

Link Vis: A novel tool for visualizing and analyzing psychotherapeutic processes.¹

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Abstract

Objective: Evaluating and comparing psychotherapeutic processes is a complex task involving multidimensional, dynamic, and time-dependent data that cannot be analyzed by conventional descriptive and statistical methods. We therefore developed LinkVis, an innovative method for visualizing and exploring highly structured data and for testing newly formulated hypotheses. The aim of our study was to explore LinkVis abilities for analyzing the data set of an ongoing clinical study.

Methods: We analyzed the data collected during the accompanying evaluation of a cognitive behavioral group therapy in adolescent girls with Anorexia Nervosa (AN). The course of psychotherapy was followed for one year using the data of various psychological tests deployed before, during, and after therapy.

Results: LinkVis and its presently available three visualisation techniques, Chernoff faces, scatter plots and parallel co-ordinates, effectively illustrated the therapeutic course, enabled us to compare attained goals and individual courses, and helped us to find out predictors of therapeutic success or failure.

Conclusion: LinkVis enables a better understanding of complex psychotherapeutic processes.

Key words: information-visualization, multidimensional time-dependent data, psychotherapy, anorexia-nervosa, adolescent

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1 Introduction

Psychotherapeutic processes are multidimensional, complex and can only partially be described explicitly [1]. Evaluation of psychotherapy is based on quantitative and qualitative data gathered before, during, and after therapy. Therapeutic process research is therefore mainly based on verbatim protocols and standardized evaluation questionnaires and mainly concentrates on the success of strategies but not on exploring and comparing the process itself.

Various techniques have successfully been applied for structurizing and visualising complex time based data [2]. Using such methods of information visualization, therapeutic processes and their dynamics could become more transparent, understandable and comparable. The goal of Information Visualization is to promote a deeper level of understanding of the data and information under investigation and to foster new insight into the underlying exploration process [3]. Methods range from geometric techniques (e.g., scatter-plots, parallel coordinates), icon-based techniques (e.g., Chernoff faces, stick figures), hierarchical techniques (e.g., Treemaps, Network visualizations [4]), to (interactive) Focus and Context techniques (e.g., distortion techniques, perspective wall, fisheye view) [5, 6, 7]. We therefore developed LinkVis [8], a new working tool for visualizing psychotherapeutic processes aiming at supporting psychotherapists in evaluating, comparing, and observing their therapies and at interactively exploring the data collected during the therapy evaluation process.

The aims of the current study were to test LinkVis abilities in a clinical example of cognitive behavioral group therapy (CBT) for anorexic girls, and to find out if information visualisation would help in gaining new insights into the therapeutic process.

2 Patients and Methods

2.1 Patients

Nine adolescent girls with restrictive or binge/ purging anorexia nervosa (AN, ICD-10 F 50.0, age ≥ 12 years) were consecutively recruited from our Eating Disorder Outpatient Clinic (head: A. Karwautz) and participated in our study. Patients were accepted if they freely consented to actively participate in the CBT sessions and in the therapy evaluation assessments.

The mean age of our patients was 14.3 (range 13 - 16) years. All 9 girls successfully attended secondary school. The mean duration of AN at the begin of therapy was 7.2 months (range 2 - 18 months). Two girls were overweight before becoming anorexic. Only two patients previously attended psychotherapy. Co morbid diagnoses were (number of patients): depression (4 girls), self mutilation (2 girls), alcohol abuse (1 girl), rheumatoid arthritis (1 girl), asthma (1 girl) and neurodermitis (1 girl). Five girls were on antidepressants.

All patients lived in their parents household. Three girls whose parents were divorced lived with their mothers. Three girls had healthy siblings, 6 were single children. Five girls were admitted to the inpatient Eating Disorders Unit prior to participating in our study, two of them repeatedly. Two girls were admitted to the inpatient Eating Disorders Unit during the study period.

Some parents had psychiatric problems (number of parents in parentheses):

alcohol addiction (1), eating disorder and social phobia (1), obsessive-compulsive personality disorder (1), and depression (1).

2.2 Treatment

Outpatient group CBT followed a specifically developed multimodal therapy manual comprizing 40 double sessions, each one lasting for 90 minutes. The treatment consisted of six therapeutic modules:

- therapeutic motivation,
- psycho education (including eating behavior and body scheme),
- problem analysis and developing an individual disorder model,
- problem solving,
- soft and communication skills,
- schema therapy.

Family therapy sessions were scheduled once a month. In case of serious clinical deterioration (BMI deteriorating to less than 11.5), patients were admitted to the inpatient Eating Disorders Unit. Because ward admitted girls could not attend CBT group sessions during their stay, one of the therapists kept in touch with them weekly.

2.3 Psychological assessments

Assessments were conducted by a research clinical psychologist who interviewed patients and families and cared for the self-report questionnaires of adolescents, parents and therapists. Assessment was carried out before, three monthly during the course, and the end of the treatment.

All patients were evaluated by standard psychological tests including questionnaires for assessing

- mood (Beck-Depressions-Inventar, Beck Depression Scale [9]),
- self esteem/ self efficacy scale (Skala zur allgemeinen Selbstwirksamkeitserwartung [10]),
- social anxiety (Social Interaction and Anxiety Scale, Social Phobia Scale [11]),
- alexithymia (Toronto-Alexithymie-Skala 26, Toronto Alexithymia Scale 26 [12]),
- mental state (Befindlichkeitsskala, Mental State Assessment Scale [13]),
- cognitive schemes (Beck-Inventar zu kognitiven Schemata, Beck Inventory for Cognitive Schemes [14]),
- motivational schemes (Fragebogen zur Analyse motivationaler Schemata, Analysis of Motivational Schemes Questionnaire [15]),

- family structure and functioning (Familienbögen, Family Questionnaire [16]),
- hedonistic behavior (Marburger Untersuchungsinstrumentarium, Marburg Inventory, [17]),
- psychopathology (Youth Self Report [18]),
- temper and character (Temperament and Character Inventory [19]),
- treatment (Fragebogen zur Beurteilung der Behandlung, Treatment Assessment Questionnaire [20]), and
- eating behavior (Eating Attitudes Test [21]), Eating Disorder Inventory [22]).

2.4 Data analyses

We used a semi-structured interview to obtain details of the history and the clinical manifestations of the disease, psychosocial behavior, nutritional status, absence of amenorrhea, mental state, psychosocial attitudes, socio-economic state, presence of bingeing, vomiting, abuse of laxatives, mood disturbance or other psychopathologic co morbidities like obsessive compulsive disorder and psychosomatoses. A thorough medical examination assessed Body Mass Index (BMI), and presence of other health related or neurological problems. We analyzed our data using conventional statistical methods (e.g. mean values, median and chi square statistics) and LinkVis [8].

2.5 LinkVis

LinkVis [8] is the prototype of an interactive exploration tool that supports the user by the analysis of heterogeneous and complex data. It utilizes multiple views to explore the same data in different views, applies linking and brushing of the different views, and uses a hyperbolic hypothesis tree to guide the users during the exploration process. LinkVis is based on three different types of InfoVis techniques, two selected techniques can be combined at a time (multiple views): Chernoff faces¹ [23], scatter plots, and parallel coordinates [24]. LinkVis is a Java based program that uses a client-server architecture and consists of three modules, data input, data storage, and data and graphical operations. Clinical data of our evaluation questionnaires were collected at the client side and stored on the server in XML (eXtended Markup Language) files format. System access and communication were SSL (security socket layer) protected.

The data and graphical operations module consists of a configuration module that allows to select patients for graphical operations. At present we use three different visualization techniques: Chernoff faces, scatter plots, and parallel co-ordinates. Two graphical methods can also be combined for synchronously displaying selected data subsets. A Basic Visualisation Interaction is described by its input, output, and operation. There are three kinds of operations: data operations, affecting the data base, set operations, affecting the control state,

¹Modified similarly to the faces of Emotivate Cartoon Agent, Emotivate Inc. (<http://www.emotivate.com/ossdemos.htm>).

and graphical operations, affecting the graphical state. Therefore the user interface of LinkVis was divided into three sections, data input and modification, data selection, and data visualization.

Chernoff faces (Fig. 1) can simultaneously represent up to 10 dimensions, e.g. by varying shape of eyes and eyebrows, size and form of the mouth, and so forth. We only used four dimensions in our testing. The advantage of the technique lies in displaying single values and an overview at the same time, the disadvantage in communicating moods which may lead to undesirable associations and interpretations.



Fig. 1. Chernoff faces: range of expressions

The faces in Fig. 1 represent four dimensions: mouth shape (BDI – Beck depression inventory), eyes and eyebrows (SWS – Selbstwirksamkeitsskala, self esteem/ self efficacy scale), number of hairs (MI - Marburg Inventory, hedonistic behavior) and face shape (BMI - body mass index). Each parameter was categorized as 6 degrees of severity (dimensions). The healthiest state is displayed in Fig. 1 on the left, the sickest state on the right. The healthier the patient, the more the mouth smiles, the eyes look open, the rounder the shape of the eyebrows, the higher the number of hairs and the broader the face.

Two dimensional scatter plots represent the relationship between two variables. In contrast to Chernoff faces, numeric values can directly be read off the graphical representation. We extended the basic functionality of scatter plots to be able to represent the temporal directions of the parameters' changes. To illustrate these temporal changes, we added arrows to the value pairs (compare Fig. 3). Scatter plots effectively display the measured values and communicate relations between variables and assess measured values. However, the number of dimensions is limited and the user does not get an impression of the whole entity. This disadvantage was resolved by simultaneously displaying Chernoff faces and scatter plots.

Data are also displayed on vertical parallel co-ordinates. Data are represented as color coded dots interconnected by lines, one measurement per time point. It is possible to combine up to 10 variables within one graph (compare Fig. 4.). Numeric values can also be read off the graph. Similar records will, however, result in overlapping lines and cause problems in identifying different records. Parallel co-ordinates provide the user with an overview information but not with the possibly confusing emotional metaphors of the Chernoff faces [25].

3 Results

3.1 Clinical characteristics of the patients before treatment

The mean-score of the Beck Depression Inventory (0-63, high numbers for severe depression) was 18 (range 9 - 29) indicating moderate depression; one girl was very severely, three girls were severely, and five moderately depressed.

Hedonistic behavior was moderately disturbed: mean 61 (range 52 - 75) points on the 22-88 points (high numbers for good hedonistic behavior) MI scale.

Self-efficacy was moderately disturbed: mean 25 (range 15 - 32) points on the 10-40 points (high numbers for high self-efficacy) ASW-scale.

The mean BMI was 15.9 (range 12.7-18.6).

3.2 Clinical characteristics of the patients during treatment (after 3 and 6 months of CBT)

After 3 months of CBT, the mean BDI score had slightly improved to 20 (= still moderately depressed, range 2 - 33); hedonism (mean score 63; range 53 - 73) and self-efficacy (mean score 23; range 13 - 34) were still moderately disturbed and mean BMI (16.8, range 13.5-20) had somewhat increased.

After 6 months of CBT, the mean BDI score had further decreased to 13 (= mildly depressed, range 1 - 36); hedonism was still moderately disturbed (mean score 65; range 50 - 76); self-efficacy had slightly improved (mean score 26; range 15 - 36), and mean BMI (16.9, range 15.7-18.5) was further increased.

3.3 Clinical characteristics of the patients at the end of treatment

No patient attended all 40 sessions of the therapy program because some started treatment later (3), had intermittent illnesses, changed to inpatient status (2), dropped out of the study (2), or because they were considered cured and did not need further treatment (2). All girls except the drop out patients continued the treatment evaluation. On average, each patient attended 17 CBT sessions (range 11 - 27). Among the girls who dropped out of the study, one had an anorectic mother and a very close, symbiotic mother-child relationship. The other one had a severe background parental conflict, and the father rejected psychotherapy for his daughter. Two girls needed additional single CBT working on their severe intrapersonal conflicts.

At the end of the treatment, the mean BDI score had clearly decreased to 10 (= no depression, range 2 - 24); hedonistic behaviour had increased (mean score 68; range 60 - 80); self-efficacy had clearly improved (mean 28; range 16 - 38). Mean BMI had further improved to 17.4 (range 14.5-20).

3.4 Visualization of the course of psychotherapy using LinkVis

The course of our 9 study participants is displayed using Chernoff faces (Fig 2), 2-D scatter plots (Fig. 3), and parallel co-ordinates (Fig. 4).

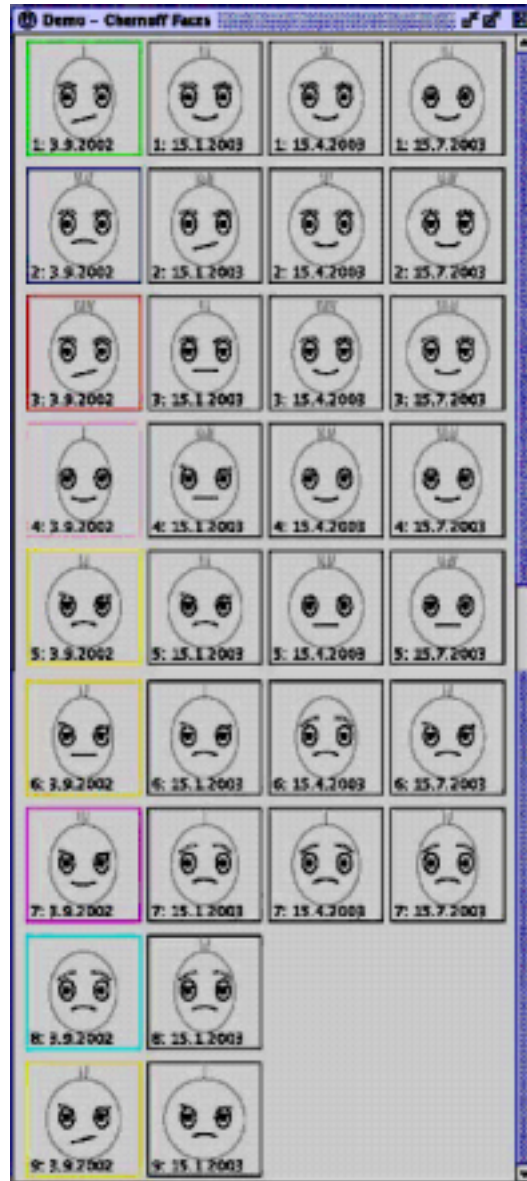


Fig. 2. Course of the 9 study participants displayed by Chernoff faces
Patients who improved at least in some parameters can clearly be identified (pat. 1-5), as well as patients who dropped out (pat. 8,9) or did not improve very much (pat. 6 and 7). The dynamics of improvement were rapid in one (pat. 1), moderate in four (pat. 2-5) and slow in not successful and drop out patients. Patients who did not improve did not improve in all four displayed parameters. Both patients initially overestimated their social competence and hedonistic behavior (1st column) but arrived at a more realistic view during therapy (2nd to 4th column).

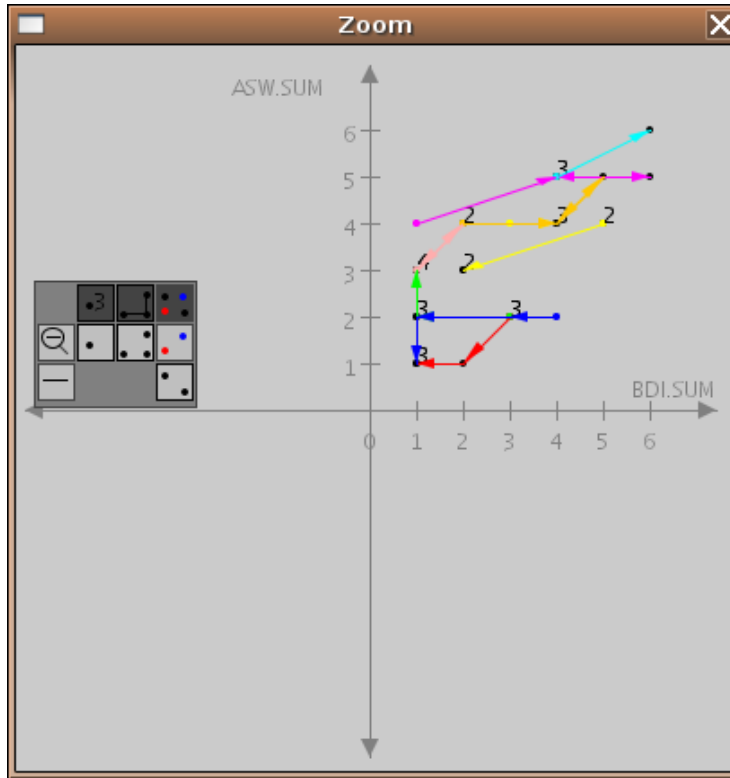


Fig. 3. 2D Scatter-Plots:

Parameters are BDI (depression score, 1 – no, 6 - very severe depression) on the x-axis and ASW (self efficacy index, low scores are classified high numbers) on the y-axis. Lines are color coded for identifying individual patients, arrows indicate the course during therapy): drop out patients, pat. 8 (turquoise) and 9 (yellow) had low self efficacy scores and pathologic BDIs and deteriorated slightly after the first 3 months. Patients responding to treatment, pat. 1-5 (colors green, blue, red, pink, yellow) improved over time in both scores, and patients not responding to treatment, pat. 6 (orange) and 7 (magenta) improved only slightly in ASW, and differently in BDI.

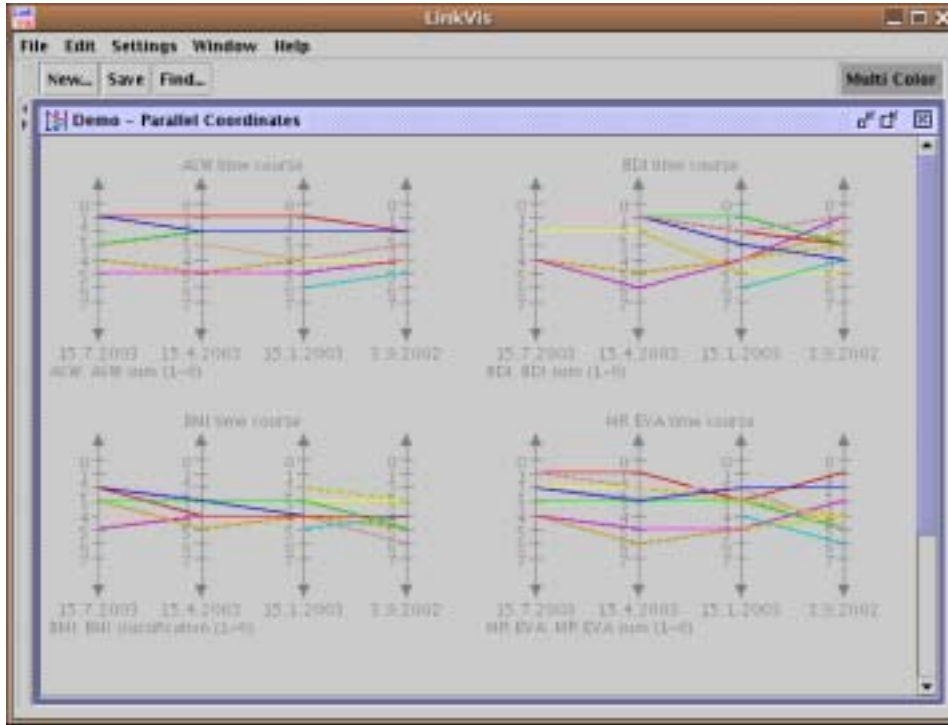


Fig. 4. Parallel Co-Ordinates:

Parameters are ASW (self esteem/ self efficacy), BDI (depression score), BMI (body mass index percentiles), and MR EVA (Marburg Inventory for assessing hedonistic behavior) vs. time (course from right to left). Lines are color coded for identifying individual patients: drop out patients, pat. 8 (turquoise) and 9 (yellow) deteriorated in ASW, BDI, behaved differently in BMI and improved in MR EVA. Patients responding to treatment, pat. 1-5 (colors green, blue, red, pink, yellow) remained stable or improved over time in all scores, and patients not responding to treatment, pat. 6 (orange) and 7 (magenta) had low initial ASW scores and rather deteriorated over time in all four parameters.

4 Discussion

Therapeutic success in our patients was as expected for anorexic patients [26,27]: one third improved rapidly, one third slower, and one third either dropped out or progressed very slowly and needed additional single therapy because of the complexity of individual problems. LinkVis, our program for visualizing psychotherapeutic processes, was well suited for displaying, analyzing, and demonstrating changes of the target parameters of the psychotherapeutic process. To our knowledge no similar approach has been published in that domain as yet. The intuitive data display allows analyzing the dynamics of change, individual progress or deterioration, and intra- and interindividual comparisons. The main advantage of information visualisation compared to conventional data analysis lies in the intuitive approach for analyzing complex and time dependent data and to represent relationships between subsets of data. We have not explored the full range of possibilities offered by our tool because we wanted to show the practicability and usability of our program and therefore concentrated on four relevant parameters of the evaluation tests. The advantage of graphical over verbal or numeric analyses of complex data lies in a more rapid and intuitive data access using synchronous data displays, and in a better recall of pictures compared to numbers [28,2]. Another advantage is the possibility to explore the data, and to generate new hypotheses that may be explored in subsequent studies and very rapidly test – affirm or discard - hypotheses. Graphical displays have to be intuitive and not overloaded [28]. Graphical analysis cannot be used alone but has to be supported by statistical analyses.

Reduction of complexity is necessary for conventional and for graphical data analysis. This was achieved in LinkVis by categorizing data – we categorized our data to a maximum of 6 categories (or steps), attaining a compromise between graphical resolution and differentiability and the need to display even small changes. Moreover, many psychological questionnaires offer 5 or 6 answering categories (e.g. very good, good, indifferent, poor, very poor). Other ways for reducing complexity, combining data derived from a single or various tests and forming groups of variables or patients, are also integrated in LinkVis.

Exploring LinkVis' Chernoff faces, we see advantages and limitations. Advantages lie in the intuitive attribution of psychological qualities to facial expressions, e.g. degree of depression – shape of the mouth, social competence – shape of eyes and eyebrows. This advantage and the fact that humans are very sensitive to facial expressions also bears limitations: it would be rather disadvantageous to attribute various qualities to the same facial structures because the user would become confused and loose track and the intuitivity of the symbols would become lost. The Chernoff faces technique despite its ability to display up to 10 dimensions within one graph was initially discredited because of the psychological implications of facial expressions [25]. We nevertheless see advantages for the use by psychotherapists especially if the above described limitations are respected. A second problem of the technique is to distinguish classes of data in graphical “steps” in order to make progress clearly visible and to obtain about equally sized “steps”. We needed for example various experiments to obtain 6 clearly differentiable modes of eye expression in an appropriate order.

2D scatter plots are common graphical tools. We used 2D scatter plots in combination with the other displays to further explore relationships between

two process variables There are, however, limitations, especially the problem of time dependence of our parameters and the not so strict relationship between time and therapeutic progress. The degree of depression, for example, which is a good indicator of therapeutic progress in anorexic patients [29] was not ideally reflected by the Depression Inventory because some patients answered the questionnaires not according to their true feelings at the initial (pretherapeutic) assessment. They rather tried to fulfil the examiners or socially desirable expectations and underestimated their state. With the progressing of psychotherapy they could more and more admit their true feelings. This false impression of deterioration at the second evaluation point (i.e. after three months of CBT) can clearly be seen in the Chernoff faces and the 2D scatter plots of BDI vs. BMI.

Data display on parallel co-ordinates is easily comprehensible but can only synchronously display changes of a few variables. Displaying the change of a “sum” parameter over time can be used to analyze the overall course of various patients. We constructed such a complex “score” parameter out of 13 test variables² and found it useful to predict overall progress: patients with a low initial value (high degree of pathology) improved much slower if ever constantly compared to patients with a medium or higher initial value (less degree of pathology).

In summary, LinkVis provides a useful tool for visualizing and analyzing the course of (cognitive behavioral) psychotherapy. We could successfully explore the systems advantages and limitations using a prospectively collected data set of therapy evaluation parameters in anorexic girls. There are, however, limitations in applying our method uncritically, mainly because Chernoff faces, if not properly used, are prone to false interpretations.

²BMI, duration of illness, number and frequency of social contacts, degree of depression, self efficacy, hedonistic behaviour (self rewarding behaviour and amount of self care), patients/therapists assessment of therapy, Selbstlenkungsfähigkeit (controlling capability), number of ward admissions for anorexia (until the end of group therapy), degree of alexithymia, restraint eating behaviour and drive for thinness, co morbidities, psychosocial diseases of the parents.

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