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Wikis: Transactive Memory Systems in Digital Form

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ABSTRACT

Wikis embed information about authors, tags, hyperlinks and other metadata into the information they create. Wiki functions use this metadata to provide pointers which allow users to track down, or be informed of, the information they need. In this paper we provide a firm theoretical conceptualization for this type of activity by showing how this metadata provides a digital foundation for a Transactive Memory System (TMS). TMS is a construct from group psychology which defines directory-based knowledge sharing processes to explain the phenomenon of "group mind". We analyzed the functions and data of two leading Wiki products to understand where and how they support the TMS. We then modeled and extracted data from these products into a network analysis product. The results confirmed that Wikis are a TMS in digital form. Network analysis highlights its characteristics as a "knowledge map", suggesting useful extensions to the internal "TMS" functions of Wikis.

Keywords

Transactive Memory, Knowledge Sharing, Network Analysis, Wiki.

INTRODUCTION

In this paper we analyze user, content and tag metadata and perform social network analysis of Wikis in order to characterize the underlying nature of the group information processing that can occur within this software. A Wiki is a type of Web site which allows immediate creation, editing and linking of web pages by users. When used, Wikis maintain an embedded directory within their database by capturing metadata about the information which is entered (the authors and their contact details, the time of capture, who is interested in the information) as a by-product of use (O'Leary, 2009).

Our analysis specifically investigates the creation by the Wiki management software of this trail of signposts. What we find is that these metadata and the functions of the software constitute a so-called Transactive Memory System (TMS) in digital form. A TMS is a construct from group psychology which explains how it is that a group appears to have a “shared mind” even though expertise might be distributed across a number of different individuals. A TMS consists of a collective knowledge directory and a set of processes which use that directory to allocate and retrieve knowledge between members of the group (Wegner, 1987). Our key research objective therefore is *to demonstrate that metadata and software functions within Wikis comprise a TMS in digital form.*

Our first motivation in demonstrating this is conceptual: the notion of TMS appears to offer a theoretical foundation within which to frame the location, sharing and retrieval of knowledge using Wikis. But furthermore, TMS has been shown to significantly improve group task performance; if we can conceptualize Wikis as a TMS, we can then draw on the extensive TMS literature to improve Wiki functions. We also show how the TMS signposts might be combined into a coherent “knowledge map” using network analysis tools and we suggest that this may lead to further research into improving the TMS capabilities within Wikis. Finally, there is also a rich body of literature about the contextual and social factors which influence the development of a TMS which we may be able to use to improve Wiki adoption and use.

In the literature review, we describe the key characteristics of Wikis and Transactive Memory Systems, and formulate our research questions. Then we show how the specific functions of two well-known Wiki products, Mediawiki and Confluence, provide the functions and data that instantiate the TMS processes and directory. In the next section we derive a conceptual data model of a TMS directory and describe how we extracted and consolidated sample metadata from the two Wiki databases into a load format for network analysis. Using the Netdraw software tool we then display the TMS directory data in order to demonstrate the coherence of the directory information and its TMS character. In the discussion section we address the research questions by moving through each dimension of the TMS, showing how the functions and models meet the criteria.

LITERATURE REVIEW

Wikis

A Wiki is “a type of web site, managed by Wiki software, which allows immediate creation, editing and linking of web pages.” (Jackson, 2010, p248). There are usually a range of standard functions in Wikis for text processing, linking to other pages, formatting, undoing changes, uploading files such as videos or images, viewing history of all changes, defining templates, managing security and so on. A Wiki web site can be dynamically constructed by users who have no knowledge of programming, but who do know, for example, how to do basic text processing.

A Wiki page is associated with information about the editors, interested parties and sometimes readers of the page: this information can be used to locate those parties. Any Wiki page can also be labeled with a tag that represents an information category. When the category is searched for and found, all pages tagged with that category will be presented in a list. In some Wikis, these categories can also be linked to each other in a meaningful way to reflect relationships in the real world. The category of hub cap might belong to the category of wheel which might itself belong to the category of chassis for example. But categories might also be less abstract: the category of William Shakespeare (a particular playwright) might be applied to Wiki pages with any information about the playwright, but also be linked to the category of Hamlet (a particular play).

Wikis are a dynamic content management software that maintains user, page and tag metadata about that content. This metadata makes it possible to follow signposts of authorship, readership, semantics or explicit hyperlinking in order to track down the information one needs. It is this characteristic that suggests to us that Wiki functions comprise a Transactive Memory System, a social system for the storage and retrieval of group information.

Transactive Memory Systems

The theory of Transactive Memory Systems comes from the area of small group psychology and it deals directly with the concept of “knowledge signposts” (Wegner, 1987,1995; Wegner, Erber, & Raymond, 1991). In families or couples for example, responsibility for cooking or repairs might be divided up between husband and wife: they specialize and information that enters the family gets allocated to the responsible person (new recipes, a window not closing, a new kind of putty). When a child cooks, they ask the mother for ‘that new recipe’ or where the pots are kept. The members of the group get to know who-knows-what and manage things accordingly. In larger commercial organizations, similar processes occur, although they might be more formalized and complicated and the media upon which knowledge directories are stored might be a loosely linked network of personal brains, paper, organization structures and roles, and electronic databases. These media are maintained and used via a variety of modalities: chatting, updating personal web pages or going to meetings for example.

At the core of a TMS is the directory: TMS separates the knowledge which group members have about a particular area from knowledge that group members have about each other. In its simplest form, the directory of knowledge about others consists of language describing the shared mental models of the group, and a pointer to the person responsible for the knowledge described by that construct. It is important to note that this TMS directory is an abstraction, much as described by Wegner in his original work: it is not necessarily one physical instance of a “table of contents”, but a set of linked signposts and pointers which have an overall coherence through the group’s shared mental models. There are three processes around this directory:

– *Directory maintenance* describes the preservation and upgrading of the knowledge signposts constructed by a group to reflect the knowledge of other members of the group.
– *Allocation* is when the directory is used to direct information to the responsible expert in a group.
– *Retrieval* is the process of using directory information to obtain the information one needs in an efficient way.

A TMS is characterised by three dimensions (Lewis, 2003; Liang, Moreland, & Argote, 1995; Richard L. Moreland & Myaskovsky, 2000):

– *Specialization* is the result of memory differentiation, which allows a group to remember or store different aspects of a task or area of knowledge (Richard L. Moreland & Myaskovsky, 2000).
– *Credibility* reflects the group’s members’ perceptions about the reliability of other members’ knowledge. The respective specialists in a TMS need to be credible in order for the directory to be of any use (Kanawattanachal & Yoo, 2007).
– *Coordination* is the level of “effective, orchestrated knowledge processing” (Lewis, 2003, p589). Any group must be able to manage their skill and knowledge interdependencies effectively through expertise

coordination, which is based upon knowing where expertise is located or needed and then bringing the needed expertise to bear.

Critical to TMS effectiveness is the development of *shared mental models* (Senge, Fall 1990). A mental model is an internal, cognitive representation of the external world: the elements the world consists of and the possible relationships between these elements. Shared mental models allow a common view of the knowledge and reasoning of a group to emerge and thereby a consistent and accurate set of signposts can develop.

The research into dyad and team performance shows that a well-developed TMS can decisively improve performance. A group with a well functioning TMS has the ability to store and recall more knowledge than individuals (Hollingshead & Brandon, 2003), can use the knowledge of others better (Stasser, Stewart, & Wittenbaum, 1995), can match issues with the group member most able to resolve them (R.L. Moreland & Levine, 1992), can coordinate tasks effectively by anticipating the capabilities of others and can reduce cognitive load because others function as external memory stores, allowing greater specialization (Wegner, 1987).

Research Objective and Reasoning

Given the metadata and software functions within Wikis, and their provision of signposts for tracking down knowledge, our research objective is to investigate whether these comprise a TMS in digital form. Drawing upon the TMS literature review, we see that a TMS has a directory, utilized by three processes and is characterized by 4 dimensions. We seek to establish *prima facie* whether Wikis satisfy each of these criteria:

1. Does the metadata in the Wikis contain adequate information to be classified as a “*TMS directory*”?
2. Are there Wiki functions to *maintain* the TMS directory?
3. Does the Wiki support the *retrieval* of information via the TMS directory?
4. Does the Wiki support the *allocation* of information via the TMS directory?
5. Is there evidence of *specialization* and clear expertise in the TMS directory within the Wiki?
6. Are the Wiki users able to work in a *coordinated* fashion using the TMS directory?
7. Is there an indication of the *credibility* of the knowledge source in the TMS directory?
8. Does the Wiki enhance the development of *shared mental models*?

The performance implications of a well-developed TMS presented in the literature review show that it is worthwhile to pursue the degree to which Wikis support the specific functions of this naturally occurring group cognition system. If such collaborative tools can provide specific “TMS” functions (such as metadata management and visual knowledge maps), this may enhance group performance. Further, the literature describing factors which influence TMS growth may also be applicable to the social and contextual aspects of Wiki implementation and adoption. Whilst some of these factors, such as a supportive culture, are general, some are quite specific: opportunities to self-disclose expertise early, role-based specializations and knowledge interdependence within a group may enhance Wiki uptake for knowledge sharing purposes.

METHODOLOGY

Wiki Product Selection

We chose two leading Wiki products, Mediawiki and Confluence, to identify and analyse the embedded TMS and its functions. Mediawiki is freeware, is in use in many corporate sites and has been adopted by large companies including Pfizer, Novell and Intel. The software is written in PHP and uses the MySQL database, both also freeware products. Confluence, a Wiki-Blog product from Atlassian is highly rated by the Gartner Group and the information industry (Drakos, 2006). Confluence resembles Mediawiki in its range of function, but is more robust, more user-friendly and probably more appropriate for the corporate market. In the following sections, we examine the transactive directory and transactive processes of directory maintenance, information allocation and retrieval within these Wiki products.

Empirical Review of Wiki Functions

Prior to beginning the specific research, we had 1 year’s exposure to both Wiki products as systems administrators in industrial environments and several years as users on the Internet. We wrote SQL scripts to extract metadata from the Wiki database and we examined the Wiki functions which maintain or use that data to retrieve or allocate content to users. To establish a clear view of the TMS directory, we needed to extract and then consolidate data into a single representational form, an abstract model of the TMS directory. Three entities, users, pages and tags, constitute the TMS directory data model. Pages are explicit information content, people are holders of tacit knowledge, and tags describe the knowledge that is contained in these repositories. Each entity can be related to other entities of the same kind or either of the other entities. So a person can be linked to a person, a person can be linked to a tag, and a person can be linked to a page of Wiki content or an attachment. This allows direct and transitive relationships to be observed. For example, if two people read or comment on the same page, they are related transitively through the page.

Then we examined functions which present the components of the model, the attributes of these components which are pertinent to transactive processes, and the links between the objects which will allow the transactive processes of allocation and retrieval to be executed.

Network Analysis of Wikis' "TMS Directory"

After discussing the functional fit between Wiki functions and TMS processes, we explored the Wiki metadata. The Wiki "TMS" functions operate at the level of specific items of information and the functions are low level, that is, at the level of a particular tag, user or specific page: there is no overall map of the meaning and context of this metadata. A pictorial, cartographic representation would help us see the overall shape of the knowledge in the Wiki and the relationships between metadata, and allow navigation between the constituent elements. We therefore conducted network analysis of the metadata to examine its TMS character.

Because Wiki pages are constructed dynamically from information stored in relational databases, link analysis was done on the basis of the meanings, or semantics, of data and functions provided by the Wikis, not upon text matching. In order to identify the relationship types in Wikis which map to the TMS Directory Model, we examined the functional capabilities of Mediawiki and Confluence and related individual functions to the entities in the TMS directory model. Each function creates a relationship between entities which is of a particular strength: when a user creates a page, it is a strong relationship between a Person and Content, when they update it, it is less so, and if they only read the page, it is even lower. Directionality (ingoing / outgoing) was generally given by the meaning of the action.

For the Confluence system, we took sample application data delivered with the Confluence product which had been created by the vendor using standard user functions for the purpose of demonstration. This database is quite extensive, with 3 users who created 127 Wiki pages, blogposts and comments and 32 tags. A fourth local user used Confluence functions to WATCH and COMMENT ON pages in order to create this type of relationship data. Generally, Wikis do not provide data on which users have READ a page, so the Confluence log was set up to record this. The local user browsed a number of pages (via search and by following hyperlinks) and the log data was subsequently extracted from the text log into the network analysis load file. In Mediawiki, we downloaded all tags and pages from Wikipedia within the subject area of "cognition" and imported this into a local instance of Mediawiki. We augmented this with tag and page data extracted from an Enterprise Wiki of a medium-sized company engaged in infrastructure construction. In total this database contained 635 Wiki pages, 3 users, 301 categories with 625 links between categories. Because this data was loaded from other systems, the originating user data was not transferred and only the 3 local users read and updated the content. The main user associated with this data was WikiSysop, the local administrator who loaded the data.

For each entity in the TMS directory model, we examined potentially useful attributes which are available in the respective databases.

– For pages: the http address, the date of creation, date of last update, the namespace, the page "star" rating and the content type (e.g. Wiki, Blog or Web page)
– For users: the full name, e-mail address, their home-page address
– For tags: the namespace, date of creation, date of last update

As both Confluence and Mediawiki were stored in MYSQL, we wrote SQL scripts to extract the above page, user and tag data automatically as nodes of different type. The relevant weightings, for relationships between these nodes depended upon the type of relationship between them.

Network analysis tools delivered highly informative, visual representations of contexts, relationships and clusters within the extracted "TMS directory". These tools analyse relationships between model nodes using algorithms which present the visualizations which reveal relationships, patterns and clusters not available at the object level to users of the Wiki functions. We used the well-known network analysis tool Netdraw. NetDraw (Borgatti, 2002) is a network visualization tool which enables us to visualize static networks as well changes to networks in a holistic and qualitative manner. The program allows multiple node attributes and relationship strength and directionality to be loaded and has been used in ecological and social analysis (Johnson, Luczkovich, Borgatti, & Snijdersd, 2009). We hoped that Netdraw would give us an overall visual map of the transactive directory.

RESULTS – REVIEW OF WIKI FUNCTIONS

The Transactive Directory and Directory Maintenance

The "transactive directory" within Wikis consists of data which when taken together, allows users to track down (retrieve) or be notified of (allocated) information when it enters the Wiki system. TMS directory metadata will consist of the concepts which constitute the knowledge of the group, a pointer from the concept to the repository of the knowledge or related content, as well as some characteristics of the repository (2008; Nevo & Wand, 2005). Within a Confluence or Mediawiki database, information about these TMS directory entries corresponds to user metadata (user login identification, real name, e-mail address and self-disclosed information), tag metadata (tag names, descriptions and links to other tags) and page metadata (Wiki article names, page links, page ratings, creation and modification dates and statistics). In Mediawiki, tags are called "categories", but we shall use the more common expression tags also when talking about Mediawiki.

Most of this data is maintained automatically as a by-product of Wiki use. However, some candidates for TMS directory information are self-disclosed: personal data (in a personal user page), the hyperlinks created by users to link to other pages, and page evaluations, or "star" ratings are added explicitly by users. The metadata points to both content data and other metadata, so it is possible to track, for example, from a page of content, to the matching tag or classifying concept, to the particular user who is interested and watches that category or page or who defined that tag in the first place.

Transactive Retrieval

Transactive retrieval is the act of tracking down, locating and retrieving information based upon the contents of the transactive directory. The following Wiki functions use transactive metadata to assist users to *retrieve information*:

– Full text Search – the search extends over pages of different types. The searcher can choose whether to search Wiki pages about users, content pages, categories or images and other uploaded files.
– Find and use tags – by displaying and clicking on a tag of interest, one will be given a list of information pages which contain information pertaining to this category of information. One then clicks on the page name to be taken to the content.
– Listing – one can simply obtain lists of pages:
    – List all pages - will enable the user to visually scan the names of all pages
    – List all tag pages - the page then displays all the pages, images, video and other objects that may contain content, that have been classified as belonging to this tag. In Mediawiki, the page also displays all tags belonging to this tag.
– Following hyperlinks – this will lead to related content, possibly in repositories other than the Wiki. For example, one can link directly to documents in content management systems, web pages or ERP database application.

Transactive Allocation

In transactive allocation, information will be routed to, or shared with, the responsible person or even "system", based upon the interests, specialization or responsibilities of the recipient. This is done on the basis of the information stored in the transactive directory. Allocation can be done by:

– "Watching" a page – via this function, the user will be informed via their e-mail of changes to the page. In Mediawiki, user can subscribe other users to a page or see who else is watching and therefore interested in, a certain information page.
– Watching a tag (Mediawiki) – this extension allows a user to be informed if any pages are changed which belong to a selected category, allowing one to monitor activity in an area of interest, rather than a particular page.
– Subscribing to a page via RSS Feed –the user's feedreader is notified that a change has occurred one a page. One might create a page about a certain topic like "Machine Maintenance" or "This Week's Events". One can then use special tags to define RSS headers which will be picked up by readers that subscribe to that page
– Following a user (Confluence) - a function with which one user can be notified of changes performed by another user, effectively providing an avenue for transactive allocation of information based upon changes made by a recognized "expert".

From this list we see there is sufficient information and function in Mediawiki and Confluence to support the automated routing of information entering the system to interested parties. This routing can be on the basis of a category (i.e. a tag), a person, or a particular Wiki article.

RESULTS - NETWORK ANALYSIS

In this section we report on the outputs provided by the visualization software in terms of the networks' nodes and relationships. Each sample display reveals some aspect of the TMS directory as a "knowledge map" that might support TMS processes.

Nodes

According to the TMS data model, nodes can be differentiated based upon their type, which was loaded as an attribute with a value of "page" (a Wiki page, Blogpost or web page), "user" or "tag" (a concept). Attributes for each node can be displayed through right mouse click, giving information directly on each node. Figure 3 shows Wiki pages (squares), web pages (circles), tags (triangles) and users (circles in squares) differentiated by shape (or colour in the original software) as well as the relationships between all nodes in the Confluence sample data, as arranged by the graph-theoretic function of Netdraw. In it we see clustering of nodes which are Wiki pages, web pages, Wiki users and tags, based upon the strength of their relationship, as well as the interfaces between these clusters. We see that the user "Barconati" has created many tags, but that these tags seldom link to pages. This suggests that Barconati has some sort of "specialization" for "tag creation". The web page "Confluence Induction" has many links to external web pages, suggesting it is a kind of informational hub, itself a kind of directory pointing to other information about induction into the company.

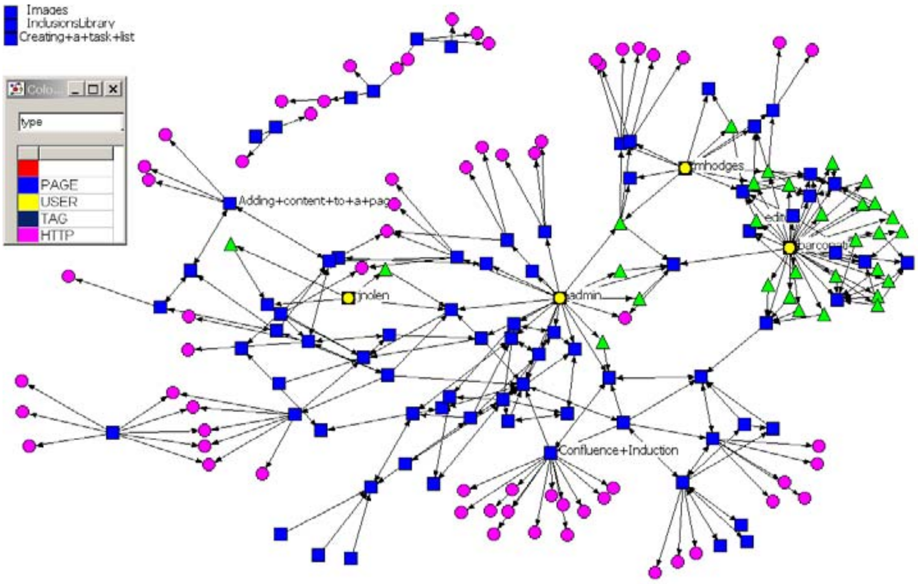

Figure 1: Netdraw Node and Relationships Display from Confluence Sample Data

Node types can be blended out of the display to show only links of a certain kind. In Figure2 below, we restrict the view of the Mediawiki data to the tags. Because Mediawiki (in contrast to Confluence) allows tags to be linked, this figure essentially depicts mental models and their associations for this knowledge domain. Inspection of the labels confirms this (not all are displayed for reasons of clarity). We see that user "WikiSysop" is at the centre of the Cognition tag cluster, a possible indicator of some form of high expertise or administrative responsibility. This makes them a "go-to" figure to approach and ask questions about the Cognition data. In this case the "author" was WikiSysop because that person was the administrator who loaded the data, but that administrator could provide a further transactive pointer to the original source in Wikipedia.

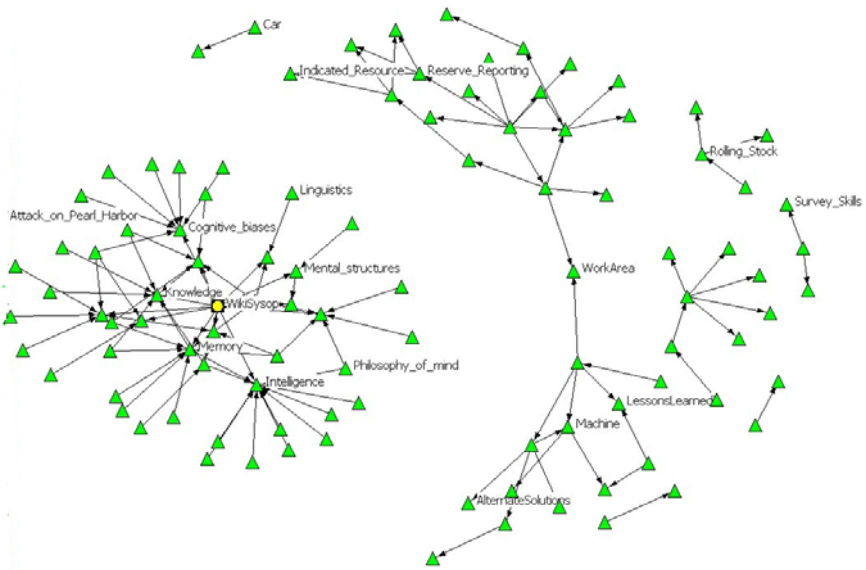

Figure 2: Netdraw Display of Tags and Tags Links In Mediawiki

There are functions within both Wikis which allow the contributions of individual users to be listed, giving an indication of interest and ability. The Egonet function of Netview can restrict the display of all nodes to those with an immediate or close relationship to the source node (for example a person) and is a powerful filter function. By gaining such an overview, one can simplify transactive retrieval of information, by using attributes and colours to highlight and filter different types of node. In the case of Figure 3 this displays the construct "Intelligence" and its links to other tags ("learning", neuroscience" etc), people ("Wikisyop") and Wiki pages ("Cognition" and Mental Age"). This is similar to zooming in on a street map to the "last mile" of the location one is trying to reach. The function also allows an assessment of the specialization of the node, whether it is a branch of knowledge or a creator of knowledge.

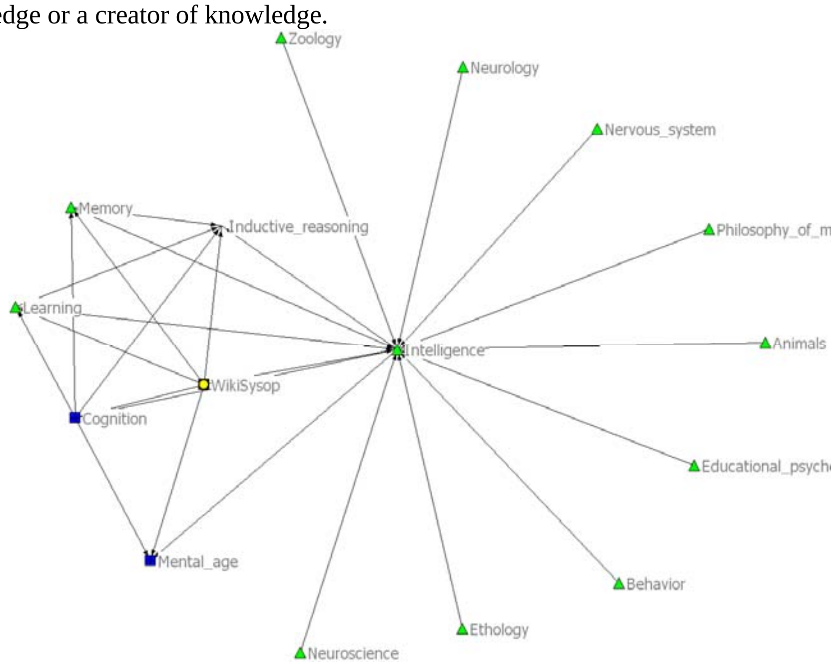

Figure 3: Netdraw Display of Egonet from "Intelligence" tag node with Mediawiki Data

Relationships

Whilst some relationships are simple to follow within the Wiki by clicking hyperlinks, the visual network representation offered here provide an overview of the knowledge, functions to blend in and out different types of relationship (that a person has read, written or comment on a page or that a tag describes a certain page), as well as the ability to integrate page-read and page-watch relationships which are not provided as standard Wiki information functions. By moving to the "relationships" tab, one can zoom in to focus on certain types of relationship between node types. For example in Figure 6, we have used the relationships filter function to focus on the pages which user "Barconati" has actively tagged and the tags he created. This also includes the strength of the relationship, shown by the numerical weighting and thickness of the connector. This may help us in transactive retrieval by establishing the interests, specialization and credibility of Barconati as a potential knowledge source.

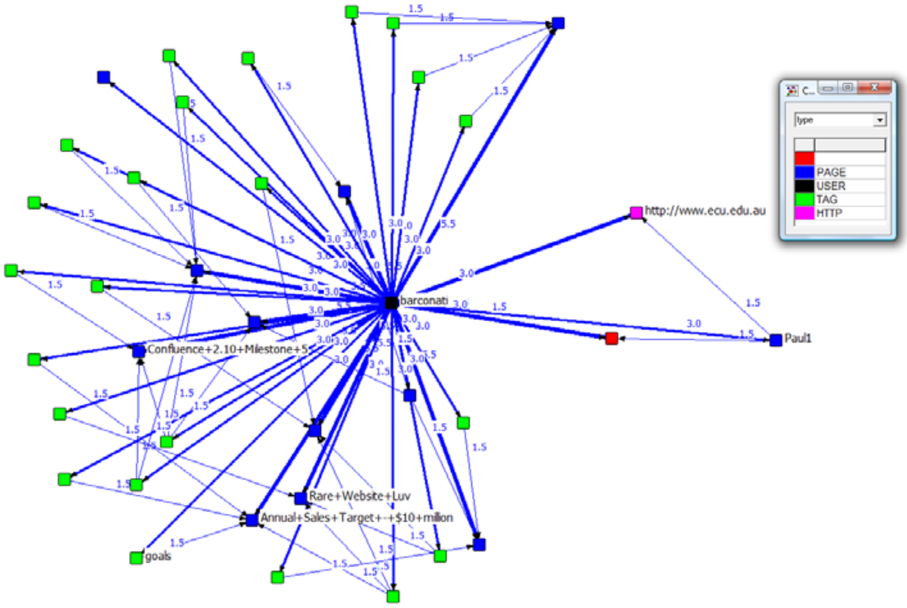

Figure 4: Netdraw Egonet showing tags and pages tagged by a user from Confluence Sample Data

DISCUSSION

In the following section we analyze each of the key characteristics of a TMS and discuss whether the results support the assertion that there is a TMS within the Wiki system.

Does the Wiki metadata contain adequate information to be a TMS Directory?

The person, tag and page information seem to be good candidates for reflecting cognitive transactive relationships. The tags are labels which classify the page information, generally for the purposes of retrieval. Those pages are linked to the people who wrote or read them and so on. The network density and groupings as nodes is suggestive of knowledge that somehow "belongs together", constituting a formal or emergent domain. The attributes of these nodes (e-mail address, http address, the page rating) also seem to provide useful information to someone navigating through this map as a "transactive directory".

Are there Wiki functions to maintain the TMS directory?

The Wiki functions within Confluence and Mediawiki store the read, write and tagging metadata. Most of this data is captured as a by-product of Wiki use. The TMS directory-type metadata that require explicit update by users are the personal user information, page links and the quality ratings of pages. Whilst the automated capture of most metadata makes it more likely that the directory will be up to date than if people had to update their information activities explicitly, it does presuppose that the Wiki software will be used to accomplish some business or knowledge sharing purpose – and the research so far about participation in organizations shows that achieving this can be problematic. This supports the notion that a TMS must also consider contextual and affective elements which influence the participants' motivations to participate (Huang, 2009).

Does the Wiki support the retrieval of information via the TMS directory?

The Confluence and Mediawiki software support retrieval quite comprehensively through functions such as text search, tag search, alphabetical page and tag listing, tag navigation and page hyper-linking. The Netdraw software shows object types (people, tags, content) and their relationships in graphical form and gives a selection of their respective attributes on right-mouse click.

Does the Wiki support the allocation of information via the TMS directory?

The Confluence and Mediawiki software support information allocation to a degree by allowing users to subscribe to changes in pages and tags, and changes by selected people. Mediawiki has extensions which allow a user to subscribe to a tag, such that any change to content tagged with a certain label notifies the subscriber.

Mediawiki also has an extension (WhoIsWatching) which allows one to add others to a subscription list. Again, this subscription is limited to information which changes within the Wiki. The visual and clustering capabilities of Netdraw assist in identifying who has been reading, or subscribing or writing to information pages (by selecting node type and these different types or relationship).

Does the Wiki enhance the development of shared mental models?

The tags applied by users or maintained by administrators are descriptive classifications of information contained in the Wiki. These may be instances of real world objects ("Josh"), concepts ("Sales_Reports") or they may be personal tags ("My_January_Contacts"). In fulfilling this function, the tags in Wikis represent mental models that are shared by users to some extent. A set of linked tags maintained by a corporate information manager about conveyor belts maintenance for example might be the normative mental models for those knowledge domains where "My_January_Sales" meaningful only to me.

Tags are clearly visible and supported in Confluence and Mediawiki. The degree to which these are shared or divergent will be contingent upon a number of factors. In Confluence, anyone can create a tag, which might lead to personal rather than shared constructs, although if many people added this tag to pages, one might assume the tag represents a generally accepted construct. Conversely, in Mediawiki, for example, the tag creation function can be limited to an administrator and these tags can be linked to each other. This introduces the ability to create a normative, convergent set of associated mental models. The tags, as shown in Netdraw, particularly any normative linked tags, provide a means for convergence around common concepts whilst allowing the emergence of new ones through social tagging. By restricting the view to tags, and viewing the number of incoming links, it might be possible to identify and then prune emerging, diverging constructs and reallocate pages to the standard vocabularies.

Is there evidence of specialization and clear expertise in the TMS directory?

Specialization and expertise are demonstrated when a user is able to judge that another user has a particular specialization or contributes good material to Wiki pages. The Mediawiki function "User Contributions" lists all page changes associated with a user, and every page history shows which user made a particular change. Quality ratings on a page can be transitively related back to the editors (via using hyperlinks in the Wiki or at a glance using network analysis). The type of content and the tags associated with that person give an idea of the area of specialization. Whilst limited, these functions give clues to a user's competence. The loading of normative, organizational roles, departments, contact details and job titles into the Wiki would further strengthen the ability of the TMS to exploit knowledge specialization and therefore improve organizational effectiveness. When displayed using the Egonet function within Netdraw, all nodes associated with, for example, a person can be displayed giving a more powerful and immediate impression of activity, knowledge domain and competence.

Is there an indication of the source's credibility in the TMS directory?

Both Confluence and Mediawiki have functions with which users can rate content explicitly, indicating the credibility and quality of Wiki pages. This can be extracted and loaded as an attribute of the page into Netdraw, giving a strong indication of the credibility of the content written or edited by particular users. IBM's social networking site "Fringe" even allows rating of individuals by their colleagues, an explicit functional manifestation of credibility for people, but this is not present in Mediawiki or Confluence.

When displayed using Egonet within Netdraw, all nodes associated with, for example, a person are shown. The sheer number of links gives an impression of the activity (writing, commenting on, reading pages) or expertise (written many pages on cognition, for example) of the person. The type of content and the tags associated with that person give an idea of the area of their specialization, if any. Normative metadata associated with a person would be useful to establish credibility: for example that someone is "chief scientist" or "legal counsel".

Are users of the Wiki able to work in a coordinated fashion using the TMS directory?

The possibility for coordinated work is present within the functional capabilities of Mediawiki and Confluence. The degree to which these are exploited depends upon the capabilities and motivations of participants. But the possibility of defining a single point of organization (for example for a meeting or conference), or a single point of collaboration (for example for a discussion in a forum), or a single point of reference for expertise (for example in a Wiki page) imply that (in theory at least) there can be consistency in content and versions and (through functions such as subscription and notification) high coordination and, through the time-sequencing and author tracking of contributions, high transparency of collaboration and knowledge status. Indeed, in the case of dispersed groups or organizations, it is likely that the visibility of information in a Wiki (enhanced by network analysis) will improve knowledge coordination.

CONCLUSION

TMS is an information processing approach to group cognition and explains how a group can appear to function as though it is a single entity, storing information in the appropriate place and retrieving it when it is required via a collective directory. Wikis, as we have demonstrated in this paper with Mediawiki and Confluence, are *an instantiation of a TMS in digital form* and directly support a group's TMS processes. We have therefore identified a theoretical base in group psychology with which to explain part of the capabilities of Wiki systems.

There are several implications of this conceptualization of Wiki functionality. Research into the TMS construct has demonstrated significant performance improvements of a well-developed TMS and identified factors which inhibit or enhance its development and operation. For technologists, this suggests that software functions which directly enhance the TMS capabilities of Wikis (for example, network analysis and visualization capabilities) will also improve group performance. Managers and systems implementers can perhaps look to the TMS research for indicators of how to strengthen the adoption of Wikis. TMS research has identified social and contextual factors which influence TMS development and in the case of Wikis, the effectiveness of the TMS may well be constrained by factors such as the available time, physical separation during team formation, opportunities for self-disclosure of expertise and specific aspects of group culture. Future technology and business research is therefore required to investigate the implications of the framing of Wiki functionality as a digital TMS.

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