An Approach for Asynchronous Awareness Support in Collaborative Non-Linear Storytelling

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Abstract.   Workspace awareness support is mandatory for group support systems. It allows users not only to follow actions of others, but to understand and respond to any changes others make to the workspace. In this paper, we present a novel approach for asynchronous awareness support by offering different filters to retrieve relevant awareness information and visualizing the evolution of the shared artifact. We illustrate our approach with a tool for collaborative non-linear storytelling in which users can jointly create a story graph of interconnected audio files. Such a story graph is an example for a non-linear story. We describe the development of a prototype that visualizes how the collaborative story has evolved over time. We evaluate our approach for asynchronous awareness support in an experiment with 40 participants exploring story graphs of different complexity. The evaluation results show that our visualization approach helps group members to assess who has modified the shared story, how it was modified, what exactly has been modified, and when it has been modified.

Key words: asynchronous workspace awareness, collaborative storytelling, information visualization, traceability

1. Introduction

Collaboration has become a critical skill for organizations (Nunamaker et al. 2009). As products and services are becoming increasingly complex, no individual has the skills to design, develop, and deliver these alone. As a result, shared artifacts are often created over time. Typical examples are co-authoring of papers, iterating designs, negotiating plans or decision-making. Often the collaboration occurs in face-to-face meetings or distributed meetings at the same time. However, there are also various examples when such synchronous interaction is not possible (Tam and Greenberg 2006):

- Users pass the joint artifact back and forth for comments and revisions.
- Users work on the artifact as time and opportunities arise, without explicitly coordinating this with the other participants.

- A group switches between synchronous co-located work and asynchronous distributed work, e.g. by starting the project in a face-to-face meeting but continuing asynchronously once the meeting is over.

Collaboration in general includes numerous challenges. On a process level free riding, dominance, group think, or hidden agendas are a few phenomena in group work that make it a non-straightforward effort (Nunamaker et al. 1997). On a group level it is essential to create a shared understanding, define rules for decision-making, and facilitate interaction in such a way that effective collaboration becomes possible (Lu et al. 2007; Piirainen et al. 2010). When considering asynchronous collaboration, as described in the examples above, the major challenge is to create shared understanding. This is often due to missing awareness support. Users have difficulties to understand recent changes as they are used to tell other users what they have done or by inspecting the artifact and identifying the changes manually. Tam and Greenberg (Tam and Greenberg 2006) conclude that in case of missing asynchronous awareness support collaboration gets out of control and missed changes can ravage the whole collaborative process unintentionally.

We have observed the need for asynchronous awareness support within a tool for collaborative audio-based storytelling (Lukosch et al. 2011). Stories convey a sequence of events and their circumstances, communicated verbally or written (Valle et al. 2003). They are an ancient way to exchange experiences (Totzke 2005). Verbally told stories convey personal perceptions, cultural aspects, good and bad practices, and speculations (Ochs and Capps 2001; Orr 1996; Bruner 1991). They are placed into context in order to improve the understanding of the audience (Bruner 1991). In oral communication stories can create shared understanding (Weick et al. 2005) by exploring different story lines accommodating facts, observations, background knowledge, and expectations with regard to human behavior. Stories are told at home between family members, see e.g. (Ochs and Capps 2001), but also in the workplace. Here, technicians (Orr 1996) and project managers (Buttler et al. 2011) have been observed to exchange stories to convey experiences and share encountered problems and their solutions.

Collaborative storytelling aims at the development of a common understanding within a group through coordinated narrating activities to make implicit knowledge explicit (Lukosch et al. 2011). In text-based approaches to collaborative storytelling a contributor is responsible for entering the content of the story. Contributors share their own experience in the form of events and circumstances. Because several contributors work on the same story, they collaboratively tell the entire experience from different perspectives. These text-based approaches have been utilized e.g. in the area of business-process engineering or to exchange experiences about past projects (Perret et al. 2004; Santoro et al. 2010). Audio-based collaborative storytelling uses the renaissance of listening which is indicated by an increased demand for audio books (Philips 2007; Friederichs and Hass 2006) and podcasts (Hein and Jasuka 2007; Martens and Amann 2007) to enable the exchange of

experiences and knowledge within a group. Thereby it provides an alternative to mainly textual techniques, e.g. wikis (Wikipedia 2011).

Within collaborative storytelling users often work on the shared story as time and opportunities arise, without explicitly coordinating it with the other participants. Similarly to reporters users collect material while working in the field and immediately integrate their changes. Often this happens while they are disconnected from the network. When connected to the network, users synchronize their changes. As a result, the shared story grows asynchronously and non-linear stories consisting of several parallel threads are created (Spaniol et al. 2006). Non-linear stories are often visualized in a so-called story graph which displays the alternative story threads. This asynchronous growth of the shared story makes it difficult to trace the story evolution. To address this issue, it is necessary to offer awareness support (Pankoke-Babatz et al. 2004; Tam and Greenberg 2006) and provide users with "an understanding of the activities of others, which provides a context for your own activity" (Dourish and Bellotti 1992).

Gutwin et al. (1996) distinguish four types of awareness: group-structural awareness, social awareness, informal awareness, and workspace awareness. In this paper, we focus on workspace awareness. Workspace awareness is "the up-to-the-moment understanding of another person's interaction with the shared workspace". Specifically, we focus on asynchronous workspace or change awareness which is defined as the ability of users to track the asynchronous changes made to a collaborative document or surface by other participants (Tam and Greenberg 2006). Asynchronous awareness explicitly focuses on two-dimensional graphical documents (Tam (2002), as cited in Tam and Greenberg (2006)) such as: figures, photos, blueprints, concept maps, graphs, UML diagrams, and collaborative workspaces containing spatially scattered artifacts. While 2D documents are widespread, techniques for displaying change awareness within them are undeveloped and are likely non-trivial (Tam (2002), as cited in Tam and Greenberg (2006)). Tam and Greenberg (2006) identified six different questions that asynchronous awareness support needs to answer:

1. Where have changes been made?
2. Who has made the changes?
3. What changes were made?
4. How were things changed?
5. When did the changes take place?
6. Why were the changes made?

Within this paper, we use Tam and Greenberg's definition to introduce a novel approach for asynchronous awareness by visualizing the story evolution of a non-linear story that is displayed as a directed graph. The visualization focuses on answering the questions where, who, what, how, and when. Answering these questions is most important to understand and assess recent changes in collaborative storytelling. Individual contributions within collaborative storytelling

often reflect the personal attitude of a user. By knowing who contributed a specific part the other users can better understand the reasons for the contribution. For the same purpose, it is also important to answer what has changed. By visualizing the changes, we implicitly answer the question where changes have been made. By answering when a change has happened users are enabled to relate the change to recent events in relation to the story. Finally, answering how a story evolved helps users to relate all individual changes. We do not address the why question, as the necessary information needs to be generated explicitly by authors when committing a change (Tam and Greenberg 2006). We integrated our approach on asynchronous awareness support into our tool for audio-based collaborative storytelling and evaluated our visualization approach in an experiment with 40 users and stories of different complexity. The results show that our approach helps group members maintain asynchronous awareness and that the visualization approach can be used to create asynchronous awareness in relation to the questions who, what, when, and how.

Non-linear stories are just one example for 2D documents containing a graph as its major structure. Our design approach can therefore not just inform asynchronous awareness for non-linear storytelling but also provides the baseline for future studies focusing on asynchronous awareness support in graphs.

In the following section, we introduce our tool for collaborative audio-based storytelling. Using a scenario in which different teams collaborate on a shared story, we determine the requirements for asynchronous workspace awareness support and the corresponding visualization. We then discuss related work and present our approach in detail. We further present the setup and results of our experiment, before we conclude with a summary and outlook on future work directions.

2. Requirements analysis

In this section we determine the requirements for supporting asynchronous workspace awareness within CASTing, a tool for collaborative non-linear storytelling (Lukosch et al. 2011). CASTing consists of three major components: the CASTing client application, the CASTing web portal, and a centralized server. After introducing the components, we refer to a scenario in which a distributed group of students creates a joint story to compare their universities with regard to different aspects such as the quality of food or the quality of education.

2.1. CASTing

CASTing (Lukosch et al. 2008; Lukosch et al. 2011) supports asynchronous collaborative audio-based storytelling. It provides a client application, a web portal, and a centralized storytelling server. The storytelling server is responsible for user and project management, and provides services to access and synchronize the shared data (e.g. links between audio recordings, nodes in the story graph).

The web portal allows users to publish podcasts and discuss, comment, vote, and reuse audio-based stories. The client application allows users to create a project team, add audio recordings, segment audio recordings, link audio recordings, and select and publish a linear story. It can be used with or without a network connection. Changes that are performed without a network connection can be synchronized with the centralized server later. Changes performed by other users can be retrieved similarly once connected to the network.

Both, the client application and the web portal support users in creating non-linear stories collaboratively. What sets non-linear stories apart from linear ones is their nature to contain several parallel threads (Spaniol et al. 2006). Non-linear stories are often visualized in a so-called story graph which displays the alternative story threads. In CASTing, a story graph consists of nodes containing audio material and linking edges.

In order to create such a non-linear story, a group has to go through a process with several stages. In the first stage, users analyze the audio material, identify segments they would like to use in the non-linear story and mark start and end point of these segments in the audio file. In the next step, users build the non-linear story. Here, they take the identified segments and drag them onto a canvas. CASTing converts these segments into nodes of the story graph. Then users can connect these nodes through directed links, thus creating a directed graph. In the last stage, users can select a single path from the story graph. The path represents a single story and can be exported as an audio file.

The client application (see Figure 1) can be used nomadically and therefore allows users to capture experiences in situ, integrate these changes in the story
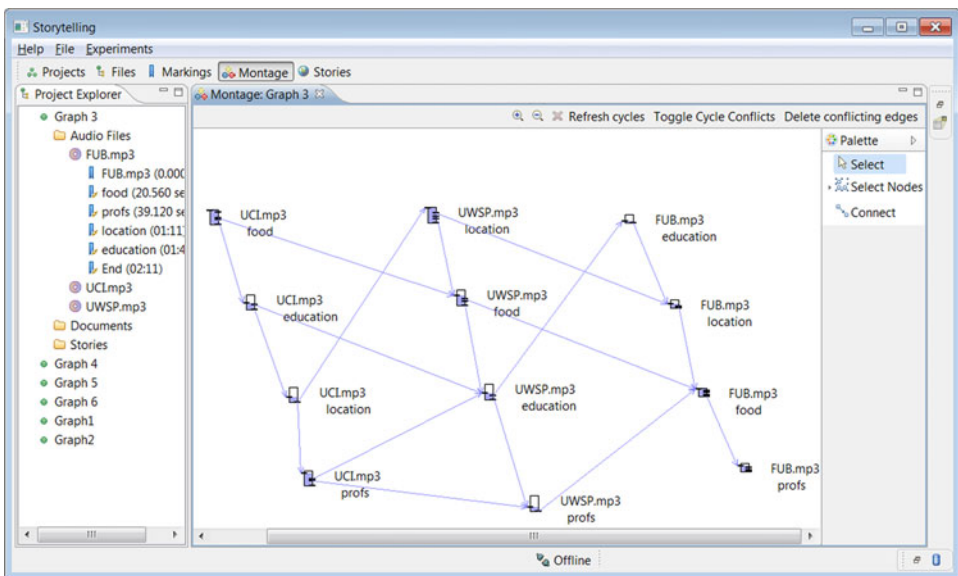

Figure 1. Story graph in the CASTing client application.

graph and later on synchronize the changes with the server. The resulting asynchronous growth of shared data makes it difficult to trace the story graph evolution. As this can play havoc with the whole collaboration, asynchronous awareness support is essential. In the following section, we describe a typical scenario in which CASTing is used to collaboratively create a story. Based on this scenario, we derive requirement for asynchronous awareness support.

2.2. Scenario

A group of students from different universities in Germany and the USA made it their business to collect differences and similarities between their educational establishments. They want to jointly create stories focusing on major topics regarding their universities and use CASTing as a tool for audio-based collaborative storytelling. It is their goal to create a podcast series and discuss in every new episode another major topic regarding their universities, e.g. the quality of the food or education. Currently three students are actively working on the project: Joe is studying at the University of California in Irvine (UCI), Daniel is studying at the University of Wisconsin in Stevens Point (UWSP), and Jesse is studying at the Freie Universität Berlin in Germany (FUB).

Each of the three students has conducted an interview about studying in their university and student life in their city. In each interview they have covered the following topics: food, location, education, teachers, and jobs. Each interview was uploaded separately as a single audio file into the CASTing system. The following paragraphs describe in more detail what has happened so far within seven working days spread over several weeks.

Working day 1. *Joe* conducts the interviews at *UCI*. He uploads his audio file and creates nodes representing three sections on the quality of the food, on how nice the region is, and on the quality of the courses. He also connects these three nodes to a directed graph.

Working day 2. *Daniel* does the same as Joe did before for *UWSP*.

Working day 3. *Jesse* conducts the interviews at *FUB*. Because he is particularly interested in a comparison of the quality of the *food* at the different universities, Jesse connects the three sections in the interviews about food and exports it as an audio file or story with the title *Food Comparison*. Now the story graph has **nine nodes** and **nine edges** (see Experimental condition #1 in Figure 8).

Working day 4. One week later *Jesse* decides to create some story paths to compare the *teachers* at the three universities. He adds one node for each

university and links them. He also finds some connections to the existing nodes (e.g. linking nodes of one story). Overall, he ends up with **twelve nodes** and **18 edges** (see Experimental condition #2 in Figure 8).

Working day 5. A couple of days later *Joe* compares the *job* situation at the three locations. He identifies the appropriate sections, adds three nodes to the graph (one for each university) and links them to each other and to the existing nodes. The story graph has **15 nodes** and **27 edges** now (see Experimental condition #3 in Figure 8).

Working day 6. Finally, *Jesse* wants to compare the everyday life (*living*) of the students at the three universities. He adds another three nodes and several edges. Altogether, the story graph has **18 nodes** and **36 edges** now (see Experimental condition #4 in Figure 8).

Working day 7. The three students have worked successfully on the project for six days spread over several weeks. Now they want to broaden their comparison by adding interviews from another university. Using CASTing, they invite Albert studying at the Technische Universität Dresden in Germany to join their project. Albert decides to join and now needs an overview of the events from the last few weeks. He wants to know who is currently working on the project and how the latest story graph evolved over time. He is also interested in listening to the already existing stories and how those stories were created, because he wants to create stories in the near future as well. For that purpose, Albert is in need of adequate asynchronous awareness support that allows him to identify who has made changes, what changes were made, where changes have been made, when changes took place, and how the story graph changed over time (Tam and Greenberg 2006).

2.3. Discussion and requirements

The scenario above is a typical storytelling task for audio-based stories. Whenever people like the three students in our scenario work together in a shared environment (virtual or face-to-face), they need information about the activities and intentions of their co-workers. This information is important especially for successful collaboration using groupware (Dourish and Bellotti 1992).

Working with complex story graphs such as in CASTing demands advanced workspace awareness. For example, Daniel needs to know that Joe already created nodes for the *UCI interview* to avoid redundancies in their work. Albert needs an overview about the recent activities to see how the story graph evolved and what he could do next to support the progress of the project. Therefore he needs to know who edited the story graph, where and when these changes took place and how the changes were done. Within CASTing the story graph captures

the current result of the collaboration and thus we base our further requirements analysis on the following hypothesis:

Hypothesis Visualizing the changes in the story graph and its evolution creates asynchronous awareness among the group members and enables them to trace the activities in relation to their story.

Based on this hypothesis and the scenario above, we now discuss the requirements for a suitable asynchronous awareness support. In our scenario Albert needs a quick overview about the activities that happened in the story graph before he joins the project. An appropriate visualization has to provide information that allows him to understand the story graph evolution based on change awareness. As mentioned in Section 1 Tam and Greenberg (Tam and Greenberg 2006) identified six different questions that asynchronous awareness support needs to answer. We focus on the questions who, what, where, when, and how. As argued before, answering these questions is most important to understand and assess recent changes in collaborative storytelling. By knowing who contributed a specific part the other users can better understand the reasons for the contribution. For the same purpose, it is also important to answer what and where something has been changed. By answering when a change has happened users are enabled to relate the change to recent events in relation to the story. Finally, answering how a story evolved helps users to relate all individual changes. We do not address the why question, as the necessary information needs to be generated explicitly by authors when committing a change (Tam and Greenberg 2006). When the who, what, where, when, and how questions are answered, Albert should be able to understand how the story graph developed over time, but also who is responsible for changes in the story graph. Thus, the following requirement has to be met:

R1: The visualization of the story graph evolution has to show information about who has made a change, what change has been made, and where, when, and how a change has been made.

Not every user might be interested in the complete evolution of the story graph. In some cases, users might only be interested in a specific time period in which they could not participate in the collaboration. Also our new group member might only be interested in the changes by a specific user, e.g. Joe, because he invited him to join the project over the CASTing web portal. These examples show that there is a need for different filter functions:

R2: The visualization has to provide different filter functions that allow users to focus on the information they are interested in (specific user or specific time period).

Within CASTing each path within the story graph represents a story. Users can select a single path in the story graph and export this path as a linear story. Thus,

stories are important artifacts and users might be interested in how a specific story was constructed. Especially Albert needs to know this in order to create consistent stories for the podcast series. As not all users continuously participate in the story graph construction, it is hard for them to understand how the current state of the story graph has been reached. To answer how an artifact has changed over time the following requirement has to be met:

> **R3**: The visualization has to provide a replay function that shows how the story graph has been constructed over time and furthermore has to allow users to highlight a specific story path.

3. Related work

In the previous section we identified the requirements for achieving awareness regarding the asynchronous growth of a story graph. In this section, we discuss existing approaches for awareness support in general and for awareness support in storytelling tools in particular, and compare these approaches to our requirements. To our knowledge there are no approaches which focus on asynchronous awareness in graphs.

Erickson and Laff (Erickson et al. 1999) added a timeline to the chat environment *Babble*, in order to better understand the history of a chat conversation. By design, a timeline allows one to focus on specific time periods (R2). In the timeline, each user is represented by a row. Each row displays the activities from all chats of that user, thereby focusing on that user (R2). Tool tips present additional information like the time of contribution and additional information about the user. The timeline enables users to discover when other users are interacting in the collaboration space and it allows users to adjust their working hours so that synchronous collaboration is possible when needed. Thus, the timeline is a suitable awareness mechanism indicating *when* a user was present. However, a timeline does not allow users to explore how an artifact such as a chat has developed over time (R3).

Virtual School is a collaboration space for student interaction. A user study has revealed that collaboration broke down several times due to lack of activity awareness (Carroll et al. 2003). One solution was to integrate a timeline into the student's workspace (Ganoe et al. 2004). For each project, the timeline showed different documents. Changes to the documents were represented by the icons on the time axis. To access documents, users were forced to select them in the timeline instead of from a list of documents, making the timeline an integral part of daily work.

User studies (Ganoe et al. 2003) have shown that the timeline was of great value to people who were observing the group's progress. For example when there were white areas on the timeline, teachers queried the students responsible for those documents about problems in their group process and provided help. Here, the

timeline allows teachers to focus on the student's workspace. However, the timeline does not allow them to focus on a single student across several projects (R2).

Overall, a timeline allows users to focus on two dimensions, the time period and one other dimension like actors or activities. It is noteworthy that in both cases the timeline does not create awareness for 2D documents such as a graph.

DreamObjects (Lukosch 2004) is a platform for managing shared data of synchronous groupware transparently. It offers flexible and extensible solutions for data distribution, concurrency control, data persistency, latecomer support, and user interface notification. Within DreamObjects, latecomers can choose between a direct state transfer and a replay of how the current state has been reached (Lukosch 2003). The replay mechanism addresses aspects of asynchronous awareness (Lauwers and Lantz 1990) both for sequential and 2D documents such as story graphs. Tam and Greenberg (2006) note that the replay mechanism is a good solution to answer the question *how* things were changed, because a replay allows a user to retrace the evolution of an artifact step by step. However, the replay mechanism does not cover the entire range of asynchronous awareness. For example, in DreamObjects it is not possible to focus on actors (R2) or artifacts (R3). Overall, it offers a possibility to target the evolution of the story graph through animation.

Facebook offers an activity feed (Facebook Developers 2010), to keep users appraised of the activities of their friends, thereby providing some meta-information. This awareness mechanism allows users to follow actions, but does not offer help in focusing on a particular friend (R2) or activities in a time period (R2).

Apart from the discussed applications there exist quite a few tools that support users in collaboratively creating stories. However, these tools do not provide adequate support for asynchronous awareness.

TellStory (Perret et al. 2004) is a collaborative application that supports groups in creating linear text-based stories. However, TellStory does not provide any awareness support regarding the growth of the story.

PhotoStory (Schäfer et al. 2004) uses storytelling to increase the awareness in the group about its external presentation but also its social activities. For that purpose, the group can create stories that consist of a series of pictures with corresponding subtitles. PhotoStory uses *BSCW* (Bentley et al. 1997) as a collaborative workspace. BSCW-specific data structures provide the basis for annotations of the pictures. Apart from story related attributes such as type of event or position of a picture in the drama arc, awareness related attributes like author and creation date are provided. While PhotoStory provides some meta-information about the images, it does not support the users in understanding the evolution of the story by focusing on specific time periods or users (R2).

The internet-based storytelling application *Voicethread* (VoiceThread LLC 2011) supports groups in creating sequences of images or video clips. Users can add textual, audio- or video-based comments to these multimedia artifacts and hence create a digital story. These comments can be associated with an author

through a picture. The comments can be played back in the order of their creation. However, Voicethread does not employ filtering mechanisms for supporting users in understanding the evolution of the story (R2).

TellStory, PhotoStory, and Voicethread all focus on linear stories. There are also storytelling applications that support users in creating non-linear stories. For example, (Röber et al. 2006) introduce the concept of *Interactive Audiobooks* where audio-based stories are combined with interactive elements to form a non-linear story. This story is represented as a story-graph to the editors of the story. Another example is *MIST* (Spaniol et al. 2006). MIST allows users to create non-linear stories using multimedia elements such as text, images, audio and video recordings. However, both Interactive Audiobooks and MIST do not focus on collaboration. In contrast, *StoryMapper* (Acosta et al. 2004) supports groups in telling a non-linear story modeled as a conceptual map. Each node in such a map represents an event consisting of facts, the time of the event, and the involved actors and links to related multimedia artifacts. The edges represent semantic relationships between the nodes. The border color of a node is used to indicate who created that node. StoryMapper provides some meta-information and utilizes color coding to show which user created a node, thereby partially addressing (R2). However, it does not have any mechanism that helps users to focus on time periods (R2) or parts of the story graph (R3). Similar to CASTing, these three applications utilize graphs to visualize the non-linear story.

The discussion above shows that existing system are aware of the need to provide awareness information. None of the systems, however, offers different filters or allows users to replay the recent changes while highlighting important artifacts. Furthermore, most systems deal with sequential documents instead of 2D documents such as a story graph. Thus, we present our approach to address our identified requirements in the next section.

4. Approach

In Section 2 we identified several requirements to improve asynchronous workspace awareness for collaborative storytelling by visualizing the story graph evolution. The main hub for exchanging ideas and discuss the evolution of a story is the CASTing web portal. For that purpose, we developed and integrated a prototype in the CASTing web portal to test our hypothesis that visualizing the story graph evolution creates asynchronous awareness among the group members and enables them to trace the activities in relation to their story.

Our prototype is divided into two main parts (see Figure 2). The upper part displays the actual story graph visualization (R1). The lower part displays the control functions to filter the displayed information in the story graph (R2) or start the replay of the story graph (R3) to understand *how* the story graph evolved. In the following, we describe in more detail how we addressed the requirements R1, R2, and R3.
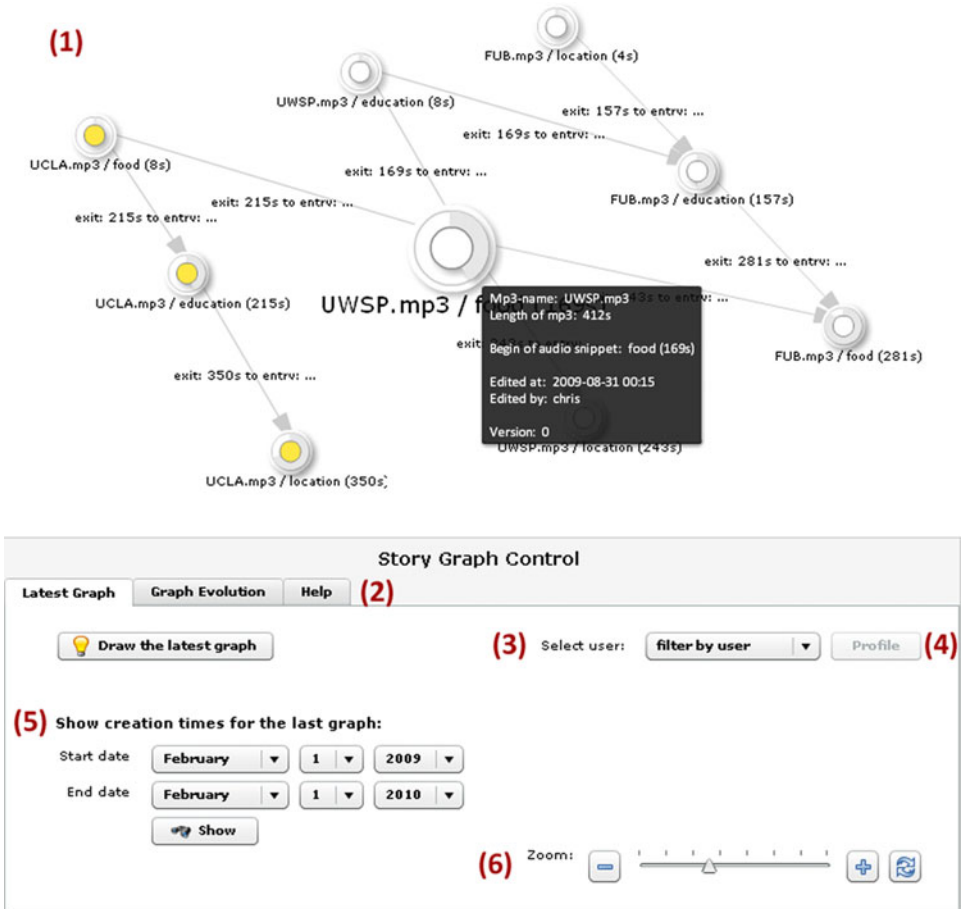
Figure 2. Story graph visualization.

4.1. Story graph visualization (R1)

The visualization (see Figure 2 (1)) shows a story graph. We chose this visualization form as the story graph is also used in the CASTing client application. Users are familiar with the client visualization as they need to use the client while creating a story collaboratively and asynchronously. When considering the story graph visualization in the client application, we have to design a simple and directed graph without loops and the possibility to display single nodes. In this way, users can still recognize the story graph they worked with in the CASTing client application.

In order to overcome the different lengths of the audio recordings in the CASTing client application, we decided to display all audio recordings independent from their length as circles of the same size. The grey colored

background changes depending on the real length of the audio recording and the part of the audio recording being used in the story. Resulting from this visualization we save visualization space, which is very important due to the limited space in the CASTing web portal.

To display the story graph evolution as effective as possible, there is a limited set of visual properties that are detected very rapidly and accurately by the human low-level visual system, e.g. the color of an object. Following these preattentive properties (Healey 2010), we colored the inner circle of the nodes in the CASTing web portal (see Figure 3 (1)). The more intense a color, the more recent a node. This enables users to preattentively recognize the age of a node and answer the question "*When* did the changes take place?" (Tam and Greenberg 2006):

- A white inner circle represents nodes which were created in the last year.
- A yellow inner circle represents nodes which were created in the last month.
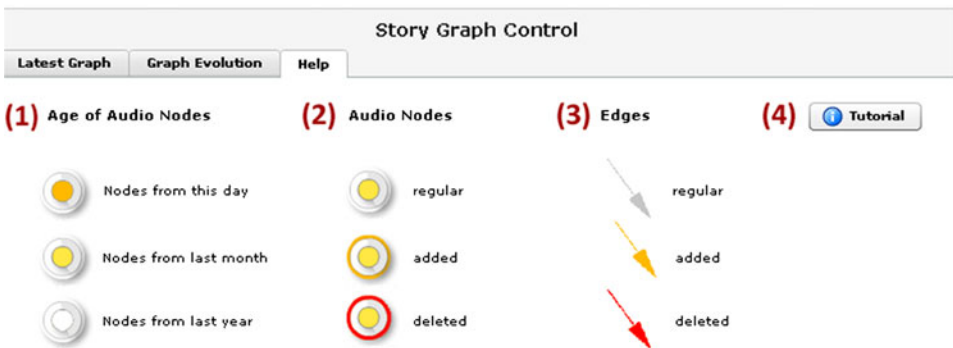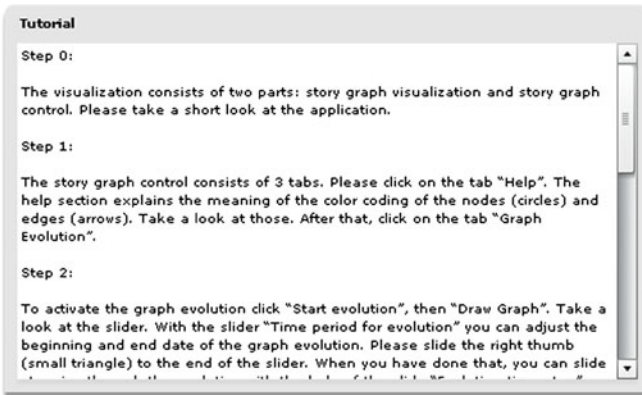- An orange inner circle represents nodes which were created on the current day.

Figure 3. Help section in the story graph control.

The outer ring of a node (see Figure 3 (2)) is used to indicate the state of the node and answer the question "*What* changes were made?" (Tam and Greenberg 2006). If the outer ring of the node is highlighted in orange, the node was created at the chosen point in time. If it is red, a user has deleted the node at the chosen point in time.

An arrow represents an edge in the story graph of the CASTing client application and connects different parts of audio recordings. For the edges, we use the same color coding as we use for the inner circles of the nodes (see Figure 3 (3)). Additionally, we included tool tips which provide information about the nodes and edges in the visualization (R1), e.g. name of audio file, length of audio file, begin of audio snippet, time of last editing, person who edited the node the last time, and a version number.

The help section in the story graph control (see Figure 3) provides a graphical and textual description of the colors and displays of a node or an edge. The help section is meant to be a legend of the story graph evolution, but it also offers a tutorial (see Figure 3 (4)) for new users.

4.2. Information filter functions (R2)

When visualizing the story graph evolution, users can filter certain information. The story graph control (see Figure 2 (2)) is divided into three parts:

1. *Latest Graph*
2. *Graph Evolution*
3. *Help*

The *Latest Graph* control allows users to explore *who* did *what* and *where* in the latest story graph. The story graph can be filtered by user (see Figure 2 (3)) which highlights the edges and the outer rings of the nodes created by the selected user (R2). A more detailed view on this filter and a sample result is shown in Figure 4. Thereby, this filter can be used to identify *who* created *what* artifact in the most current view and thus answers the question "*Who* has made the changes?" (Tam and Greenberg 2006). It also allows users to literally see *where* in the latest graph a person has changed something. In addition, users can choose to display the profile of the selected user (see Figure 2 (4)).

The story graph can also be filtered by creation date of nodes and edges (R2) in the project (see Figure 2 (5)). A more detailed view on this filter and a sample result is shown in Figure 5. If a node or an edge was created in the selected time period, these nodes and edges are highlighted (R2). This function offers the ability to see *when* an artifact was created in the latest graph view. By using this function the question "*When* did the changes take place?" (Tam and Greenberg 2006) is answered for the users.

(a) User filter control

(b) Result of filtering by user
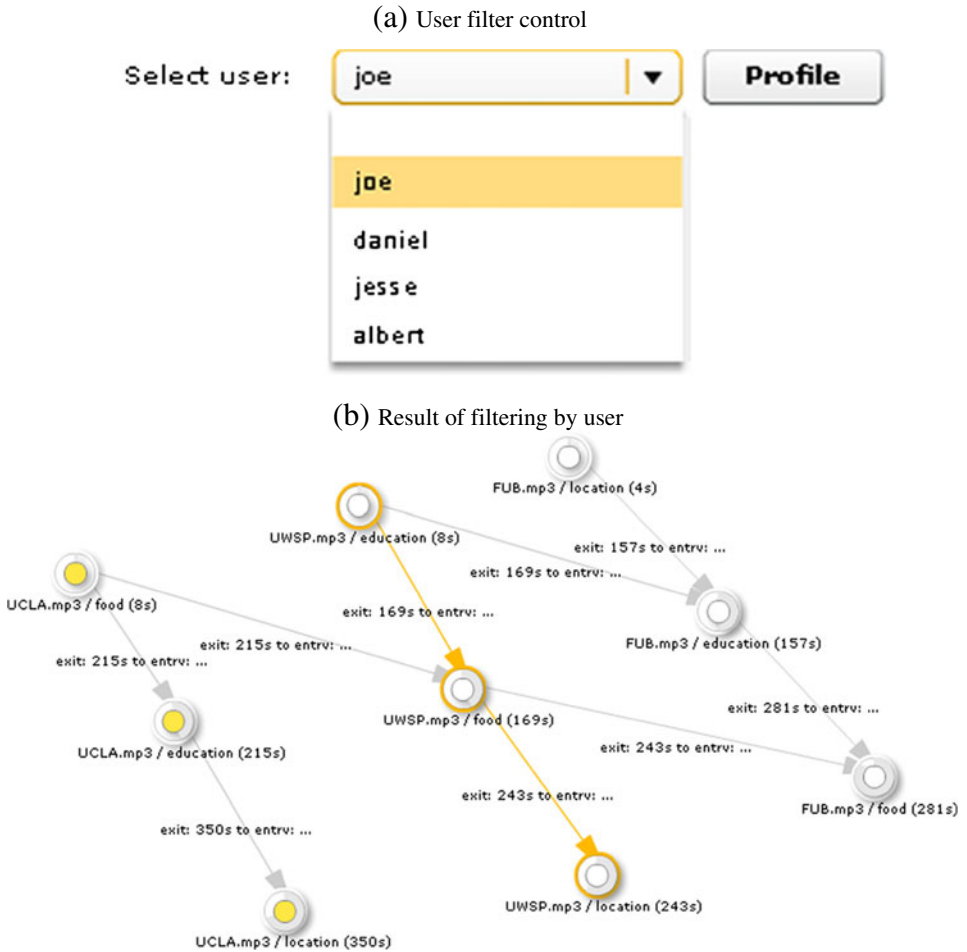
Figure 4. Filtering by user.

Overall, the latest graph control can be used to answer who has changed an artifact, what has been changed, and when it has been changed.

The *Latest Graph* control also offers a zoom feature (see Figure 2 (6)) for zooming in and out of the latest story graph. Thereby, we allow users to take a look at the full graph or have a closer look at specific nodes or edges. The zoom function is also available for the *Graph Evolution* as described in the following.

4.3. Evolution of the story graph (R3)

The second part of the story graph control is the *Graph Evolution* (see Figure 6). The Graph Evolution control addresses the question on *how* an artifact has

(a) Creation time filter control

(b) Result of filtering by creation times
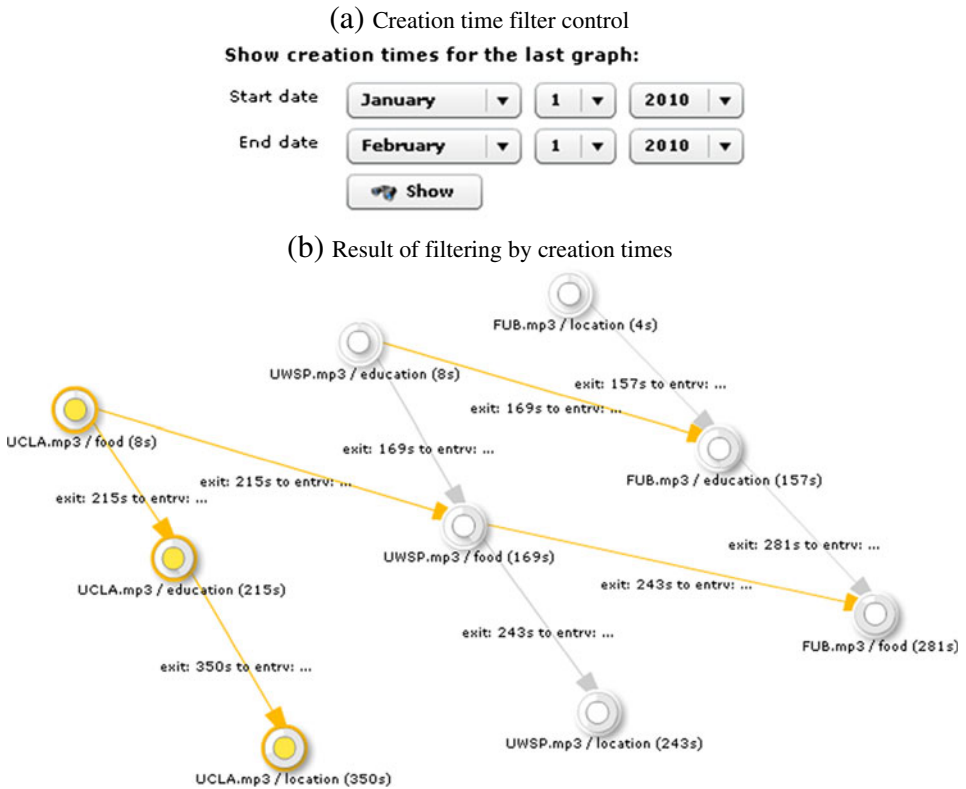
Figure 5. Filtering by creation times.

changed over time by providing several filter functions that allow users to display the activities that took place on the story graph according to a TIMELINE (Schümmer and Lukosch 2007). These filters allow users to retrieve information about all graph artifacts and on how they were created, modified or deleted over time.

By selecting a story (see Figure 6 (1)), the user filters the story graph evolution with regard to the created stories in the project. If a node or an edge is part of the selected story, then these nodes and edges are highlighted in the story graph. This filter offers the ability to see how the stories in the project were created. Additionally, a user can go directly to the rating of the selected story in the CASTing web portal.

The evolution function allows a user to REPLAY (Schümmer and Lukosch 2007) *how* the story graph developed over time (R3) and how the current state of the collaboration has been reached. Two sliders allow a user to replay the story evolution. The lower slider (see Figure 6 (3)) allows a user to pre-select a specific time period and the upper slider (see Figure 6 (2)) enables the user to slide through that selected time period. The current slide

FUB.mp3 / location (4s)

UWSP.mp3 / education (8s)

exit: 157s to entry: ...

exit: 169s to entry: ...

FUB.mp3 / education (157s)

UWSP.mp3 / food (169s)

exit: 281s to entry: ...

exit: 243s to entry: ...

FUB.mp3 / food (281s)

UWSP.mp3 / location (243s)

Story Graph Control

Latest Graph   **Graph Evolution**   Help

💡 Start evolution

(1) Select story: filter by story ▼ Rate

Evolution time step: 0 **(2)**   72

Time period for evolution: 0 **(3)**   72

(4)   Current step: 11

Current time: 2009-03-12 23:14:00.0   Zoom: ⊖ ⌄ ⊕ ⟳

Figure 6. Story graph evolution.

step and time are displayed in the lower part of the evolution function (see Figure 6 (4)).

4.4. Summary

The functionalities above address the identified requirements R1, R2 and R3. Considering asynchronous workspace awareness the following questions (Tam and Greenberg 2006) are answered:

1. *Where have changes been made?*: By visualizing the story graph evolution and highlighting the changes using different color schemes, users become aware of the location of changes.

2. *Who has made the changes?*: By offering users to filter by user and including tool tips, users become aware of the originator of changes. Additionally they can assess further information about a user via user profiles.
3. *What changes were made?*: The different color codes highlight what recent changes were made and make users aware of these changes.
4. *How were things changed?*: By replaying the story evolution users can understand how a story has been created.
5. *When did the changes take place?*: By offering users to filter by creation date of nodes and edges, users become aware of when changes were conducted. Similarly the color coding of the inner rings supports users in assessing when changes happened. Furthermore users can track the development of nodes and edges over time via the story graph evolution function.

5. Implementation

CASTing itself consists of three major components (see Figure 7): the CASTing client, the CASTing web portal, and a centralized storytelling server. The client application allows users to asynchronously create a project team, add audio recordings, segment audio recordings, link audio recordings and select and publish a linear story. Using the client application users can retrieve the most current version of the story graph and synchronize their local changes. The CASTing web portal allows users to publish podcasts on the Web and discuss, comment, vote and reuse audio-based stories. Both the web portal and the client access a centralized storytelling server. The server is responsible for user and project management, and provides services to access and synchronize the shared data (e.g. links between audio recordings, nodes in the story graph). These services are contained in the Storytelling Kernel and can be accessed both from the client application and the web portal.

In order to support the different filtering and highlighting functions as well as the story graph evolution, we created a persistent history of the user's activities. Using this history we can filter information and reconstruct the state of the story graph for a specific point in time. For creating and accessing the history two components were added to the storytelling kernel: an Activity Log (Schümmer and Lukosch 2007) and a service which utilizes the activity log. More precisely, the activity log records every change to the story graph in the database. The client as well as the web portal interact with the log by adding, consuming, or querying activities. Additionally, a service utilizing the activity log to provide information for the visualization and the filter mechanisms was implemented. The activity log stores

- the type of the activity, such as editing, creating, removing elements from the story graph,
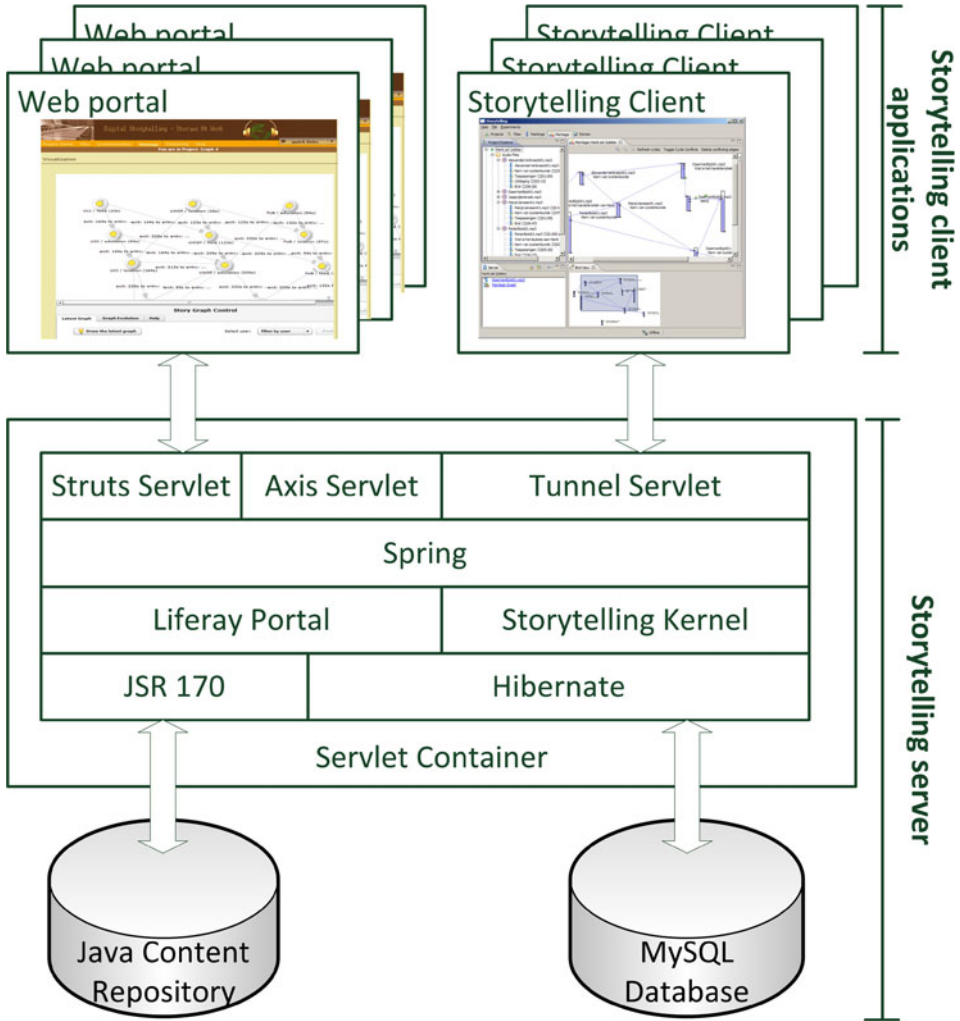
Figure 7. CASTing system architecture.

- the element of the story graph that was touched during the activity,
- the time at which the activity took place and
- the user who performed the activity.

The graph visualization itself and the control sections were developed as rich internet applications (RIA) and integrated into the web portal. They are based on BirdEye (Birdeye Group 2011) and Adobe Flex (Adobe Systems Incorporated 2011). BirdEye is a community project to advance the design and development of a comprehensive open source information visualization and visual analytics library for Adobe Flex. The library enables the creation of multi-dimensional data visualization interfaces for the analysis and presentation of information.

6. Evaluation

In this section, we evaluate the visualization based on the framework for asynchronous awareness (Tam and Greenberg 2006) by testing the following hypothesis:

Hypothesis Visualizing the changes in the story graph and its evolution creates asynchronous awareness among the group members and enables them to trace the activities in relation to their story.

The asynchronous awareness framework provides detailed questions for its different categories. However, not all of these categories are evaluated. First, the asynchronous awareness framework discusses three different views: the artifact-based view, the person-based view, and the workspace view. The workspace view goes beyond the story graph and includes audio files and time indexes in these files. It is therefore outside the scope of our approach, and consequentially not evaluated. Second, as argued in the introduction, we do not address the question *why*. Third, the evaluation does not address the question *Who made changes with this person?* and *Who has this person interacted with?*. Both questions refer to synchronous interactions among the users of the system. As CASTing is only supporting asynchronous interactions the question of synchronous co-authorship is irrelevant for the users of the system. Last, the question *how* is supported by the replay mechanism of the visualization. This replay function addresses the question how changes were made and how a person has changed things. It is a common technique for addressing asynchronous awareness related to the question how changes were made (see also Section 3). It is therefore not necessary to further evaluate whether the visualization supports this aspect of the awareness framework.

Overall, the focus of the evaluation regarding asynchronous awareness is on the questions *who*, *when*, and *what* for the artifact- and person-based view. Table 1 gives an overview about those questions of the framework that we address in our evaluation.

In addition to the questions derived from the asynchronous awareness framework, we also evaluate whether the user interface is easy to handle for the project members. If it is easy then the users are able to get all the information they need. So the asynchronous workspace awareness is supported in an indirect way.

6.1. Experimental design and procedure

In order to test our hypothesis we conducted an experiment with four conditions, each consisting of a different story graph (see Figure 8). The story graphs increase in complexity and correspond to the scenario in Section 2.2.

Table 1. Evaluation of asynchronous awareness.

	Information elements	General items	Artifact-based view	Items	Person-based view	Items	Total
Who	Identity	2	Who made a particular change to this artefact?	9, 12, 14	Which artefacts has this person changed?	9, 10, 12, 14	2, 9, 10, 12, 14
	Authorship History	3, 4, 6	Who has changed this artefact (overview)?	1, 10	–		1, 3, 4, 6, 10
When	Event History		When was this artefact changed? When was a particular change to this artefact made? In what order were changes made to this artefact?	7, 8, 11, 13	When did a person make changes? When did a person make a particular change? In what order did this person make changes?	5	5, 7, 8, 11, 13
What	Action History		What changes have been made to the artefact?	5 7–14 (without 10), only implied	What artefacts has a person changed? What activities has a person engaged in?	9, 10, 12,14	5, 7–14

The experimental conditions differ not just with regard to the complexity of the graph, but also with regard to the scrolling behavior required of the participants. The first condition consisted of a graph with nine nodes and nine edges (see Figure 8 (a)). The participants were able to see the entire graph without scrolling. The second condition consisted of a graph with twelve nodes and 18 edges (see Figure 8 (b)). We thus added three nodes and seven edges to the existing graph. Here, the participants did not have to scroll, but had to deal with a more complex graph. For the third condition we added three nodes and nine edges to the existing graph (see Figure 8 (b)). In this condition the participants had to scroll a little bit to see the entire graph. For the last condition we used a graph with 18 nodes and 36 edges (see Figure 8 (d)). This graph was the most complex one and the participants had to scroll in all directions to see the entire graph. Figure 9 provides an overview about the different graph complexities.

Overall, the experimental design allows us to study how the size and complexity of the story graph influences the asynchronous awareness of the participants, but it does not provide us with a control condition. Literature also does not provide a basis for comparison for asynchronous awareness support in graphs (see also Section 3). However, by comparing the results obtained in the experimental conditions with chance levels for asynchronous awareness, we can assess whether the visualization has an effect on the awareness level of the participants (see also Section 6.3 for details).

The experiment itself was divided into two phases. In the first phase each participant was provided with basic information about storytelling and what he/she can expect to see in the visualization prototype. Thus, the participant acquired basic knowledge about the scenario for completing the experiment. In addition, each participant provided demographic information as well as information about their previous knowledge (see Figure 10 for the results). In the second phase each participant worked with the visualization and filled out a digital questionnaire at the same time. The participant was free to choose the time at which he or she completed the experiment.

6.2. Participants

Altogether 40 voluntary participants within the age of 22 to 53 took part in the experiment. The participants were assigned to the four experimental conditions, with ten participants per condition. Eleven of them were female and 29 were male. The participants had different cultural backgrounds (Europe, Africa, North America and Asia). Overall, it took the participants of the first three conditions 21 minutes on average to complete the session. In the fourth condition, the most complex graph, they needed 31 minutes on average.

(a) Experimental condition 1
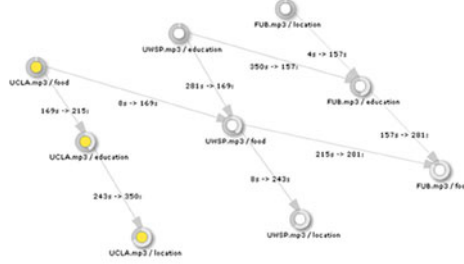
(b) Experimental condition 2
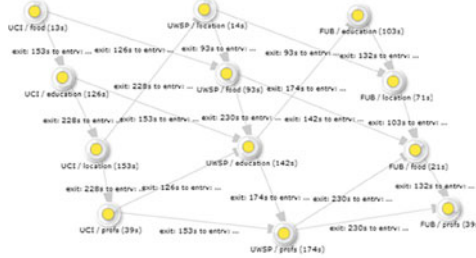
(c) Experimental condition 3
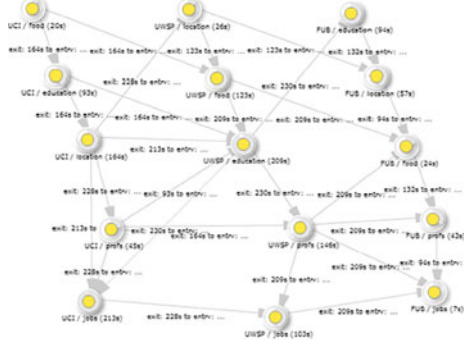
(d) Experimental condition 4
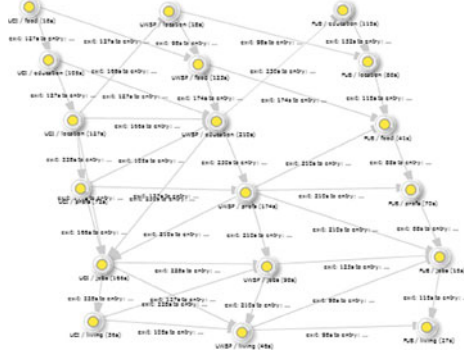
Figure 8. Story graphs used in the four experimental conditions.
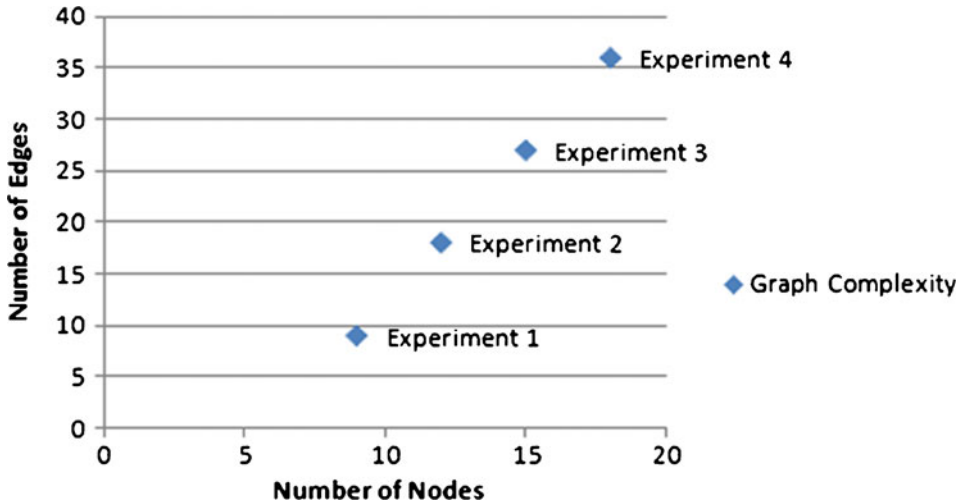
Figure 9. Graph complexity.

Before the experiment, we asked the participants to judge their experience with storytelling, groupware, and group awareness support (see Figure 10). Altogether, the participants had little experience with storytelling and group awareness support. Only three participants had used storytelling techniques, and another three considered themselves experts in this area. Similarly, only nine participants had used group awareness techniques, and only one participant considered him- or herself an expert. Both for storytelling and group awareness support, at least 75% of the participants claimed to have not used these techniques before. In contrast, the experience with groupware is much higher. 50% of the participants have at least used groupware before. Eight of these consider themselves experts in this area. All in all, the experience level of the participants was mixed from "not heard of it before" to "expert" for all three theoretical categories.

6.3. Measurements and analysis

In order to evaluate how bad or well the visualization supports asynchronous awareness, we provided the participants with a questionnaire with multiple-choice questions addressing different categories in the awareness framework. Table 2 provides an overview over the items, and Table 1 relates these items to the different categories of the awareness framework. The items do not address the question *where* changes were made. By interacting with changed nodes and edges in the visualization users already demonstrate awareness that changes have been
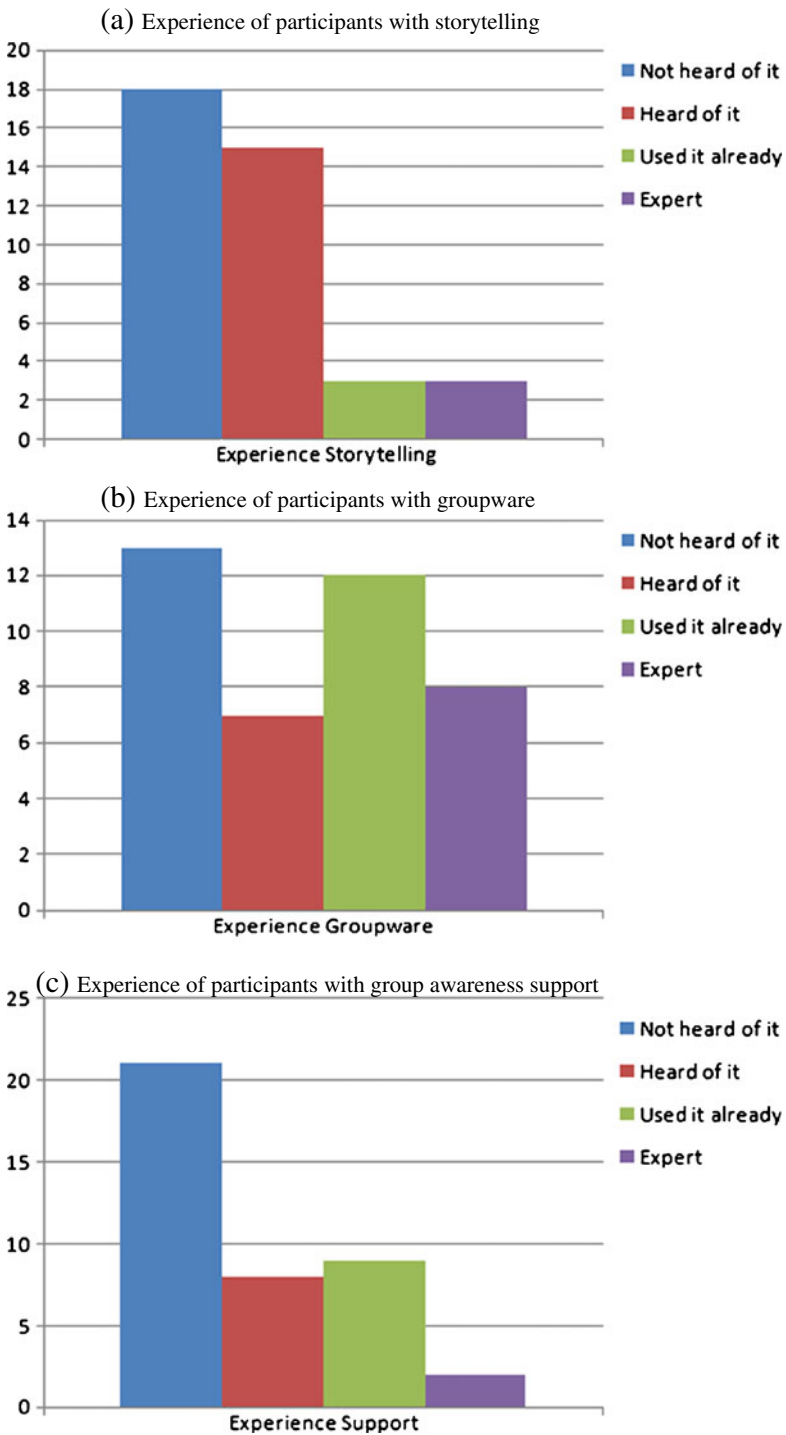
Figure 10. Experiences of participants.

made to that artifact. Thus, *where* changes have been made is not explicitly measured.

In order to address the increasing complexity of the story graphs and to ensure that participants had to look at the entire story graph the number of questions increases with the complexity of the story graph.

We extended the authorship history of the awareness framework with three questions relating to the activity levels of the characters working on the story graph. Specifically, we assessed whether the participants showed any awareness on *who* is the most active or inactive person working on the story graph (item 3 and 4 respectively). This kind of information is particularly relevant for any newcomer to an existing project, because it indicates the people who have the best (or worst) understanding of the story graph. Even though these items are relevant for the authorship history, they do not have a clear mapping to any view in the awareness framework, because they ask for a summary instead of particular details about what an author did. Thus, we treated them as general items in this category. In addition to the activity levels, we assessed whether the participants showed any awareness of *who* was the last person working on the story graph (item 6). This information is relevant for anybody who wants to continue to work on the story graph. As with the activity levels, this information could not be assigned to any specific view. Even though the question clearly asks about an author of the story graph, it also contains a time component making it difficult to match a view to this question.

For each participant we calculated the percentage (the score) of correct answers for the different categories in the awareness framework. Furthermore, we

Table 2. Multiple-choice questions for assessing awareness.

Item	Question	Used in Condition			
		1	2	3	4
1	Which persons have applied changes to the story graph?	x	x	x	x
2	What is John's last name	x	x	x	x
3	Which person is the most active regarding to the story graph	x	x	x	x
4	Which person is the most inactive regarding to the story graph	x	x	x	x
5	What did Jesse do on March 20th	x	x	x	x
6	Which person was the last working on the story graph?	x	x	x	x
7	At which point in time was added the node "UWSP / location"?	x	x	x	x
8	At which point in time was added "UCI / profs"?	–	x	x	x
9	Who added the edge "UWSP / profs" to "FUB / profs"?	x	x	x	x
10	Which person would you contact, if you have questions to the UWSP Interview?	x	x	x	x
11	At which point in time was added the node "FUB /jobs"?	–	–	x	x
12	Who added the edge from "UCI / jobs" to "UWSP / jobs"?	–	–	x	x
13	At which point in time was added the node "UWSP / living"?	–	–	–	x
14	Who added the edge from "UCI / living" to "UWSP / living"?	–	–	–	x

calculated the mean score for each experimental condition and each assessed category of the awareness framework.

The experiment does not contain a control group. In order to provide a baseline and thus assess whether the awareness mechanisms are effective, we obtained a chance level by simulating how somebody trying to guess the right answer would have performed. First, the items in the questionnaire were answered using a random number generator. Altogether, 100 additional cases forming a 'random group' were created. This 'random group' was then analyzed using the same methods as for the experimental conditions. Specifically, a mean random result [1] was obtained for the different categories of the awareness framework and for each task.

A Mann-Whitney U test (see e.g. Field 2009) was used to assess whether there are significant differences between awareness levels in the experimental conditions and the chance level, or between awareness levels in different experimental conditions.

Regarding usability aspects of the visualization we obtained qualitative as well as quantitative feedback from the participants. The quantitative measurements were obtained using the following two items (using a five-point Likert scale):

- The handling of the story graph visualization was easy to learn.
- I always knew where I am and what to do.

7. Evaluation results

In the following, we analyze and discuss the results of the experiment and compare the experimental conditions with each other and with the chance level. Table 3 provides an overview about the mean scores per category of the awareness framework. The mean scores per item in the questionnaire can be found in the Appendix 9 in Table 4. The Appendix also contains the results of the Mann-Whitney U tests in Tables 5 and 6.

The mean values for all experimental conditions are considerably higher than the chance levels (see Table 3) for all tested awareness categories. In addition, the Mann-Whitney U tests (see Table 6) showed that these differences are significant. There is one exception, however. For the most complex graph (experimental condition four) the awareness displayed by the participants in relation to the question *when* in the person-based view is not better than the chance level. Consequently, the visualization is effective in

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[1] Using probability theory we could have obtained exact probabilities for guessing the right answer. However, without simulated cases we could not assess whether the differences are significant.

Table 3. Mean score per category in the awareness framework.

Awareness	Category		Condition 1	Condition 2	Conditon 3	Condition 4	Random results
Who	Identity	Artefact Based View	100.00	100.00	95.00	70.00	19.33
		Person Based View	100.00	95.00	96.67	72.50	30.50
		Total	100.00	93.33	92.50	76.00	27.60
	Authorship	Artefact Based View	100.00	95.00	100.00	80.00	32.00
	History	Total	94.00	96.00	94.00	84.00	25.40
	Total	Artefact Based View	100.00	96.67	97.50	74.00	24.40
		Person Based View	100.00	95.00	96.67	72.50	30.50
		Total	95.71	95.71	92.50	80.00	22.33
When	Event	Artefact Based View	100.00	90.00	93.33	92.50	19.50
	History	Person Based View	100.00	60.00	80.00	40.00	25.00
		Total	100.00	75.00	86.67	66.25	22.25
What	Action	Artefact Based View	100.00	85.00	91.67	77.50	20.13
	History	Person Based View	100.00	95.00	96.67	72.50	30.50
		Total	100.00	86.00	92.86	77.78	25.00
Artefact-Based View		Total	100.00	88.00	92.86	77.78	17.89
Person-Based View		Total	100.00	83.33	92.50	66.00	29.40

creating asynchronous awareness for increasingly complex story graphs in relation to the questions *who*, *what*, and *when*, both for the artifact-based view and the person-based view. The exception relating to the person-based view of the question *when* was measured with a single item. Here, further research is necessary to establish that this exception holds for the visualization of the story graph.

When comparing the mean values of the experimental conditions with each other (see Table 3), we can observe that the mean awareness scores frequently increase from experimental condition 2 to the experimental condition 3. The Mann-Whitney U test (Table 5) showed, however, that these increases are not significant. From an interaction perspective the participants in condition 2 did not need to scroll. However, in condition 3 the participants were required to scroll in order to interact with the whole story graph. Thus, the transition from 'not scrolling' to 'scrolling' had little effect.

Another pattern visible in the mean scores is that the awareness of the participants working with the most complex graph (experimental condition 4) is considerably lower than in the other experimental conditions, particularly compared to the least complex graph (experimental condition 1). The Mann-Whitney U test (Table 5) showed that the differences between conditions 1 and 4 are significant, with the exception of the artifact-based view relating to the question *when* and the authorship history relating to the question *who*.

The exception *who*/authorship history applies only to the total score, but not to the partial score relating to the artifact-based view. This can be explained by looking at the differences in the multiple-choice questions between these two categories. These questions ask about a summary of the data, e.g. '*who* is the most active / inactive person?' or '*Who* was the last person working on the story graph?'. Considering that the filter mechanisms in combination with the color-coding allow a quick overview over *who* changed *what*, we can conclude that this combination is a suitable mechanism for creating awareness regarding such a summary.

Overall, the awareness levels and usability of the graph visualization (see Figure 11) decreases slightly with increasing complexity. We expected this because graph visualizations usually tend to get confusing the more complex they are. In general, this still shows that the visualization prototype provides the user with all necessary awareness information to get an overview about what happened within a project in the past.

As part of the usability evaluation, the participants provided some feedback for further improvement of the visualization. Some of them mentioned that the color contrast between the age of nodes should be stronger. Also the arrows (edges) should be placed outside the circle and the label on the edges bothered the participants. One of them mentioned to use green color instead of orange for new nodes and edges, because it is more distinguishing. Another improvement would be to create more space between the single nodes and provide in general more screen space for the story graph. The slide bar was not very easy to use. A button for stepwise going through the development of the story graph would be better. Furthermore it would be a nice feature if participants had an actual insight in the visualized audio files with the story graph, e.g. playing the selected part of an audio file by clicking on a specific node.

In addition, the participants requested additional functionality, e.g. highlighting a specific date and a specific user at the same time. Another useful improvement could be to highlight nodes that come from the same audio file, as well as the possibility to move nodes in the visualization and the use of semantic zoom. Finally, as some were not able to see the entire graph while looking at detailed information, they suggested to include an overview map to tackle this issue. The impact of some of these suggestions on the various awareness questions remains an interesting topic for future research.

All in all, the visualization is effective in creating asynchronous awareness for increasingly complex graphs among group members and enables them to trace activities in relation to their story. The results also show that the visualization makes users aware of other users within the story graph and the project. This fact and the easy learning of the story graph handling enables users to track the
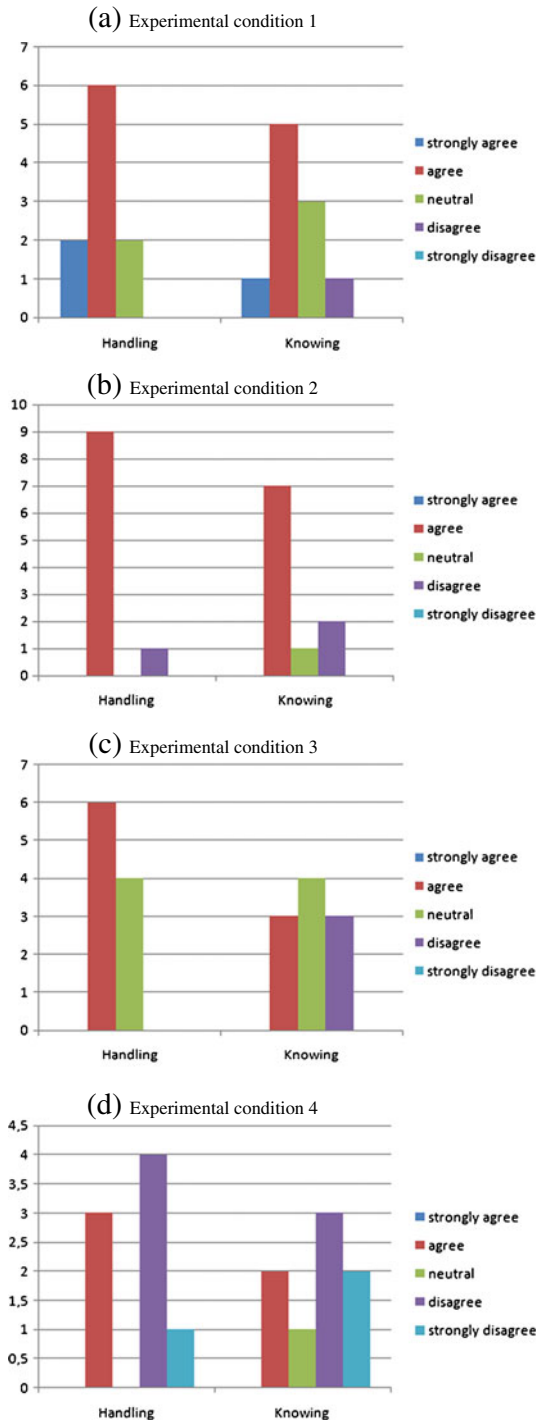
Figure 11. Usability results in the four experimental conditions.

activities of other users and to question and understand the work results of other users.

8. Conclusions and future work

One of the major challenges for collaboration is to achieve shared understanding. When considering asynchronous collaboration, it is essential to provide awareness support that allows users to understand recent changes. Otherwise collaboration can get out of control and missed changes can unintentionally play havoc with the whole collaborative process (Tam and Greenberg 2006).

We have observed the above within CASTing, a tool for collaborative audio-based storytelling (Lukosch et al. 2011). In CASTing, users often collaborate asynchronously and the asynchronously growing story graphs make it difficult for users to trace the evolution of these graphs. Based on the concept of asynchronous workspace awareness (Tam and Greenberg 2006) we identified requirements for a novel approach to visualize the story graph evolution and provide asynchronous awareness support. Our approach focuses on the questions *where* changes have been made, *who* has made changes, *what* changes were made, *how* things were changed, and *when* changes did take place. To answer these questions, our approach uses the following key elements:

- The visualization of the story graph evolution and highlights the changes as well as their point in time using different color schemes.
- Tooltips and labels provide users with additional contextual information about nodes and edges in the story graph.
- Different filters allow users aware to identify who has made changes and when changes happened.
- The replay of the story evolution explains how changes were conducted.

We implemented our approach within CASTing and evaluated it in an experiment with 40 participants exploring story graphs of different complexity. The results obtained in this experiment can serve as a baseline comparison for future studies focusing on asynchronous awareness in graphs. We also extended the framework of Tam and Greenberg (Tam and Greenberg 2006) with questions focusing on summaries of the authorship history, e.g. '*Who* has been the most active / inactive person working on the story graph?' or '*Who* was the last person working on the story graph?'.

Overall, the experiment showed that our visualization approach enables users to acquire awareness by accessing information about previous work of other users and to follow the development process of the story graphs. More specifically, the visualization is effective in creating asynchronous awareness relating to the

questions *who*, *when*, and *what*, with the exception of *when* in a person-based view for complex graphs. Another interesting result is that the need to scroll did not have a significant effect on awareness levels, even though it became more difficult for users to navigate in the story graph. Furthermore, for most awareness categories, we could observe a significant decrease in awareness levels when comparing the least complex story graph with the most complex story graph. One notable exception relates to awareness levels regarding summaries of authorship information. Here, awareness levels do not decrease significantly with increasing complexity of the story graph.

The results of the experiment and its limitations also point out several opportunities for further research. First, further research is necessary to overcome the issues in relation with the question *when* in the person-based view. Second, further research should target the question how awareness support for increasingly complex graphs could look like. Third, the experiment only employed graphs with a regular structure. This regular structure emulates a user's tendency to arrange the nodes in graph to make it easy to gain an overview and thus reduce the complexity of the graph. However, it limits the conclusions we can draw about asynchronous awareness in graphs with a more irregular structure (e.g. graphs that are not planar). In addition, the number of users working on the non-linear story as well as the number of audio files used in the story graph were kept constant during the experiment. Thus, future research could explore how changes in these two variables affect asynchronouns awareness.

During the experiment we also discovered limitations of the prototype which inform future improvements, such as changes to the color coding or additional filters. In addition, users are not able to access the audio files represented by the nodes. While the story graph visualization provides awareness regarding changes to the graph itself, awareness support for the evolution of the underlying content is still missing.

Furthermore, future work should address asynchronous awareness support for the question '*Why* were changes made?' (see also Section 1).

In future work, we plan to explore the impact of the suggestions above. Furthermore we plan to address the following questions: Do users require less time to introduce themselves to a project when using our asynchronous awareness support? Does our visualization approach lead to a better coordination and communication between project members? By answering those questions we want to extend our asynchronous awareness support in the future.

9. Appendix

Table 4. Mean score of items.

Item	Condition 1	Condition 2	Condition 3	Condition 4	Random Results
1	100	100	100	80	0
2	100	90	80	90	16
3	90	90	90	70	25
4	80	100	80	100	13
5	100	60	80	40	25
6	100	100	100	90	25
7	100	80	90	100	19
8	–	100	90	90	21
9	100	100	90	60	18
10	100	90	100	80	64
11	–	–	100	90	15
12	–	–	100	70	21
13	–	–	–	90	23
14	–	–	–	80	19

Table 5. Significance of differences in the means between experimental conditions.

Task category	Experiment 1 vs 2		Experiment 1 vs 3		Experiment 1 vs 4		Experiment 2 vs 3		Experiment 2 vs 4		Experiment 3 vs 4	
	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed
Who–Identity–Artefact Based View	ns	ns	ns	ns	ns	0.043	ns	ns	ns	0.043	ns	ns
Who–Identity–Person Based View	ns	ns	ns	ns	0.033	0.016	ns	ns	ns	0.049	ns	0.038
Who–Identity–Total	ns	ns	ns	ns	0.033	0.016	ns	ns	ns	ns	ns	ns
Who–Authorship History–Artefact Based View	ns	ns	ns	ns	ns	0.043	ns	ns	ns	ns	ns	0.043
Who–Authorship History–Total	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.050	ns	ns
Who–Artefact Based View–Total	ns	ns	ns	ns	0.011	0.005	ns	ns	0.034	0.017	0.034	0.017
Who–Person Based View–Total	ns	ns	ns	ns	0.033	0.016	ns	ns	ns	0.049	ns	0.038
Who–Total	ns	ns	ns	ns	0.036	0.018	ns	ns	ns	0.028	ns	ns
When–Event History–Artefact Based View	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
When–Event History–Person Based View	ns	0.043	ns	ns	0.011	0.005	ns	ns	ns	ns	ns	ns

Table 5. (continued).

Task category	Experiment 1 vs 2		Experiment 1 vs 3		Experiment 1 vs 4		Experiment 2 vs 3		Experiment 2 vs 4		Experiment 3 vs 4	
	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed
When–Total	ns	0.043	ns	ns	0.011	0.005	ns	ns	ns	ns	ns	0.050
What–Action History–Artefact Based View	ns	0.043	ns	ns	0.003	0.002	ns	ns	ns	ns	ns	0.048
What–Action History–Person Based View	ns	ns	ns	ns	0.033	0.016	ns	ns	ns	0.049	ns	0.038
What–Total	0.033	0.016	ns	ns	0.003	0.002	ns	ns	ns	ns	ns	0.045
Artefact Based View–Total	ns	0.043	ns	ns	0.001	0.000	ns	ns	ns	ns	0.039	0.020
Person Based View–Total	0.033	0.016	ns	ns	0.003	0.002	ns	ns	ns	ns	ns	0.044

Table 6. Significance of differences in the means of experimental conditions and random results.

Task Category	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed
Who–Identity–Artefact Based View	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Who–Identity–Person Based View	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Who–Identity–Total	0.000	0.000	0.000	0000	0.000	0.000	0.000	0.000
Who–Authorship History–Artefact Based View	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Who–Authorship History–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Who–Artefact Based View–Total	0.000	0.000	0.000	0000	0.000	0.000	0.000	0.000
Who–Person Based View–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Who–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
When–Event History–Artefact Based View	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
When–Event History–Person Based View	0.000	0.000	0.029	0.029	0.001	0.001	**0.451**	**0.249**
When–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
What–Action History–Artefact Based View	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
What–Action History–Person Based View	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 6. (continued).

Task Category	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed	2-tailed	1-tailed
What–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Artefact Based View–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Person Based View–Total	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000

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