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ELECTRONIC BRAINSTORMING WITH GRAPHICAL STRUCTURES OF IDEAS

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ABSTRACT

Group brainstorming is a very popular technique for the creation of ideas, although the state of the art in psychological research backs from this kind of brainstorming. Electronic brainstorming overcomes some of the drawbacks and regains some value. Unfortunately, the electronic brainstorming still is in infantile state and lacks some modern techniques which may make the whole approach more effective. On a well-founded psychological background, we present a new tool for effective electronic group brainstorming which is designed according to modern information technology.

1 INTRODUCTION AND PREVIOUS WORK

In 1957, when Osborn [11] developed the idea-generation technique brainstorming, he claimed that brainstorming groups could generate more ideas than the same number of individuals working separately without communication. Contrary to this view, the first study on brainstorming by Taylor, Berry, and Block [16] showed that nominal groups, i.e. pooling the ideas of individuals working separately, outperformed the interacting groups. Diehl and Ziegler [2] pointed out that four decades of research failed to prove the superiority of group brainstorming. Despite this empirical evidence of the technique's ineffectiveness, brainstorming seems to have gained considerable popularity in managerial practice and management textbooks [9].

With the occurrence of networked microcomputers during the 1980s, electronic brainstorming has received growing popularity. With electronic brainstorming face-to-face communication is substituted by computer-mediated communication. Although research on electronic brainstorming has revealed strong evidence that the new variation overcomes some of the deficits of face-to-face brainstorming [7], the current situation is not satisfying. Jonas and Linneweh criticize that the tools for electronic brainstorming are still not developed in detail, but purely technologically oriented [3]. This indicates that the main challenge with electronic brainstorming is the interaction of information technology with social science. In [9], Connolly describes various aspects making this interaction difficult, including:

Different time frames. Technology develops and changes quickly and a new brainstorming tool can be realized within months, while the time frame for empirical research is more in years.

Demand for special research methodologies. Traditional research methodologies are too slow and expensive to guide technology in real time.

Despite these difficulties, we present a new tool for electronic brainstorming that is based on a well-founded psychological background and uses modern software technology. With this approach, the tool is both a proper aid for brainstorming groups and, perhaps more importantly, a groundwork for empirical research, as the flexible software architecture ensures simple adjustments for manipulating variables in empirical evaluation.

1.1 Basics on brainstorming

Brainstorming is an idea-generation technique that encourages a free flowing stream of ideas. According to Osborn, the basic principles of brainstorming are the deferment of judgment and the principle that quantity breeds quality. From these principles, the four rules of brainstorming can be derived: the more ideas the better, the wilder the ideas the better, improve or combine ideas already suggested and do not be critical. The main reason for group brainstorming is the assumption that mutual stimulation increases the number and quality of ideas. More than 20 empirical studies have compared the performance of nominal groups and face-to-face groups, and all disproved this traditional assumption [6].

In order to get guidelines for developing a new electronic brainstorming tool, it seems worthwhile to examine plausible reasons for the ineffectiveness of face-to-face groups. The only difference between nominal groups and face-to-face groups is the communication. In face-to-face groups, members can communicate, while in nominal groups, they cannot. According to Steiner [14] communication leads to process gains that increase performance and process losses that decrease performance. If nominal groups perform better than face-to-face groups, then process losses outweigh process gains.

The most important process losses in face-to-face groups have been identified to be free riding, evaluation apprehension and production blocking. *Free-riding* denotes the strategy to rely on others to accomplish the task. The main reasons for free-riding are that increasing group size lowers the identifiability of individual contributions and decreases the perceived effectiveness of individual contributions [6]. Secondly, *evaluation apprehension* occurs since despite brainstorming instructions, group members might fear negative evaluations from others and, therefore, suppress uncommon ideas. Finally, *production blocking* results from the fact that the contributions have to be made in sequential order, i.e. at a given instant only one member can talk. Diehl and Stroebe [6] specify two potential consequences: first, while waiting for their turn to speak, group members may forget ideas or suppress them because they seem less relevant at later time. Second, the simultaneous reception of other ideas could cause distraction and may interfere with the persons' own thinking. Furthermore, they could show that production blocking accounts for most of the groups' process losses.

1.2 Basics on electronic brainstorming

In general, electronic brainstorming tools allow each member to enter ideas into a computer workstation and provide a mechanism for distributing the ideas to the workstations of others. The usual way to realize such tools is the client/server paradigm. All ideas entered into the client workstations are sent to a central server workstation and stored there as a 'group memory'. On a member's request, this group memory or a part of it is sent to the corresponding client workstation.

In [5], Dennis and Valacich describe that electronic brainstorming may affect process gains and losses in at least three ways:

Degree of parallelism: As each member has her own input device, members can enter their ideas simultaneously at any given instant and, therefore, the main reason for production blocking no longer exists.

Group Memory: The stored group memory can be requested from the members at any time. This asynchronous communication should provide an advantage of electronic brainstorming over both nominal groups and face-to-face groups. In contrast to nominal groups, the possibility to communicate ideas preserves the process gains; for example, mutual stimulation and avoidance of redundant ideas. In contrast to face-to-face groups, the asynchronous form of communication prevents production blocking.

Anonymity: With electronic brainstorming, the degree of anonymity can be manipulated easily. However there is a trade-off between the temptation to free-ride and evaluation apprehension. In anonymous groups, members may be tempted to free-ride, as the authors of specific ideas cannot be identified. On

the other hand, in identified groups, evaluation apprehension might be high. The usual ways to realize identified groups are name tags or photos tied to the ideas in group memory. Most authors agree that anonymity is favorable for groups with members of different status. McLeod, after an analysis of empirical studies on anonymity in idea-generating tasks, concludes that on average "anonymous groups produce more and higher quality ideas than do identified groups" [10].

It seems indisputable that electronic brainstorming groups generate more ideas than face-to-face groups [7], but whether electronic brainstorming groups outperform nominal groups in general is not clear cut. For large groups (12 persons) evidence is given that electronic brainstorming groups generate more ideas than nominal groups do, while for small groups (6 persons), there seems to be no difference [5, 18]. With electronic brainstorming groups, the process gains seem to outweigh the process losses in large groups, but not in small groups. In [5], Dennis and Valacich give two possible hypotheses to explain these findings. First, redundancy avoidance, i.e. using the group memory to avoid repeating ideas already produced, may play a more important role in large groups. Second, larger groups may experience more synergy, as the ideas in group memory might be more heterogenous, due to different experience and knowledge of the members. In the next section, we discuss a more theoretical model for cognitive creativity, in order to obtain new concepts for brainstorming tools (section3).

2 THE CREATIVITY MODEL

There are at least three important aspects for creativity itself [8]: *the result* of creative thinking, *the process* of getting results and *the persons* developing the creativity. Our approach follows the cognitive process oriented view, and takes into account that the synthesis or merging of previously separate concepts plays an important role when creating creative ideas [15]. In the next subsection, we will review the results of Santanen, Briggs and Vreede [12].

2.1 The cognitive network model of creativity

Santanen, Briggs and Vreede denote homogenous bundles of related items in memory as *frames* and assume that such frames are the basic units of knowledge stored and manipulated in memory. Individual frames that currently occupy short-term memory are referred to as *salient* and the process that causes some particular frame to become salient is referred to as *activation*. When two or more frames are simultaneously salient, they are said to be *associated*. Activation of successive frames is assumed to spread through memory by traversing the links which connect some salient frame to other frames. A frame becoming salient causes the activation of yet other frames. According to the model, these activation patterns are frequent and regular.

The widely accepted assumption that highly creative ideas often arise from the combination of previously unrelated concepts can be formulated in terms of the model: "...the creativity of a solution is a function of the degree to which frames that were previously distant from one another become saliently associated in the context of problem-solving" [12]. According to the model it is not easy to get certain distant frames associated, due to the potentially large number of intermediate frames. Due to the limited resources of short term memory and the enormous size of semantic memory, only a tiny fraction of frames can be salient at a certain point. When the limited resources of short term memory become consumed, salient frames have to be 'abandoned' to get space for new frames, so it can be necessary to displace the content of short term memory many times to reach distant areas of the knowledge network. The model implies another obstacle for creativity: The more that resources of short term memory

are bound by salient frames, the less resources remain available for evaluating combinations of those frames.

The authors conclude that the limits of short term memory, together with the frequent and regular activation patterns of frames “form barriers which may help explain why people rarely venture beyond highly familiar concepts while generating creative solutions to problems [12]”.

3 REQUIREMENTS FOR A NEW TOOL

3.1 Requirements derived from the research on (electronic) brainstorming

Maintain the empirically proven advantages of existing tools. Two aspects are crucial here: First, preserving process gains by supporting communication through the group memory and second, reducing the main process loss production blocking by supporting the parallel input of ideas and asynchronous access to the group memory.

Anonymous groups and flexible logging facility. To ensure anonymity between the members, the visualization of the group memory should have no hints on how to find out who entered an idea. But it is not enough to consider the brainstorming group alone. A mechanism for logging the actions of the group members may be necessary in some situations. Logging data is important for experimenters evaluating the tool, or may be used to generate statistics with the relative performance of each member, in order to reduce the free-riding effect. As the ratio between social recognition and demand for anonymity depends on the specific situation, the tool should be quite flexible in this aspect and leave the decision on an adequate ratio to the users.

Display the whole group memory. In order to avoid redundant ideas, members should be able to examine the whole group memory and not just random selections of it.

Reduce costs of interaction. Overhead costs of interaction should be reduced, so that even in small groups with homogenous ideas, the process gains of interaction can outweigh the losses.

3.2 Requirements derived from the cognitive network model of creativity

The cognitive model of creativity indicates that brainstorming tools can support members in producing creative ideas in two ways: First, in reducing the cognitive load and second, by facilitating the combination of distant frames.

Reducing the cognitive load. Cognitive load can be reduced by coding several frames that are simultaneously and repeatedly salient into a new, more abstract chunk [12]. A new brainstorming tool that provides different abstraction layers, i.e. allows one to distinguish between concrete ideas and generic categories, might support the building of more abstract concepts. The abstract categories in group memory may provide additional benefits. As the properties of categories will be less specific than those tied to concrete ideas, abstract categories might be more useful in stimulating various new ideas.

Facilitate the combination of previously unrelated concepts. Reducing cognitive load by supporting more abstract categories might already facilitate the process of making new associations between previous unrelated concepts. Our approach explicitly tries to support this important concept for creativity. The key to overcoming the described restrictions of creativity caused by the regular activation patterns of a person is to utilize group collaboration. As no two persons have the same cognitive networks and

activation patterns [12, 2], it is likely that with different persons, the same concept subsequently activates quite different concepts. If the tool displays all these concepts of various members in one close area, each member can view different but related concepts at a glance, while these concepts may be quite distant in her own cognitive network.

4 THE NEW TOOL BRAINSTORM

Through a visual representation of ideas, we were able to put the above design goals into practice. The visual representation of ideas as nodes, together with the option to connect certain nodes with each other, allows the users to build individual idea structures. The central concept of *Brainstorm* is to concatenate these individual structures into a common group structure or group memory.

4.1 *Brainstorm* from a user's point of view

Two roles of users can be discriminated, members of brainstorming groups using the *Brainstorm* client and the moderator operating the *Brainstorm* server. The moderator can open a brainstorming session by simply specifying a session name and the brainstorming topic. After closing the session, she can edit and save the session results.

While a session is open, members can log in by specifying a pseudonym, the session name and the address of the server workstation. After logging in, a member gets a workspace for the individual idea structure. On this workspace, nodes for ideas can be created and edges can be dragged between nodes, in order to indicate some kind of relation. A member can edit the text of nodes, move nodes, delete nodes or edges and change the type of nodes. Three different types of nodes are available: idea nodes, category nodes and domain nodes (cf. figure 1).

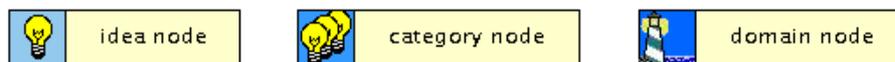


Figure 1: Node types of *Brainstorm*

To get stimulated from the ideas of others, a view of the group memory can be requested at any time. A view of the group memory is generated for each member individually in a way that the member's own individual structure can be recognized easily within the group memory (cf. figure 2). Within the view of the group memory, members can fade in/fade out each of the three levels of abstraction by pressing/releasing the corresponding buttons. While the view of the group memory is displayed, two additional operations are possible. Per drag and drop, members can take over nodes from the view or join nodes from the view with nodes of the individual structure. A node dragged from the view can be dropped on the workspace to take it over, or it can be dropped on a node of the individual structure to join the nodes. In group memory, these taken or joined nodes become links between individual structures. In the individual structure, these nodes are on par with the nodes created by the member, i.e. these nodes can be altered or deleted, just as other nodes can.

As the structures might become quite huge during a brainstorming session, the client user interface includes different aids for zooming and simple navigation within structures that do not fit entirely on the screen.

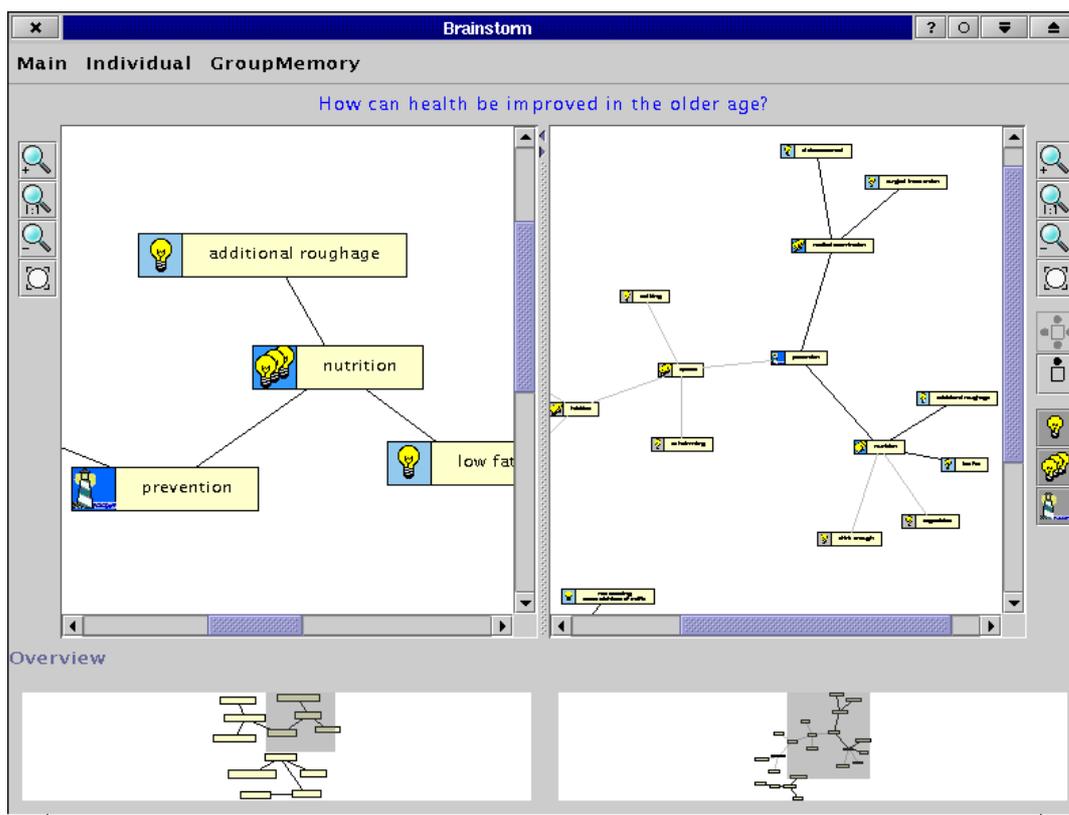


Figure 2: *Brainstorm* client with view of the group memory shown on the right side. Within the view, two kinds of nodes are differentiated: own nodes, i.e. nodes corresponding to nodes from the individual structure having a blue border at the left side and nodes from other members having a grey border. Accordingly, edges corresponding to edges from the individual structure are black and other edges are grey. Furthermore, own nodes are ordered in a similar way to in the individual structure. These features make it easy for a member to spot her own individual structure within the view of the group memory. The overviews at the bottom show the entire structures and can be used for navigation.

Members can log off from a session at any point of time. As long as the session is open, a member can re-register with her pseudonym, possibly from another workstation.

4.2 The new architecture and the underlying yFiles library

One goal of *Brainstorm* is to facilitate empirical research, so the software architecture should support the easy and rapid implementation of special variations. In order to achieve this goal, modularity and extensibility were the main design goals for the software architecture. Figure 3 illustrate that the user interface and the implementation of the communication mechanism are separated from the application logic by well-defined interfaces. This allows changes in one module, for example the user interface, without impingement on the rest of the system. Additionally, *Brainstorm* has a layered architecture, making it possible to replace a certain layer or add an additional layer with specific features. The *protocol layer* is responsible for the communication between the client and the server. The *application layer* provides the higher layers with general features for distributed application, for example log in and log off mechanisms. The *graph layer* offers functions for the distributed manipulation of graph

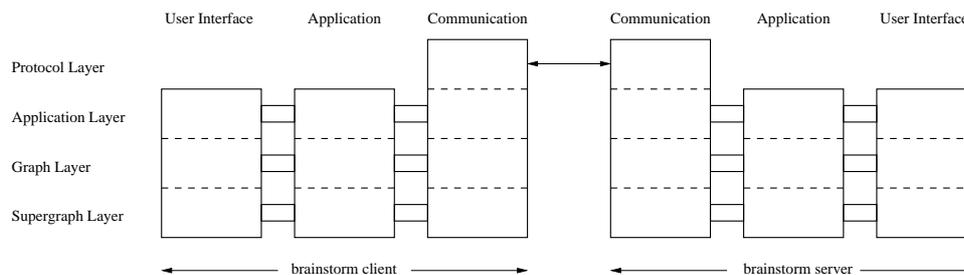


Figure 3: The *Brainstorm* architecture

structures and the transmission of graph structures across computer networks. The *super-graph layer* quite specifically fulfills the requirements formulated in section 3, and will now be described in more detail.

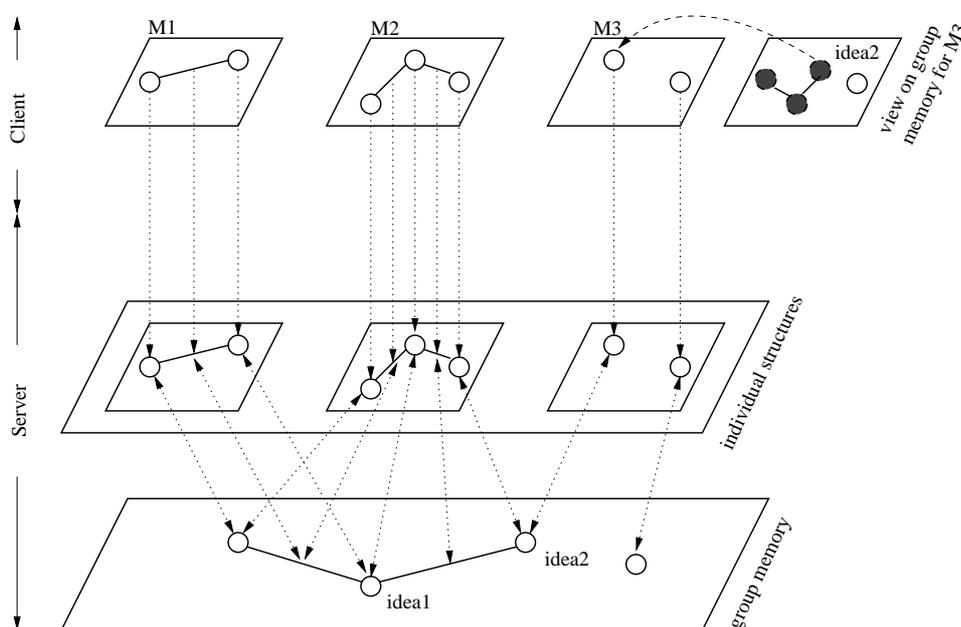


Figure 4: Super-graph layer

Figure 4 shows a schematic representation of the super-graph layer's data structures. The figure shows an example session with three members M_1 , M_2 and M_3 , and indicates two copies of each individual structure, one within the client of a certain member and one within the server. If a member alters her individual structure, the corresponding individual structure at the server side will be altered accordingly. However, most alterations of an individual structure have implications on the group memory as well. The fundamental concept of the super-graph layer is that each specific idea, category, or domain has exactly one representative in group memory, while there may be representations of an idea, category, or domain in various individual structures. The representative is mutually referenced with each of its representations. For example, in figure 4, *idea1* is represented in the individual structures of M_1 and M_2 . For the operations members can execute on their individual structures, the super-graph layer defines the corresponding operations on the group memory. Now, if a member connects two ideas with an edge, the representatives of these two ideas will be connected in group memory.

The two additional operations 'take node' and 'join nodes' described above are defined by the super-graph layer as well. Figure 4 illustrates the 'take over' operation: Member M_3 had dragged the *idea2*

from the view of the group memory into her own individual structure. Thereby, a new representation of *idea2* was created within the corresponding individual structure at server side, and this new representation will be mutually referenced with the representative of *idea2*. Thus, the representative of *idea2* has become a link in group memory between the individual structures of M_2 and M_3 .

With this conception of the super-graph layer, there is no concept of ownership, i.e. all the representations of a representative are totally equal. Nevertheless, an idea will not be deleted from group memory unless the author deletes the idea herself. More accurately, a representative is removed from group memory if and only if a member deletes the last representation.

4.3 Short Description of yFiles

For the implementation of the upper two layers, the *graph layer* and the *super-graph layer*, the *yFiles* library [19] is used. The *yFiles* is a Java-based library for the visualization and automatic layout of graph structures. Included features are data structures, graph algorithms, diverse layout and labeling algorithms and a graph viewer component. The viewer component supports features like zooming, scrolling, layout morphing and different levels of detail rendering. Within the *Brainstorm* client this viewer component is used for displaying the individual structure and the view of the group memory. Within the *Brainstorm* server, the data structures of the *yFiles* library are used for the individual structures and the group memory.

Currently, *yFiles* includes graph layout algorithms for a variety of different layout styles. For the automatic layout of the view of the group memory, *Brainstorm* uses the organic layout of the *yFiles*. This layout algorithm follows the force-directed layout paradigm. The vertices are modeled by charged balls repelling each other to observe even spacing, while the edges are modeled by springs to observe closeness of adjacent vertices. Various energy-minimization approaches lead to layouts with nice features: clusters, as well as symmetries can easily be recognized, the vertices spread well on the page, adjacent vertices are placed in each other's neighborhood, additional constraints can be incorporated, etc. For an overview, see e.g. [1].

5 EVALUATION AND DISCUSSION

The most important condition for the new concept of *Brainstorm* is that members create structures by dragging edges between nodes. We have done some informal experiments with *Brainstorm* and it seems that people connect related nodes intuitively. Furthermore, these informal tests have shown that in general people need less than five minutes to get used to the *Brainstorm* client. At the institute of psychology in Tübingen, *Brainstorm* will be empirically evaluated and compared to the traditional approach, which will show how far the new concepts will lead. For this study we have enhanced the tool by simply adding another software layer providing features for a more sophisticated evaluation, including:

Time frames. All logged in clients can be simultaneously enabled and will be simultaneously disabled when a selected time frame expires. Progress bars show the consumed time.

Keeping certain features independent. We have installed four modi, namely either the group memory is enabled or disabled, for the user, and secondly, the graphical view shows either either the two-dimensional structure as described above, or just a linear list of nodes. So, we are able to experimentally evaluate the effect of each of the features.

As we have no data from these experiments yet, we will explain how the requirements have been met by our tool *Brainstorm* on a more theoretical basis.

Maintain the empirically proven advantages of existing tools. With *Brainstorm*, members can create nodes to enter ideas at any time, just as they can request the group memory at any time.

Due to the graphical visualization of ideas additional operations, for example 'moving a node', are necessary. In order to avoid a new kind of production blocking caused by difficulties in operating the client, the interaction with the client user interface has been kept simple and intuitive. For example, all the operations on the individual structure, for example, create nodes or delete edges, work independently whether a view of the group memory is displayed or not.

Anonymous groups and flexible logging facility. Within a view of the group memory, two kinds of nodes are visually distinguished: nodes of the individual structure and other nodes. No other information is given, in particular, no hints on who created a specific node. The degree of anonymity at the server side depends largely on 'social protocols'. A group can agree to use their real names or meaningless pseudonyms while logging in to a session. Furthermore, the server user interface allows one to disable the logging mechanism completely.

Display the whole group memory and reduce costs of interaction. These two requirements seem contradictory at first glance, as an examination of the whole group memory might take a long time. With *Brainstorm*, this conflict can be resolved. In group memory, related nodes are displayed nearby and different levels of abstraction are supported. The combination of these two features allows the members to find ideas of interest quickly and with little distraction and should, therefore, reduce the costs of interaction. Members thinking of ideas on a special aspect must not read all ideas of an arbitrary or chronological list, but can concentrate on the specific region for that aspect. Locating a region of interest is facilitated by the possibility of initially merely displaying the more abstract levels.

Decreasing cognitive load. The possibility of specifying categories or domains and examining the categories or domains of others may promote the generation of abstract chunks of information.

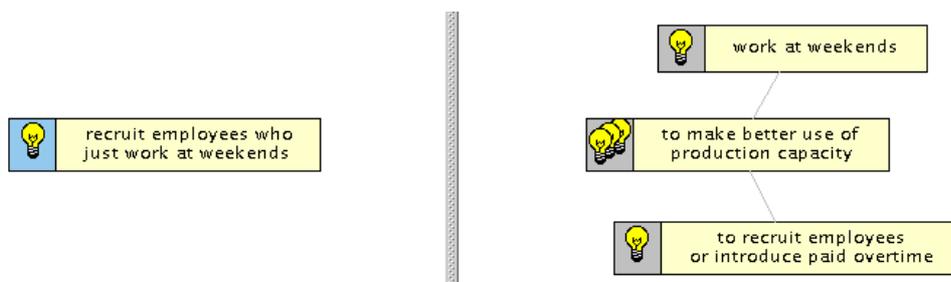


Figure 5: Related ideas are displayed nearby

Facilitate the combination of previous unrelated concepts. *Brainstorm* creates views on the group memory which display related nodes nearby. It is safe to assume that due to different cognitive networks and activation patterns, different people produce different ideas and specify different subjective meaningful relations between the ideas. So *Brainstorm* displays concepts nearby, which might be distant and not related in the cognitive network of a particular member. This is illustrated in figure 5, which shows part of the *Brainstorm* client of a member M_1 participating at a brainstorming session to improve a company's profit. The group memory on the right side shows the category 'make better use of the production capacities' and two related ideas of other members. The ideas 'work at weekends' and 'recruit employees' displayed nearby might stimulate M_1 to the new idea of recruiting new employees who just

work at weekends.¹

Note that our approach to graphically support the cognitive networks of individuals and for combining those networks for group brainstorming reminds of recent employments of cognitive maps. In this paper, we tried to avoid the connection to *cognitive maps*, since it has been used in many different and not always well-defined ways. Originally, it has been a tool to describe the way rats memorize their food path through a labyrinth [17], and more generally, it is used to identify individual perception in a certain environment. Nowadays, it is even employed as a tool for marketing. Recently, people have tried to find ways to combine cognitive maps of individuals [13]. This should reflect a common perception of a group of individuals for a certain situation. We are aware of those approaches and will compare them with ours in the future.

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¹The Swedish company *Perstop Corporation* put exactly this idea into practice with big success. [4]

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