Making use of collective knowledge – a cognitive approach

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Abstract: From a cognitive perspective, *knowledge* resides in people's minds., and there is no conceptualization of 'collective knowledge'. In the socio-cultural approach the concept of collective knowledge is central. The Co-Evolution Model of Individual Learning and Collaborative Knowledge Building (Cress & Kimmerle, 2008; Moskaliuk, Kimmerle & Cress, 2009, 2012) combines both approaches and considers internal-individual and external-collaborative processes that take place when people work on a shared artifact. We apply this framework to social tagging and explain how tag clouds represent collective knowledge. Referring to the Information Foraging Theory (Pirolli, 2007; Pirolli & Card, 1999) we show how people make use of collective knowledge when navigating with tag clouds. We give an overview of several experimental studies that induce situations where individual and collective knowledge contradict each other. The results show that in such situations incidental learning takes place, and users' individual conceptual knowledge assimilates to the collective conceptual knowledge.

Introduction

As long as CSCL has existed as a research topic, there has been discourse about whether cognition and knowledge are bound to individual minds, or if they also describe group phenomena (Koshmann, 1996; Roschelle, 1996; Stahl, 2005). In this dialogue, the cognitive research tradition is based on the information-processing approach and states that internal mental presentations provide the 'substrate' of knowledge. Thus, this position denies that knowledge can exit outside a person's mind. Opposite to this point of view, the socio-cultural tradition sees the substrate of knowledge in situations, social interaction and cultural affordances. With this understanding, people do not have knowledge or acquire knowledge but instead participate in social practices which enable knowing (Sfard, 1998). The *Co-Evolution- Model of Individual Learning and Collective Knowledge Building* (Cress & Kimmerle, 2008), which is shown in Figure 1, integrates both perspectives and describes how individual and collective knowledge develop when people work with shared artifacts.

The co-evolution model combines a systemic and a cognitive perspective, conceptualizing users as cognitive systems and the collaborating group as social system. Each system has its specific mode of operation. A cognitive system operates by cognitive processes such as perceiving, thinking, or problem solving. These processes take place within the individuals. They are described in detail by the information-processing approach. The social system, which comes into existence whenever people behave and communicate in a stable and expected manner, operates according to rules or social norms (cf. Luhmann, 1984). When people collaboratively work with shared artifacts, the operations of the social system become manifest and observable. In Wikis, for example, text passages provided by users are deleted, revised or interlinked with other text passages. Over time in the Wiki a coherent text develops, where the single contributions of different users become indistinguishably interwoven (Kimmerle et al, 2012). These processes are social in nature, and they happen according to rules and norms of the group. In the Wikipedia, e.g. these rules are explicit (Oeberst, Halatchlyiski & Cress, resubm). In other communities they may be implicit, but nevertheless they determine how individuals deal with the contributions of others (Kimmerle, et al, in press).

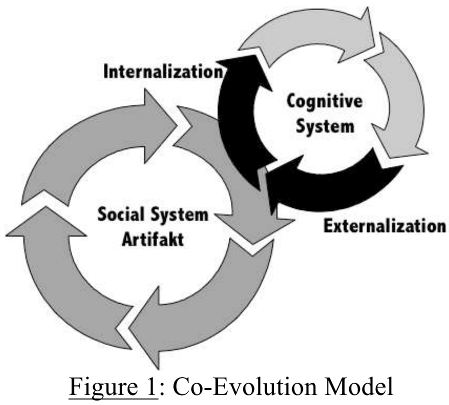

Figure 1: Co-Evolution Model

The Co-evolution model states that if people work on a shared artifact, the social and cognitive systems influence each and dynamically co-evolve. This takes place through processes of *externalization* and *internalization*. An individual externalizes his or her own (i.e., internal) knowledge and conveys it into the shared artifact. There, it is processed according to the system's rules. If it is relevant for the system, it becomes part of the collective knowledge. This collective knowledge is an emerging phenomenon. It results from people's single activities and contributions, but it is not just an aggregation of people's individual knowledge. The individual contributions are further processed and integrated within the artifact. The resulting collective knowledge exists only in the artefact, and thus outside of people's minds. By working on the artifact a user may process and internalize it. Through these exchange processes, the cognitive systems as well as the social system develop.

The model states that incongruities between (individual) knowledge in the cognitive system and (collective) knowledge in the artifact trigger this co-evolution (Moskaliuk, Kimmerle & Cress, 2009, 2012). For a user, the incongruity leads to a cognitive conflict. One possibility to solve this conflict is that users work on the artifact and make it fit their own knowledge structure (equilibration through externalization). The other possibility is that users solve this conflict by adapting their own cognitive structures to the conceptual structure of the artifact (equilibration through internalization).

Up to now the model has been applied to small and large groups working with wikis (Moskaliuk, et al., 2011; Moskaliuk, Kimmerle & Cress, 2009; Kimmerle, Moskaliuk, Harrer & Cress, 2010), and to knowledge creation in Wikipedia (Oeberst, Halatchlyiski & Cress, 2012). In this paper we apply the Co-Evolution Model to social tagging systems. Social tagging systems are web 2.0 tools that enable users to annotate digital resources with individually chosen tags. The tags of all users are aggregated and can be visualized by tags clouds. As social tagging systems are highly analogous to human memories (both can be described with models of spreading activation), they are a good example to describe co-evolutional processes on a find-grained and cognitive level.

The structure of the paper is as follows: First we show why tag clouds are external representations of collective knowledge, and why they have a structural similarity to a human's individual internal knowledge. We then focus on internal cognitive processes by referring to a prominent cognitive theory about web navigation (Information Foraging Theory: Pirolli, 2007; Pirolli & Card, 1999). This theory describes how individual knowledge determines which links people select when they navigate on the Web. We expand this model by considering the influence of the collective knowledge inherent in tags. We give an overview of several experimental studies that induced situations where individual and collective conceptual knowledge contradicted each other. All studies confirm the extended model and show that users make use of the collective knowledge and internalize it. Their own knowledge assimilates to the collective conceptual knowledge – just by navigation, and without any intention to learn. This confirms the assumption of the Co-Evolution Model.

In sum, this paper gives evidence that even from a cognitive point of view it make sense to conceptualize collective knowledge, to consider it as an emerging phenomenon that exists outside people's heads but influences people's individual knowledge.

Structure of Collective Knowledge created in Social Tagging Systems

Social tagging is an activity of annotating digital resources, for instance, bookmarks (e.g., delicious.com), pictures (e.g., flickr.com), blogs (e.g., Technorati), or products (e.g., on amazon.com) with 'tags' (cf. Golder & Huberman, 2006; Trant, 2009). In most applications, a user can choose individual tags for stored resources. So a tag reflects a user's internal association with a resource and represents the specific meaning or relevance for the respective user. On this individual level tags are metadata that help individuals to structure, organize, and re-find their own stored Web resources. If people tag resources, they externalize their individual associations.

Social tagging systems extend this individual level to a collective level. They aggregate the tags of all users and enable the creation of a folksonomy (Trant, 2009; Vander Wal, 2005). This folksonomy results from the tripartite network among users, tags, and resources and enables detecting similarities. For example, resources that are frequently annotated with the same tag are somewhat similar; and different tags that co-occur frequently across different resources or users indicate that they have something in common.

Figure 2 visualizes these processes: Figure 2a shows the tripartite network of resources and tags assigned by two users. Figure 2b shows the one-mode network tag-tag relation network derived from the two-mode resource-tag network. The nodes in the tag-tag one-mode network represent tags, the linking lines represent resources that the tags have in common.

User X tags resource 1 with the tags b,c and d, therefore these tags are connected in Figure 2a. Since both users X and Y annotate the resources 1 and 3 with the same tags c and d, the respective link has a higher weight, and the association strength between the tags c and d is higher.

The frequency of co-occurrence of two tags across all resources determines the *association strength* between these two tags (different weighting measures are discussed in Markines et al., 2009). So what results from the tagging activity is a semantic network. It shows how tags are semantically related to each other on the basis of a common set of resources. In Figure 2b it is obvious that the tags b,c and d have a strong semantic relation, especially the tags c and d. This semantic knowledge just emerged from of the aggregation of tags. Users X and Y have different knowledge structures compared to the aggregated knowledge structure.

A common way of visualizing the association strengths between tags is the use of tag clouds (one is presented in Figure 6 later on in this paper). Tag clouds present those tags with the strongest associations to the search term: the stronger the association strength, the larger the font size of the tag. This means for our example in Figure 2: If one would search for c, a tag cloud would present a,b and d with d with the largest font size.

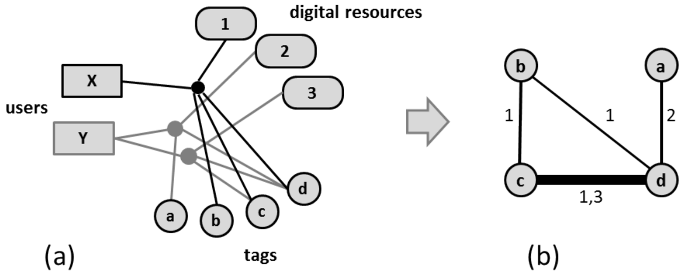

Figure 2: Example for social tagging: (a) Two users annotate tags a-d for resources 1-3. Social Tagging Systems make use of the information in this tripartite network. (b) They transform the tripartite graph in a one-mode network representing weighted tag-tag relations. Tags a-d are represented as nodes, linking lines represent resources that tags have in common. Numbers on the links indicate the number of the resource in (a).

The way social tagging systems create collective knowledge out of single contributions is highly analogous to processes in the semantic memory of individuals. We explain this conceptual correspondence between individual internal knowledge and collective external knowledge in the following section.

Structure of Individual Knowledge

A variety of cognitive models describe declarative knowledge in human memory as a network of *chunks* (e.g., Anderson, 1983; Collins & Loftus, 1975). Each of the chunks is connected to other chunks with a different strength of association. The strength of association derives from people's past learning experiences. When two chunks frequently co-occur in a meaningful context, their association becomes stronger. If, e.g. "sun" often co-occurs with "Florida", a strong association between these two chunks is established.

The strength of association determines the retrieval of chunks in semantic memory: in order to retrieve a chunk it has to be activated by other chunks. The activation spreads from one chunk to another. The stronger the association, the higher is the likelihood that a chunk will stimulate a certain level of activation. Figure 3 shows an example where somebody is asked where she would like to go on holiday. Through this question the chunks Florida and Himalaya are activated, and activation spreads to all linked chunks according to the association strengths.

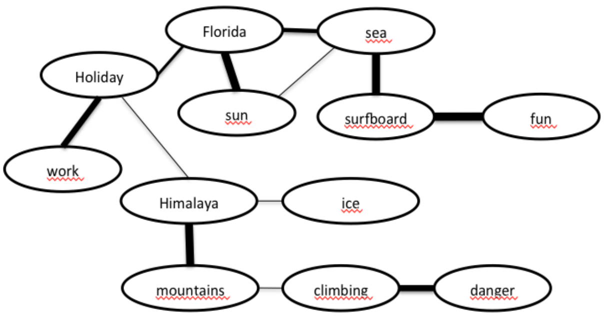

Figure 3: Activation in semantic memory

Similarity between Social Tagging and Individual Knowledge

Already the visualizations in Figure 2 and Figure 3 demonstrate the structural similarity of social tagging systems and human memory. Both systems have a network structure that is the basis of semantic knowledge. In the individual (Figure 3) case this knowledge is created through experiences made in the past, in the social case (Figure 2) it is created through people's tagging of resources and the automated aggregation of these tags. And both systems develop analogously: An individual's knowledge develops whenever two chunks are activated simultaneously: Then a relation is created, or an already existing one is strengthened. The collective knowledge develops whenever an individual tags a resource and thus creates a new relation or strengthens an already existing one.

Interaction of collective and individual systems

The Co-Evolution model states that collective and individual knowledge systems interact by two processes: Externalization and internalization. This paper focuses on internalization. It shows how people make use of the collective knowledge in information search and how this leads to individual learning processes.

We focus on a situation where people navigate through tagged resources, and we base our considerations on the most prominent model about Web search, the Information Foraging Theory (Pirolli, 2007; Pirolli & Card, 1999). This theory states that people's knowledge about the searched topic plays a crucial role in a user's navigation. When navigating through resources, a user has to decide which links or tags lead to the topic he is interested in. This decision is based on a user's association strength between chunks activated by the link and those activated by the search topic (topic of interest). This strength of association predicts that (subjective) probability that a link will lead to the desired topic. In the Information Foraging Theory this probability is called *information scent*. This information scent is the association strength between the terms used in a link and the searched topic (topic of interest in Figure 4). The stronger a link is associated with the topic of interest the higher is its information scent. This means that the individual knowledge determines which link a user selects. In Figure 4a the user would select tag *a* because it has the highest association strength with the desired topic.

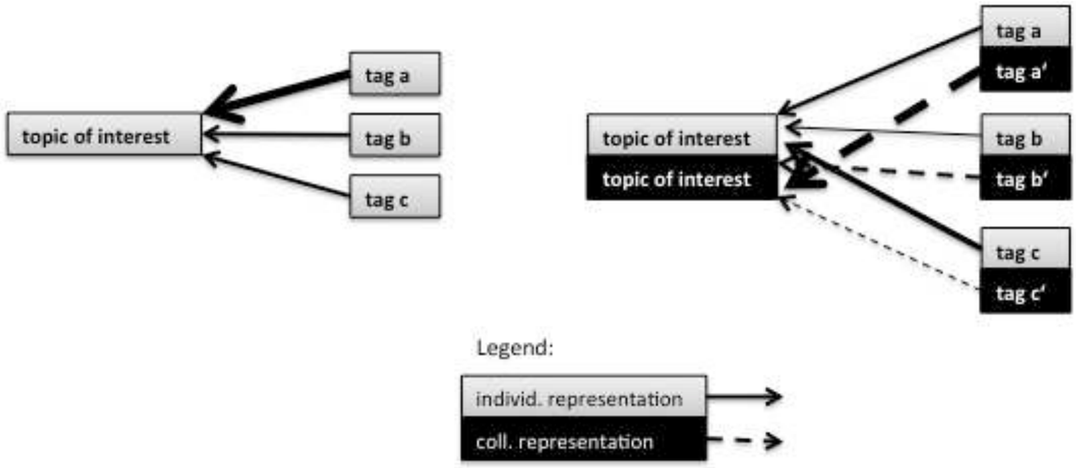

Figure 4a: Information-scent model (Pirolli, 2007)

Figure 4b: Collectively extended information scent (Cress, Held & Kimmerle, 2013)

Several studies have confirmed the information scent model and have shown that people's knowledge determines their Web navigation (e.g., Blackmon et al., 2002; Fu & Pirolli, 2007). We build on these results and ask whether people make use of the collective knowledge when they navigate in a tagging environment. Taking co-evolutional processes between individual knowledge and collective knowledge into account, we propose an *extended information scent model* as it is shown in Figure 4b. This model states that the information scent is a linear combination of a user's individual knowledge structure and the collective knowledge structure. The individual knowledge structure (displayed in light grey) is based on individual representations (chunks), the collective knowledge structure (dark grey) is based on tags and the folksonomy defining their interrelations. Individual and collective knowledge do not need to be consistent. The association strengths as well as the individual and collaborative representations may differ. The model states that the 'extended information scent' is a linear function of the individual and the collective association strengths. When users use tags for their navigation, individual learning processes take place. Then the internal representation of the topic of interest assimilates to the external and collective representation given by the folksonomy. The cognitive system in turn develops, and the internal knowledge structure assimilates to the collective knowledge structure.

Experimental Evidence for an Extended Information Scent

In the following sections we show three experiments we conducted in our Lab that give evidence for this model. We present here only the main results. Many more details about the materials, procedure and results with regard to other dependent variables are described in Cress and Held (in press), Held, Kimmerle and Cresss (2012) and Cress, Held and Kimmerle (2013).

All three experiments induced some incongruity between the individual's knowledge strengths of associations and the collective strength of associations in topic domains previously unknown to the participants. The incongruity was established by (1) manipulating a user's individual knowledge through providing information *before* the navigation task and/or by (2) manipulating the collective knowledge *during* the navigation task (through manipulation of the tag clouds). In the first experiment, people could navigate in the Web. In the other two experiments, an experimental setting was used where users navigated in a highly controlled but artificial tagging scenario. In all three experiments, we expected to confirm the model of the extended information scent shown in Figure 4. So we expected that the participants' prior knowledge as well as the collective knowledge inherent in the tag clouds would influence people's knowledge after they had interacted with the tag system.

1st Experiment: Navigation with the Tool Brower-extension "Search Cloudlet"

Materials and Procedure In the first experiment (Cress & Held, in press), participants could freely navigate in the Web. In order to be able to manipulate the participants' prior knowledge, we selected three topic domains that were unknown to the participants and for which we could easily induce incorrect prior knowledge. The domains were 'EMDR', 'Dannsa Biodag' and 'Manipogo'. The participants received, for example, the information that *Manipogo* is a Golf festival at the Manitoba Lake, whereas in fact it is a monster in the Manipogo Lake. The participants' task was to find more information about the three topics by navigating through the Web. The Firefox browser extension 'Search Cloudlet' was used for navigation. Cloudlet automatically creates tag clouds from the Google result list. It visualizes those words that are part of many search results with a larger font size. So the tag clouds represent a kind of aggregated knowledge of the Web with respect to the topics of interest.

During the task, the participants could not see the search results, they saw only the tag clouds. Figure 5 shows the tag cloud for the search term 'Manipogo Manitoba Lake'. It shows a strong association with *monster* and a smaller with *creature* or *Loch* and *Ness*, but only a weak association with *golf*.

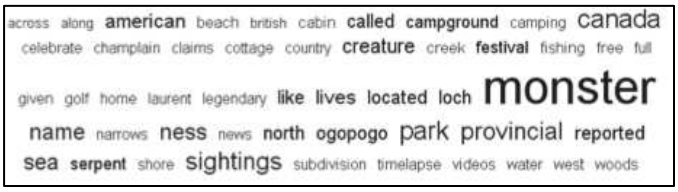

Figure 5. Tag clouds for the search term 'Manipogo Manitoba Lake'.

Design The experiment implemented a 2x3 factorial design. The *individual's knowledge* was manipulated as within-factor: Before the navigation, each user received information that was either congruent with the collective knowledge (e.g. *Dannsa Biodag* is a North European war dance), or incongruent with the Web resources (*Dannsa Biodag* is a South American war dance), or they received no information. This within-factor was permutated. The second factor *collective knowledge* served as between-factor. The experimental condition could use the Cloudlet tool and could enter search terms. For each search term they received a tag cloud based on all information in the Web. So these tag clouds are representations of the Web knowledge. The control group did not receive any tag clouds. So the control group had no access to the collective knowledge and they could not navigate in any way. This group served as a treatment check for the manipulation of the individual knowledge, it had now access to any further knowledge.

At the end of the experiment all participants had to complete a post-test that tested their knowledge about the three domains.

Results The results of the study (n=54) confirmed the model of the extended information scent. Collective knowledge inherent in tag clouds and the individual knowledge people had built through the information provided before the navigation had a significant effect on people's knowledge scores in the post test (collective knowledge: $F(1, 52) = 22.94$, $p < .001$; individual knowledge $F(2, 104) = 23.45$, $p < .001$). If tag clouds gave users access to the collective knowledge, people internalized this knowledge and adapted their own cognitive structures to it. The two independent variables did not interact.

Discussion The results confirmed the model of the extended information scent. It shows that people make use of the collective knowledge in social tag clouds. Their individual association strengths adapted to the collective knowledge. As this first experiment was done in the real Web, the collective knowledge presented in tag clouds resulted from the majority of the search results. This means that in this experiment the association strengths could not be systematically manipulated for each single tag. The following two experiments were designed to go more into detail and measure the influence of single association strengths between a tag and a concept.

2nd Experiment: Navigation with weighted/unweighted tags

Materials and Procedure The second experiment (Held, Kimmerle & Cress, 2012) was done in a controlled setting where all participants were provided with tag clouds. With the domain 'Georgian Wine' (typical

Georgian wine regions, Georgian grapes and Georgian wine aromas), we chose a knowledge domain about which people had no prior knowledge.

The experiment was set up online. Participants were told that the overall goal of the task was to investigate how people search for products with the help of tags. We did not inform the participants that the experiment was intended to measure any kind of learning. The experiment started with a general introduction to tags, and the participants were informed that the tag clouds a user would encounter were based on tags of wine experts. The participants were instructed to find *typical Georgian wines* to build up a presentable wine cellar.

During the experiment the participants received tag clouds. The tag clouds showed representative tags related to, for example, specific wines or parts of Georgia. Figure 6 shows such a tag cloud. It shows a tag cloud for the search "Georgian wine regions".

Figure 6: Tag cloud for the search 'Georgian wine regions'.

For each presented tag cloud the participants had to click on that tag which seemed most appropriate for leading them to typical Georgian wines. After navigating through nine tag clouds, the participants had to complete a post-test. They had to indicate how strongly they associated specific tags with Georgian wine by rating their typicality (e.g., 'How typical is the wine region 'Kakheti' for Georgian wine?') on a rating scale of 1 to 7 (from very untypical to very typical.*)*.

Design The experiment implemented a mixed 3x2 factorial design. Analogous to the first study we induced *individual knowledge* by providing some information before a participant could navigate. For it, we presented a Weblog where an anonymous user told participants that 'Kakheti' was a typical Georgian wine (which is congruent with the collective knowledge shown in Figure 6), or the information, that 'Tsageri' was a typical Georgian wine. In a third condition we presented no such information. Analogous to the first experiment we manipulated the factor *individual knowledge* as within-factor (permutated across the three domains (wine regions, wine grapes and wine aromas). The between-factor *collective knowledge* had two levels: the tag clouds a user received had weighted tags (tag sizes varied according to their collective association with the search term), or the tags were not weighted. The weighted tag cloud made the collective association strengths visible, whereas the weighted tag clouds did not deliver this information. As dependent variable we analysed people's scores of the *knowledge test* provided after the experimental task.

Results. The study (n=207) revealed the expected main effects: Participants' post-test scores were not just influenced by their *individual knowledge* $F(2, 352) = 40.34$, $p < .001$ but also by the *collective knowledge*, $F(1, 176) = 12.77$, $p < .001$. Also here we found no interaction.

So also the second experiment confirmed the model of the extended information scent: individual knowledge as well as collective knowledge influenced people's knowledge test after the navigation.

3rd Experiment: Fine-grained Variation of Association Strengths

The third experiment (Cress, Held & Kimmerle, 2013; 1st experiment) varied individual knowledge and collective knowledge in a much more fine-grained manner than in the experiments before. It manipulated the association strengths of individual and collective knowledge in a linear way.

Materials and Procedure The experiment used the same domain as the second one, 'Georgian Wine'. In the first phase of the experiment we manipulated the individual knowledge much more implicitly than in the second experiment. We provided participants with a wine list given from somebody 'who loves Georgian wines' and asked them to provide feedback on design features of this list. It was not mentioned in any way that participants should memorize any content of the wine list, nor were the participants informed that the content had any specific relevance for further steps of the task. The list was presented to the participants for 30 seconds, followed by five general questions about the design and information of the list (e.g., 'Would it be helpful to provide further information on specific wine regions?') in order to direct attention to the content of the list. The wine list was still available to the participants while they were answering the questions. The *second phase* of the experiment was a navigation task like the one in the second experiment. In this phase, participants had the task of collecting typical Georgian wine. After a basic introduction to social tags, participants were presented tag clouds and asked to click on that tag of each cloud which would lead them to a typical Georgian wine. After this task, the participants had to complete the same post-test we used in experiment 2.

Design A 5 x 4 between-subjects design was used. We manipulated a user's *individual strength of association* between the wine region 'Kakheti' and 'Georgian wine' by varying the content of the wine list that was presented in the first phase of the experiment. This wine list showed five Georgian wines. Wines from the region 'Kakheti' were part of the list (1) not at all, (2) once, (3) twice, (4) three times, or (5) four times.

We manipulated the collective strength of association by changing the size of the tag 'Imereti' in the tag clouds, which the participants encountered in the second phase of the experiment. The *size 'Imereti'* had four continuous levels: (1) the tag 'Imereti' had the same size as the tag 'Kakheti' (2) or was 33%, (3) 67%, or (4) 100% larger. No other tags varied in size.

As dependent variables we used ratings in the post-test, where we asked how typical 'Kakheti' and 'Imereti' are for Georgian wines.

Results The study was done with n=596 participants. In order to test the impact of the individual strength of association and the collective strength of association on people's resulting knowledge, we conducted multiple regression analyses. The predictor variables (*frequency Kakheti in the wine list* and *size Imereti in the tag cloud*) were centered, and the interaction term was computed by a multiplication of both variables. The regressions revealed that both independent variables had the expected effect on user's association strengths after the experiment (association for Kakheti: effect of individual knowledge $\beta = .25$, $p < .001$; effect of collective knowledge $\beta = -.10$, $p < .05$ and association for Imereti: effect of individual knowledge $\beta = -.14$, $p < .01$; effect of collective knowledge $\beta = .21$, $p < .001$). We found no significant interactions.

So in sum the results also confirm the proposed model. The linear regressions show that both the individual association strengths as well as the collective associations strengths have an additive liner effect on people's knowledge.

General Discussion

The use of tagging systems provides valuable insights into the exchange processes between individual and collective knowledge. The Co-Evolution Model states that within the social system, social processes occur that create a collective product out of the individual contributions. With regard to social tagging systems, this is primarily an automatic process. The only social rule is that the users are expected to tag resources with tags that are meaningful for them, and that have some relation to the resource. If users consider these rules then the tagging algorithm leads to a semantically meaningful network of tags, which represents the collective knowledge. A tag provided by an individual user then builds new associations within this collective knowledge or changes the association strengths of existing ones. Thus the externalization of an individual directly changes the knowledge within the social system.

What our experiments showed is the fact that users internalize this collective knowledge when they navigate with tag clouds. All three experiments confirmed the model of the extended information scent: When people navigate with tag clouds, their navigation is not only influenced by their individual knowledge, but also by the collective knowledge inherent in the tag clouds. This shows that people make use of the collective associations represented in the clouds. And this process happens incidentally during navigation, and without any explicit instruction to learn something about the topic. Across all three studies the effects were very congruent: we found main effects for individual and collective knowledge but no interaction. In all experiments the effect of people's individual knowledge was at least as strong as the effect of the collective knowledge. This is remarkable, because in our experimental setting, people's individual knowledge was just based on the information of an "anonymous blogger in a Weblog", whereas the collective knowledge was based on tags 'from wine experts'. Thus, objectively seen, the collective knowledge should have been much more credible than the individual knowledge. It seems, that once an association is established, it has a high impact. The next step in research will be to examine the variables that determine what influence collective knowledge has compared to individual knowledge.

In sum, the data strongly support the model of the collectively extended information scent. This describes the internalization processes at the cognitive level and thus provides a first fine-grained model to demonstrate co-evolutional processes as described by the co-evolution model. With regard to their formal structure, information in tagging systems can be considered as collective knowledge. Further experiments will have to proof, if users consider tag clouds as information coming from a collective, or if they just make us of it because they provide some additional information.

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