree-concept explicitly by means of graphical aids take shorter time to perform better with tree-structures.**

6.2. Analysis of Influence Paths

6.2.1. Measurement of Information Behavior

a. Data Gathering

The foregoing analysis has shown that presentation format **does** influence efficiency of an income statement analysis, but it could not show **how** presentation format exerts these influences. To analyze these intervening mechanisms we have to measure information behavior.

Our measurement approach conceptualizes information behavior as a sequence of different activities which are performed at different objects. We classify each behavioral element by at least three criteria:

1. chronological order,
2. type of information-activity, and
3. type of information-object.

Ad 1: Chronological Order

Chronological order of information search is measured by means of information-display-boards (see above). The analysts signs the sequence of information-acquisition-activities. The other information-activities are gathered by means of a content analysis of the reports which the analysts have written. Sequence of activities can be identified by applying usual rules for reading and writing (e. g. from left to right, from top to bottom) and by different colours of the pens which are changed every 15 minutes.

Ad 2: Information Activities

We distinguish the following types of information-activities:

* search,
* recording,
* calculation,
* marking,
* evaluation, and
* question-asking.

Information search is operationalized as an acquisition of an information card from an information-display-board. Since these cards are not very "handy" do many analysts prefer to write the information on their papers in table- or tree-structured records. Such a copying of information is called **recording. Calculations** are arithmetic operations performed with financial data to yield certain results which promise a higher subjective information value e. g. ratios, differences, or increments. **Marking** is an activity by which the analyst emphasizes features of a case which appear extraordinary to him. Marking can be done by using circles, exclamation marks, question-marks or other graphical emphasizers. An **evaluation** is a verbalized judgment concerning the firm's economic situation based on accounting information. **Questions** are articulated information-needs which often include an hypothesis explaining cause-effect-relationships which cannot be tested with information given.

Since evaluation activities and questions are already used for our efficiency measurement, we do not use them as independent variables in our path-analysis.

Ad 3: Information Objects

Information activities are performed at different information objects. We can classify information objects according to:

* content,
* degree of aggregation, and
* material object which is referenced.

According to **content** we can distinguish between information which is taken from an income-statement and information which is part of a balance sheet. With respect to **degree of aggregation** we differentiate between raw-data and aggregated data which are derived from raw-data by means of calculation activities. Raw-data are those data usually offered in published balance-sheets and income statements. Data are offered for the current and previous year of a mis-management firm, and for the previous year of a comparable case. This means that we can differentiate between three **material reference objects.** Comparisons of data which belong to different referent objects allow a classification of different comparison techniques, e. g. inter-temporal and inter-firm comparisons.

Reliability of our measurement is very high:

* Measurement of information-search is neither influenced by working-place and distance to the boards, nor by experimental room. Both effects explain less than 1 % of variance and are not significant. Besides, working places are randomly distributed for each case.

* Measurement of the other activities (recording, calculation, and marking), have very high reliability: intercoder-agreement and Cohen's Kappa are higher than 0.98. Intercoder agreement and Cohen's Kappa for sequence of activities are 0.99. These very high values are achieved by precise written coding rules and thorough training.

b. Construction of Scales

For our path-analysis of information-behavior the elements cannot be taken as such. Rather, we have to develop **scales** which catch the essential dimensions of information behavior. We feel that information processes should at least be classified by three aspects:[1)]

1. sequence of information-behavior,
2. structure of information-behavior, and
3. intensity of information-behavior.

To catch these different aspects we have constructed several scales.

Ad 1: Sequence of Information Behavior

Information-processes can be ordered according to (at least) two different principles: activity-wise and object-wise processing (see above). To measure the degree of object-wise processing we use the following index, proposed by Wossidlo (Sequenz-Analyse 1975) and Petersen (Verlauf 1986):

$$\text{Degree of Object-wise Processing} = \frac{\text{I before B} - \text{B before I}}{\text{I before B} + \text{B before I}}$$

with:

I before B: Number of sequential relationships in which an information-element belonging to income-statement analysis occurs before an information-element belonging to balance-sheet analysis.

B before I: Number of sequential relationships in which an information-element belonging to balance-sheet analysis occurs before an information-element belonging to income-statement analysis.

This measure follows the construction of Kendall's tau, i. e. the number of sequential relationships is counted for **all** pairs of information-elements. It is a generalization of transition analysis indices which are usually restricted to **adjacent** elements. The measure for activity-wise processing is defined in a similar way.

Ad 2: Structure of Information Behavior

We have also constructed two scales for structure of information behavior:

* The **degree of aggregation** is defined as the share of information-activities which are performed with aggregated data.

* The **complexity of comparisons** is measured by the share of pairwise inter-firm comparisons. This simple measure is sufficient because a cluster-analysis from Knorr (Informationsnachfrage 1986) showed that there are basically two types of analysts: Those which only make inter-temporal comparisions and those which make inter-temporal and pairwise inter-firm comparisons. Comparisons with external standards (industry averages etc.) occur very seldom and do not contribute to the typology. So this comparison-technique can be neglected.

Ad 3: Intensity of Information Behavior

Intensity of information behavior is measured by the amount of information activities. We construct three dimensions by counting the **number of search, recording, and calculation activities.**

6.2.2. Path Analysis

Having introduced our seven dimensions of information behavior we can now perform our path analysis. We call it an exploratory analysis because our dimensions are aimed at catching the essential aspects of observable information behavior in a comprehensive and non-redundant framework. They are not constructed to test the specific influence hypotheses which were derived in our theoretical framework to explain why we expect a higher efficiency for tree-structured presentation formats. Doing this requires an even more detailed monitoring of information behavior. E. g. we should have used eye-movement-cameras to monitor how people "branch and bound" when using tree-structured presentation forms. (We have used an eye-movement-camera in a pre-test with a very small sample and we found confirming evidence, but it was virtually impossible to use this instrument for all 412 information processes, each lasting 90 minutes. Besides, an earlier experiment was filmed with video-cameras).

Our analyses of variance showed a strong effect of learning. To eliminate this effect, and in order to get more generalizable results we have averaged our seven dimensions of information behavior and our efficiency measure over the four cases. (Averaging is justified by the fact that Cron-

bach's Alpha values for the seven dimensions lie between 0.59 and 0.89).

The results of our path analysis are shown in table 6 and figure 6. (For the sake of clarity only paths greater than 0.10 are included in the graph. Paths from the variable "acticity-wise processing" are omitted, because the total effect of this variable is less than 0.10).

Tree structures have a considerable influence on accuracy: the total effect is 0.326. This effect is exerted through four different pathes:

1. Keeping constant all observed information dimensions, tree-structures show a **direct effect** of 0.13. This path can be explained by our assumption that tree-strutures stimulate pattern formation and recognition. A given amount of acquired and recorded data is **integrated** stronger than in a tabular structure where the links between different numbers are not emphasized.

2. Tree-structures stimulate **more intensive information search**, and a higher amount of acquired information items enables analysts to produce more accurate reports. Multiplying the direct effect of trees vs. tables on information search with the total effect of information search on accuracy we get an indirect effect of about 0.075 (0.075=0.29 * 0.26).

3. Tree-structures reinforce a **preference for aggregated data**, and a higher degree of aggregated data leads to higher accuracy. Through this path tree-structures reduce information load. The strength of this indirect path is about 0.110 (0.23 * 0.48).

4. Tree-structures stimulate **object-wise processing** and object-wise processing in turn stimulates preference for aggregated data and intensity of information search. This indirect effect is about 0.43. (0.31 * 0.43).

Considering all findings, three of our four theoretical assumptions which explain why and how a higher efficiency is expected for tree-structured presentation formats are confirmed: Tree-structures do stimulate more intensive information processing, they do support pattern formation and re-

Figure 6: Influence Paths of Presentation Format and Information Behavior

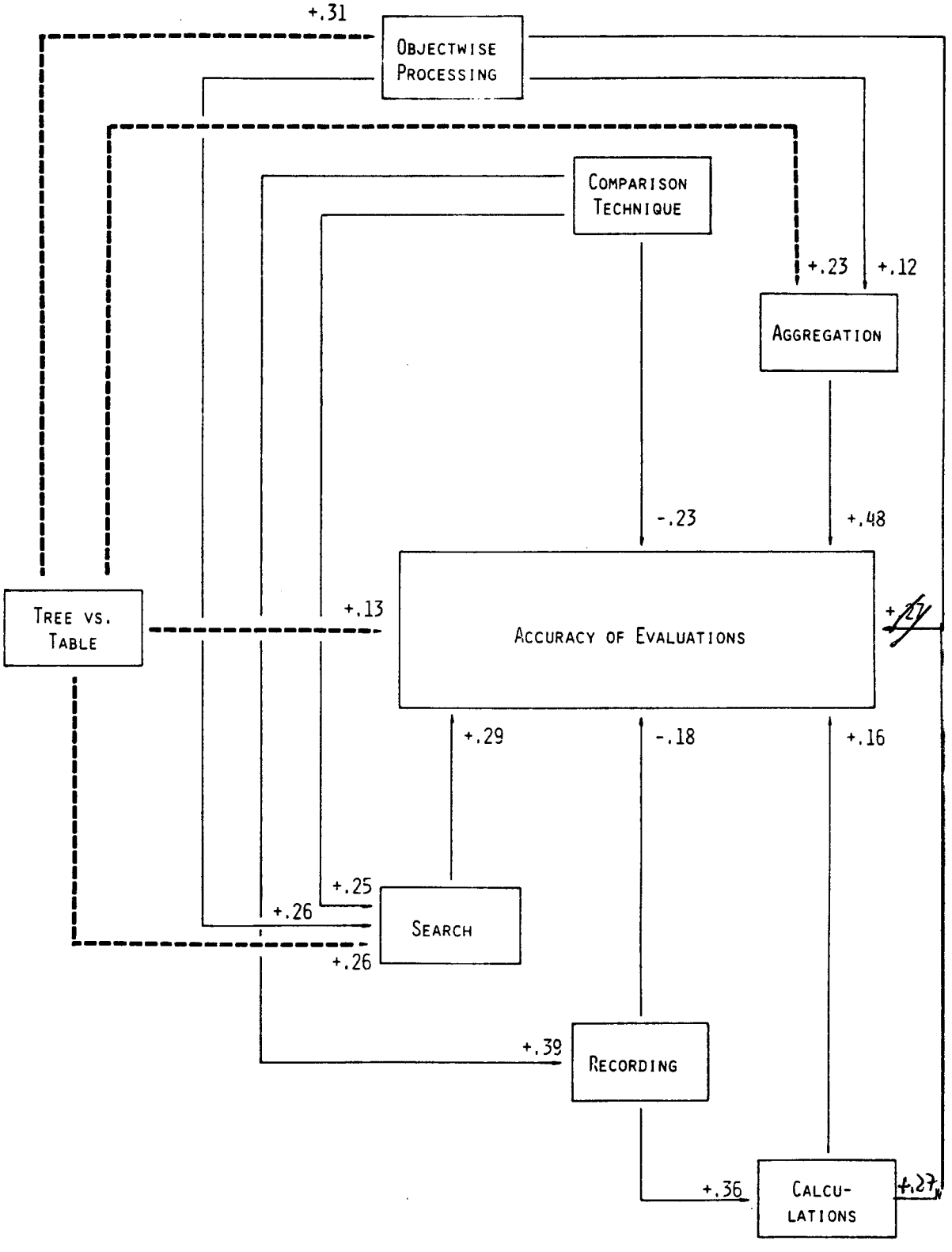


Table 5: Path Analysis of Presentation Form, Information Behavior and Accuracy of Evaluation (Base: 103 averaged values of information behavior and accuracy)

Dependent Variables	Independent Variables	Explained Variance	Direct Effect	Total Effect	Indirect Effect	Correlation
Degree of Activity-wise Processing	Tree vs. Table	0.004	0.002	0.002	-----	-0.024
	Gießen vs. Kiel 84		-0.028	-0.028	-----	-0.049
	Gießen vs. Kiel 82		0.042	0.042	-----	0.056
Degree of Object-wise Processing	Tree vs. Table	0.121	0.308	0.308	-----	0.114
	Gießen vs. Kiel 84		-0.409	-0.409	-----	-0.218
	Gießen vs. Kiel 82		-0.064	-0.064	-----	0.058
Complexity of Comparison Technique	Tree vs. Table	0.288	-0.005	0.019	0.024	0.222
	Gießen vs. Kiel 84		0.570	0.531	-0.039	0.410
	Gießen vs. Kiel 82		0.253	0.259	0.006	-0.013
	Activitywise Processing		0.259	0.259	-----	0.239
	Objectwise Processing		0.078	0.078	-----	-0.051
Degree of Using Aggregated Data	Tree vs. Table	0.261	0.227	0.266	0.038	0.010
	Gießen vs. Kiel 84		-0.629	-0.637	-0.008	-0.366
	Gießen vs. Kiel 82		-0.281	-0.267	0.013	-0.018
	Activitywise Processing		0.031	0.051	0.020	0.050
	Objectwise Processing		0.119	0.125	0.006	0.260
	Comparison Technique		0.077	0.077	-----	-0.124
Amount of Information Search	Tree vs. Table	0.206	0.257	0.296	0.039	0.327
	Gießen vs. Kiel 84		-0.108	-0.007	0.100	0.209
	Gießen vs. Kiel 82		-0.201	-0.129	0.072	-0.205
	Activitywise Processing		0.061	0.122	0.060	0.093
	Objectwise Processing		0.165	0.177	0.011	0.173
	Comparison Technique		0.246	0.242	-0.004	0.276
	Degree of Aggregation		-0.061	-0.061	-----	-0.000
Amount of Information Recording	Tree vs. Table	0.285	0.040	0.096	0.055	0.060
	Gießen vs. Kiel 84		-0.114	0.026	0.140	-0.016
	Gießen vs. Kiel 82		0.110	0.182	0.072	0.143
	Activitywise Processing		0.218	0.336	0.118	0.338
	Objectwise Processing		-0.024	0.035	0.060	0.018
	Comparison Technique		0.393	0.423	0.029	0.417
	Degree of Aggregation		0.112	0.107	-0.005	0.108
	Information Search		0.084	0.084	-----	0.175
Amount of Calculation Activity	Tree vs. Table	0.212	-0.083	0.038	0.122	0.060
	Gießen vs. Kiel 84		0.067	0.006	-0.060	0.060
	Gießen vs. Kiel 82		-0.109	-0.067	0.042	-0.081
	Activitywise Processing		-0.193	-0.073	0.120	-0.102
	Objectwise Processing		0.271	0.287	0.016	0.257
	Comparison Technique		-0.033	0.136	0.169	0.104
	Degree of Aggregation		-0.084	-0.050	0.033	-0.003
	Information Search		0.091	0.122	0.030	0.185
	Recording Activity		0.364	0.364	-----	0.274
Accuracy of Evaluation of Income Statement Analysis	Tree vs. Table	0.384	0.126	0.326	0.200	0.278
	Gießen vs. Kiel 84		0.283	-0.158	-0.442	0.071
	Gießen vs. Kiel 82		0.147	-0.124	-0.271	-0.132
	Activitywise Processing		0.017	-0.057	-0.074	-0.075
	Objectwise Processing		0.005	0.139	0.134	0.192
	Comparison Technique		-0.234	-0.182	0.052	-0.128
	Degree of Aggregation		0.484	0.438	-0.046	0.390
	Information Search		0.289	0.293	0.004	0.295
	Recording Activity		-0.184	-0.124	0.059	-0.103
	Calculation Activity		0.163	0.163	-----	0.153

cognition, and they do reinforce object-wise processing. We could not test whether tree-structures exclude irrelevant information. However, taking into account that ratios based on higher aggregated data usually discriminate better between poorly managed and well managed firms, we may interpret a preference for aggregated data as a preference for data with a higher information-value. Thus, tree-structures also stimulate a concentration on more relevant data.

The following important qualifications have to be added to this finding:

1. Presentation format explains a substantial share of the inter-personal variation of information behavior and efficiency but not all. The total effect of presentation form 0.326 is considerably smaller than the multiple correlation which is 0.621. This means future research should concentrate on the **autonomous influences of information behavior on efficiency** and make allowance for the substantial German research in this field.[2)]

Experimental studies and field studies have analysed the role of information search. They could show that information demand must fulfill certain conditions to improve efficiency: a) adressee-adequate articulation of information-need (Möllhoff (Informationsnachfrage 1978)), b) quality of acquired information (Gemünden (Informationsnachfrage und Effizienz 1986)), c) coordination with information-supply (Witte (Informationsverhalten 1972)), and other problem-solving activities (Gemünden/Hauschildt (Top Management Decisions 1985), (Gemünden (Informationsnachfrage und Effizienz 1986)). Research has also shown that information search may be substituted by knowledge under certain conditions (Brockhoff (Forecasting Quality 1984)). Therefore it is not sufficient to explain efficiency by sequence, content, and amount of information **search** (e.g. Shields (Supply and Demand 1983), Jacoby/Kuß/Mazursky/Troutman (Effectiveness 1985)). Rather, a multidimensional approach to information behavior is needed which is implemented by a multi-measurement approach. Information behavior is a complex and dynamic system, isolating one element, which can be observed easily is no feasible solution.

2. The positive effect of a tree-structure was repeatedly found for income statement analysis, but also repeatedly **falsified for balance sheet analysis.** This has several reasons:

a) Trees for income statement and balance sheet differ in concept and content: The "tree" for balance sheet analysis is oriented at the T-form of an account. The branches of this "tree" are basically to very simple trees which decompose assets and liabilities. These two sub-trees cannot be combined to typical patterns indicating a firm crisis in the same way as the branches of the income statement tree. One can add and subtract different sources of income but one cannot add and subtract different kinds of assets with different kinds of liabilities.

b) Information in trees for income statement and balance sheet have different predictive ability: We could validate predictive validity of income-statement decomposition - a result which agrees with the vast majority of failure prediction studies documenting the predictive ability of earnings. However, we could not validate predictive validity of ratios based on asset structure.

c) The concept of income statement decomposition was explained intensively during the feed-back sessions, in experiments A and B without graphical aids, in experiment C by using tree-structures. Concepts of balance sheet analysis were used, but not emphasized.

This means: It is not sufficient just to change one element of information environment, e. g. one aspect of presentation form. One has to look at a whole **mix of different instruments** which must have a close fit to each other. That's the instrumental version of the contingency approach.

3. Our extended research framework offers many useful informations for such a contingency approach. It shows a whole network of influence structures and offers a lot of different chances to influence information behavior and to increase productivity. It also shows the risks and the dysfunctional "side"-effects which should be avoided. Like an ecologic system human information behavior is a sensitive and dynamic system. Therefore we have to

perceive it in its complex and dynamic nature. Instead of proposing simple, mechanistic solutions we should explore behavior carefully. This requires a dynamic approach. In this report we have only analyzed the inter-individual effects of information behavior. Other reports will focus on the intra-individual inter-temporal learning effects.

Footnotes to Chapter 6

1) Extensions and applications of this paradigm to accounting problems are presented by Shields (Information Load 1978), Weigel (Informationsverhalten 1980), Jacoby/Kuß/Mazursky/Troutman (Effectiveness 1985), Hofacker (Informationsverarbeitung 1985) and Knorr (Informationsnachfrage 1986).

2) Particularly Witte (Informationsverhalten 1972), Brockhoff (Delphi-Prognosen 1979), Hauschildt/Gemünden/Grotz-Martin/Haidle (Geschäftsführung 1983), and Gemünden (Informationsverhalten und Effizienz 1986) with a systematic review including English sources and research from German psychologists.

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