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WANG, Jing <http://orcid.org/0000-0002-5418-0217>, HO, Yufang, XU, Zhijie, MCINTYRE, Dan and LUGEA, Jane

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The Visualisation of Cognitive Structures in Forensic Statements

Jing Wang[1], Yufang Ho[2], Zhijie Xu[1], Dan McIntyre[2], Jane Lugea[2]
[1]School of Computing and Engineering, University of Huddersfield, UK
[2]School of Music, Humanities and Media, University of Huddersfield, UK
{j.wang2, y.ho, z.xu, d.mcintyre, j.lugea}@ hud.ac.uk,

Abstract

Forensic statements are often unstructured, intricate, and thus difficult to interpret and assess. This is due to the varied nature and format of how interviews with victims, witnesses, or suspects are conducted. It is even more difficult for police investigators, lawyers or other legal practitioners to grasp intuitively and accurately the key information pertaining within the varied statements. This research investigates the opportunities in the convergence of linguistic approaches to extracting and reconstructing the cognitive structure, i.e. "Text-Worlds", in a statement, and the computerised operational settings for enabling effective and hopefully more accurate interpretation of forensic discourse through visualisation.

Keywords--- **Information Visualisation; Text World Theory; Forensic Stylistics**

1. Introduction

Forensic statements are the text records made by victims, witnesses and suspects. Those statements, along with other physical evidence, are often used to reconstruct truthful crime stories during criminal investigations and court proceedings. However, legal practitioners usually have to face necessarily detailed, extremely complicated and large amounts of text records. It is often challenging for them to identify connections between disparate pieces of linguistic evidence, and to properly assess their probative values to the case in question. Various approaches have been developed for evidence representation, manipulation and automated analysis [1-3]. However, a rigorous method that can facilitate the interpretation of detailed forensic statements and assist in objective judgments is still underdeveloped.

Recently, there has been a trend in using graphical representation tools to interpret raw text. For example, some researchers have used Word Clouds [4] to highlight the primary topics/themes of a text, or draw a Similar Diversity [5] graph to measure the words similarity in an article. Those tools allow researchers to quickly visualise some general patterns in text. However, they focus mainly on the frequency analysis at word/phrase level from the original text, and the content analysis at the semantic or discourse level tends to be neglected.

Many researchers from forensic and computing sciences, such as [6-8], have developed visualisation tools to represent spatial-temporal distribution, causality, arguments and contradictions in text evidence, based on empirical or quantitative analysis augmented by other data inputs such as DNA test, body fluid examination, and fingerprints comparison. However, no research attempt has been made in systematically representing cognitive linguistic structures in a statement into an intuitive visualisation format for forensic applications.

The research has built on and improved existing techniques in the field by operationalising a sophisticated cognitive model of human discourse processing known as Text World Theory (TWT) [9, 10]. A prototype of linguistic information visualisation system named as *Worldbuilder* has been developed. *Worldbuilder* is a web-based visual inference system that is designed to help users to understand complicated forensic statements. The system applies a mark-up scheme that encompasses the range of descriptive categories found in TWT to raw statements annotation. The mark-up scheme provides a systematic and replicable structure that could be useful in examining which elements of the text are likely to be important for criminal investigation. An interactive visualisation platform is then deployed for the purpose of assisting users in understanding the crime stories reconstructed from the annotated data.

This paper highlights two contributions: firstly, a TWT mark-up scheme has been developed, which provides a structured framework for quantitative analysis of complicated information from human language and raw text; secondly, cognitive structures of forensic statements can be visualised through a graphical human computer interface, which helps forensic linguistic experts or potential end-users (*e.g.* investigators, judges, prosecuting and defence counsels, *etc*.) to understand and evaluate those forensic statements.

This paper is structured as follows: Section 2 gives a brief introduction to TWT; Section 3 highlights the key design and development of the *Worldbuilder* system. In Section 4, based on our previous text-world analysis [11] of three controversial police statements recorded from a real crime case, the murder of Meredith Kercher, we illustrate how the designed information visualisation scheme represents complicated cognitive structures

projected in the statements. Section 5 concludes the paper with envisaged future works.

2. Introduction to Text World Theory

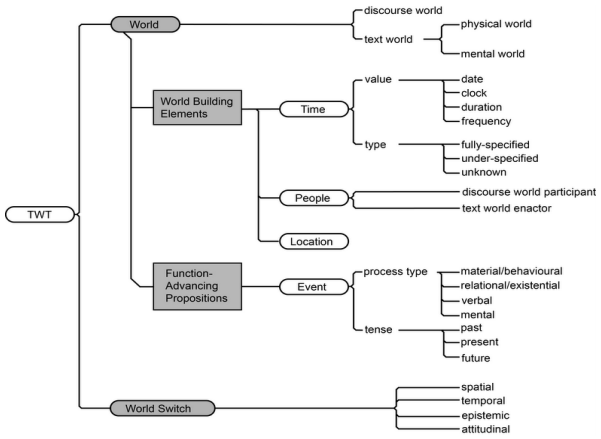

Figure 1 TWT cognitive framework

Text World Theory [9, 10] is situated within the tradition of cognitive stylistics, focusing on relating linguistic choices to cognitive structures and processes that underlie the production and reception of language. In this research, TWT has been operationalised as a structured framework as shown in Figure 1.

The cognitive model of human discourse processing divides all discourse situations into three manageable levels of conceptual activity: *discourse world*, *text worlds*, and *world switches*. In this framework, the *worlds* are constructed via *world building elements* and linked by the *world switches*, e.g. a shift in time and/or location from one world to another. These elements constitute the fundamental quantitative inputs for the visualisation process.

- **World**

TWT makes an initial distinction between the *discourse world* and the *text world*. The *discourse world* is a specific real-life context where the language event takes place. It comprises the discourse participants and the immediate physical surroundings (e.g. the police investigators interview a witness in a police station). The next level is the *text-world*, which is the detailed *mental representation* (of time, location, people or the reported actions/events/states) that the discourse participants construct in their mind as they communicate.

- **World building elements**

The language features that establish the spatial-temporal parameters and the people who populate a world are called *world-building elements*. The elements of building a world include "time" (realised through adverbs of time or the tense/aspect of verb phrases), "people" (discourse participants or text-world enactors, realised through proper nouns or pronouns) and "location" (realised through adverbials or noun phrases specifying place).

- **Function-advancing propositions**

Within the model, the propositions that propel the discourse forwards in some way for the participants to achieve certain communicative objectives are known as *function-advancing propositions*. They are categorised into four main process types (based on Halliday's 1985 and 1994 Systemic Functional framework [12, 13]). We use process types (realised via verb phrases) to identify the reported "events" in a text.

Take the sentence: *On November 1st, I woke up at around 11 in my house, I had breakfast with Amanda, then she went out and I went back to bed*, for example. In this proposition, the linguistic reference to time (*on November 1st, at around 11*), enactors (*Amanda and I*), location (*my house*), and events (*woke up, had breakfast, etc.*), come together to form our mental representation of *that* world we constructed from processing the text.

- **World switches**

As the cognitive model also intends to capture the dynamic nature of the discourse process, the third level is called *world-switches*, which indicate a departure from the initial or preceding text-world parameters, for example, the change of time or location (e.g. *we met soon after at about 21:00 at the basketball court*), or the change in a speaker's knowledge/belief with regard to a particular subject matter (e.g. *I do not remember if Meredith was screaming*).

It should be noted that the *world-building elements* encompass WHO-WHEN-WHERE information regarding the discourse world (which in our data constitutes a legal setting, e.g. police station or court room), or text-worlds (e.g. the mental constructs of the states/events reported by discourse participants such as victims, witnesses or suspects). *Function-advancing propositions* and *world-switches* cover 'WHAT HAPPENED'. All of these information components constitute key factors in crime investigation and judicial reasoning. A detailed analysis of the subtle spatial/temporal and epistemic world-switches projected in any given forensic statement can be of great use for forensic specialists in reconstructing the events reported by various parties involved, evaluating alibis and/or assessing truthful or deceptive statements.

3. The *Worldbuilder* Annotation and Visualisation System

Based on the cognitive framework specified in Section 2, *Worldbuilder* has then been developed with two primary objectives: (a) to assist human researchers in the manual annotation of the key linguistic elements associated with the cognitive structure in a forensic text; and (b) as a result of the mark-up of data, to improve computer-based techniques for visualising complex information and accordingly enhancing the readability of forensic statements. This mark-up scheme is a significant improvement on existing practices due to its systematic and replicable operational approach. This section reports the development of the *Worldbuilder* annotation interface and the resulting visualisation outputs.

To present the text-worlds cognitive structure effectively, both aesthetic form and functionality need to go hand in hand, providing insights into complex data by communicating its key aspects in an intuitive way. The

following figure explains the operational process of the proposed system.

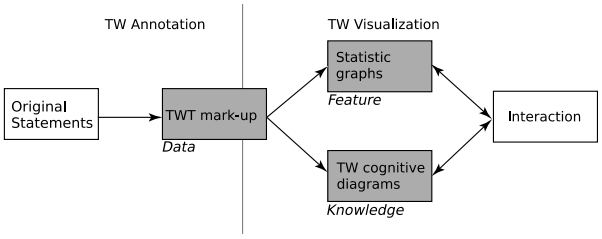

Figure 2 *Worldbuilder* operational pipeline

As shown in Figure 2, *Worldbuilder* contains two major consecutive operations. At first, raw forensic statements are manually annotated according to the principles and rules of the devised TWT framework. Then, the digitised and structured data can be interpreted and analysed through the proposed interactive visualisation scheme. As highlighted by the shaded rectangles in Figure 2, three types of information are essential for visualisation:

- Data: original text information
- Feature: TWT statistical information
- Knowledge: TWT cognitive structure

It is also based upon this computerised process that the different nature of text information can be classified, categorised and quantified for further analysis, for example, using statistical tools like histograms and pie-chats to represent percentage and frequencies of specific TWT elements that occur in a statement. This helps linguistic experts to observe textual patterns that may not be readily accessible via qualitative analysis, and to analyse the macro-level cognitive structures of statements from the case in hand. The details will be explained in Section 3.1 and 3.2.

3.1. TWT mark-up

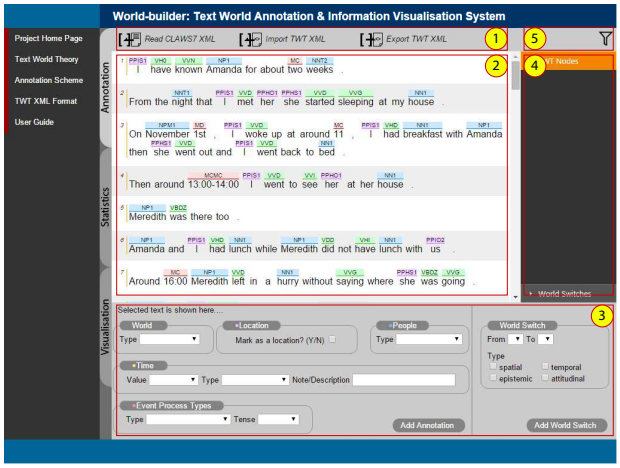

Figure 3 Snapshots of UI

As shown in Figure 3, *Worldbuilder* is a web-based system developed in this research for assisting forensic linguistic analysis. The system is developed by using the Hypertext Mark-up Language (HTML5) and JavaScript, which can be readily processed and displayed by mainstream Web Browsers such as Internet Explorer, Safari, Firefox, and Chrome. This approach also provides great portability for the system usage in various legal proceedings.

It is worth noting that the colour features at the linguistic annotation stage is driven by the real demands from linguistic analysts for improving user experience. Visualising raw texts in this manner, especially through highlighting their grammatical properties, can help annotators to locate "world building elements" and "events" more efficiently. The outcome of this annotation process is a diagram of text-worlds projected in each statement (see Section 4). The TWT mark-up process in this design will then convert raw statements into structured format for ease of processing data quantification and information visualization.

As shown in Figure 3, the annotation interface contains 5 zones (referred as Z1, Z2, Z3, Z4 and Z5). Z1 is used for project and file management with functions like saving and loading TWT mark-ups as XML files. Z2 provides an editing window with Z3 offering the TWT mark-up tools. The annotation will be automatically highlighted by coloured underlines in Z2.

Z4 displays the marked world-building elements (time/location/people) and the "events" in a world in a list format. As shown in Figure 4, Z4, in this case, generates a list of "World Nodes" and a separate list of "World Switches" after annotation.

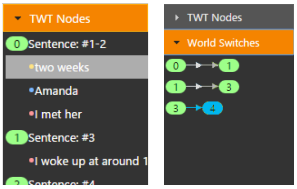

Figure 4 List of annotated data

In the "World Nodes" list, multiple text-worlds are represented by solid oval shapes containing the world index numbers. The world building elements are listed as bullets points. In "World Switches" list, the movement between worlds are represented with arrows pointing from one world to another, and the colour is designed for illustrating different switch types. In certain scenarios, multiple types of world-switches can happen. For example, when a shift in both spatial and temporal locations is observed and marked, two arrows are used conjointly to connect the two text-worlds.

To ensure intuitive and user-friendly experience, the CLAWS7 tag-set [14] for automatic parts-of-speech (POS) annotation is adopted to assist annotators in locating important TWT elements from the raw text input. At the current stage, we only choose to highlight certain CLAWS7 tags (e.g. nouns, verbs, pronouns and numbers) that are particularly relevant to the mark-up of TWT cognitive structure. They are differentiated by the coloured box with the POS label attached on top of the word. Z5 is designed for filtering purposes, that is, for the annotators to decide which grammatical features to

be shown in the raw text, to keep the information clean and clear.

Corpus linguists often make use of quantitative methods for an objective analysis of the linguistic features in a given text. After data annotation, *Worldbuilder* is also designed to generate graphical presentation of quantitative information with regard to the annotated data, for ease of further linguistic analysis (see Section 4).

3.2. TW cognitive diagrams

As discussed in Section 2, the TWT cognitive framework is employed for analysing forensic statements via reconstructing the text-worlds projected in a text. The *world building elements*, together with *world-switches*, offer the building blocks for answering the questions such as WHO-WHEN-WHERE and WHAT HAPPENED around a case. A cognitive diagram is the graphical representation of those mental projections which outline a story presented by a person who is involved in a crime (e.g. victim, witness or suspect) through the formation of the world-building elements (nodes) and the connecting switches. Instead of reading original statements, the potential end-users can easily follow the diagram, identify links and contradictions among elements, and interact with other lay-users through visual deliberation.

As shown in Figure 5, the TW cognitive diagram is designed as a directed network that is capable of storing multiple layers of information. Interactions and animations can also be introduced through augmented transitional operations.

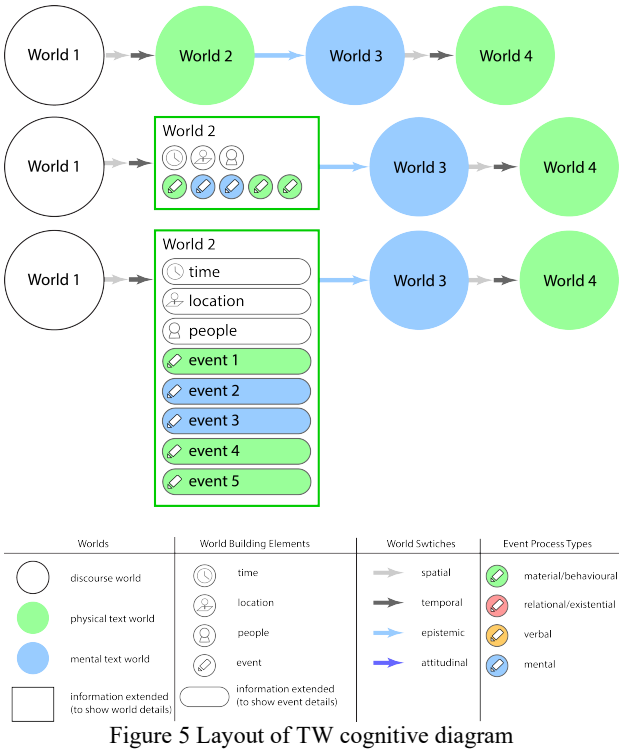

Figure 5 Layout of TW cognitive diagram

The cognitive diagram is ideal for visualising the topological structure of text-worlds. As shown in Figure 5, the coloured circles represent specific types of worlds (i.e. white indicates *discourse world*, green indicates a text-world that projects the actual happenings in *physical world*, and blue indicates a text-world that projects the happenings *within one's mind, i.e. mental world*). The directed and coloured lines indicate different types of world switches.

This initial setup creates a clear and simple view of the entire cognitive structure. Users can gain a brief overview and understanding of the key relationships among all conceptual activities. Interactions and animations are used when exploring the diagram. As illustrated in the middle and bottom of Figure 5, a world node can be expanded to different levels of detail to show its world building elements such as time, location, enactors, as well as event-related information.

Another important advantage of using such structured information and representation lies in its potential in comparing different statements, i.e. stories reported by various parties. *Worldbuilder* is designed to show multiple cognitive diagrams drawn from multiple statements, to support cross-referencing and validation. This function is pivotal when evaluating multiple statements either from repeated interviews of the same subject or from different interested parties.

4. Illustrative Example

This research and corresponding developments have used the infamous Meredith Kercher murder case for testing purposes. We choose this case for our pilot study due to its complexity arising from multifaceted forensic evidence and the fact that this has resulted in multiple appeals against the outcome of the original trial. It therefore makes an ideal test case for the proposed visualisation system. The original legal documents and the English translations are open to the public which can be referred from [15].

We use *Worldbuilder* to illustrate the visualisations of the three controversial statements Amanda Knox, who was accused of the murder, made to the police on November 6, 2007, the day she was arrested. The statements are hereafter referred to as S1, S2 and S3. The cognitive diagrams are illustrated in Figure 7. For detailed linguistic analysis and the manually plotted text-world diagrams of the three statements, see [11].

In S1, the propositions in the initial text-world are in present tense, at the police station in Perugia, after that, three spatial-temporal world-switches are observed, and two of them (sentences 3-4 and 6) are flashbacks, reflecting what happened on November 1, the night of the murder. In the flashbacks, Knox places herself in the crime scene, as indicated in the text message she sent in reply to Patrick, whom she implicated as 'the murderer', and in the affirmative declaration: *I met Patrick at the basketball court*, and then *we went home* (i.e. the crime scene), as shown in Figure 7a. Following the same annotation scheme, S2 shows a very similar pattern to

S1, where Knox is making the same affirmative claim that she was at the crime scene with Patrick, 'the murderer' (see Figure 7b).

In S3, Knox does not make the same strongly incriminating claim as she did in S1 and S2, saying that she was at the crime scene on the night of the murder. However, neither does she intend to deny what was said in her previous statements. It is observed that her original affirmative declarations in S1 and S2 with regard to the actual happenings, i.e. her meeting Patrick, staying in the kitchen and hearing Meredith screaming, all become embedded in her mental world in S3: *in my mind*, *in my head*, *seem unreal to me*, *like a dream* (see Figure 7c). Knox is not sure if these are real things that happened or just dreams in her head. The events she reported affirmatively in S1 and S2 have all been shifted back to her mental world in S3, and the truth value of the propositions thus becomes inaccessible, in text world theoretical terms.

As mentioned earlier, after data annotation, in addition to the cognitive diagrams, *Worldbuilder* is also able to generate graphical presentation of quantitative information for ease of further linguistic analysis. Figure 6 shows one kind of quantitative results generated from the annotated data.

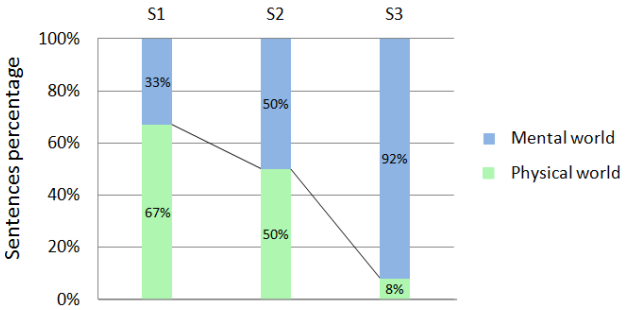

Figure 6 Types of text-worlds projected in S1, S2 and S3

The analysis of the types of text-worlds projected in the three statements indicates that S1 and S2 show more prominent projection of the actual happenings in *physical world* (i.e. material processes of intentional actions or events), where Knox is often presented as an *actor*, responsible for the actions described. By contrast, in S3, we see that text–worlds projecting the happenings *within her mind*, (i.e. *mental world*) are more prominent, as compared to S1 and S2. She seems to be struggling herself to figure out what happened on the night of the murder as well as on the night of the police interrogation.

A text-world analysis of these three statements shows that the cognitive structures of S1 and S2 are very different from that of Knox's hand-written statement in S3. The contrasting statements (S1, S2 vs. S3) thus lead us to examine further in which statement she was communicating the truth, which information in her statements seems more truthful or deceptive, and if the confessions that she made in S1 and S2 are possibly false confessions [11].

5. Conclusion and future works

In this paper, an information visualisation scheme for annotating and representing complicated forensic statements has been outlined. A prototype of visualisation system - *Worldbuilder* - has been developed with the theoretical underpinnings of Text World Theory. During the research, we have devised a structured framework based on the cognitive linguistic model for abstracting and encapsulating key elements – the "World Nodes" and the "World Switches" – in a given statement. The cognitive structure of a statement is visualised as an interactive diagram. We will further enable functions like filtering and integration for assisting cross referencing, interpretation and validation demands. Our illustrative example has demonstrated the advantages and potential of the designed annotation and visualisation system to be used by legal practitioners to support forensic investigation and case deliberation. This research is a pilot study to bring closer and improve the often tedious and painstakingly slow analytical work carried out by linguistic experts through harnessing latest information technology and computer science advancement, especially in the visualisation paradigm.

Currently, the annotation process requires linguistic experts' input in a largely manual fashion - although assisted by the Z2 and Z3 functions as explained in Section 3.1. There is still a major technical barrier towards fully automating the system. The annotation carried out by different linguistic experts may also generate different outputs, causing an issue of how to evaluate and ensure the accuracy and consistency of manual annotation. However, rather than seeing this as a problem, we embrace this opportunity to identify potential theoretical or practical issues and improve the TWT structured framework and the visualization system.

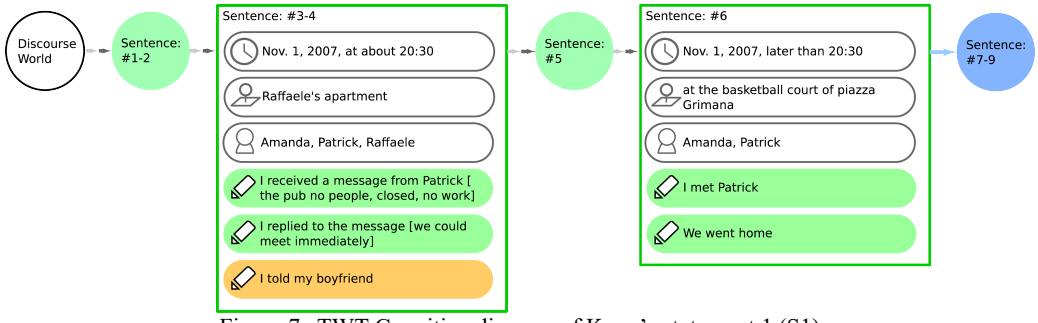

Figure 7a TWT Cognitive diagram of Knox's statement 1 (S1)

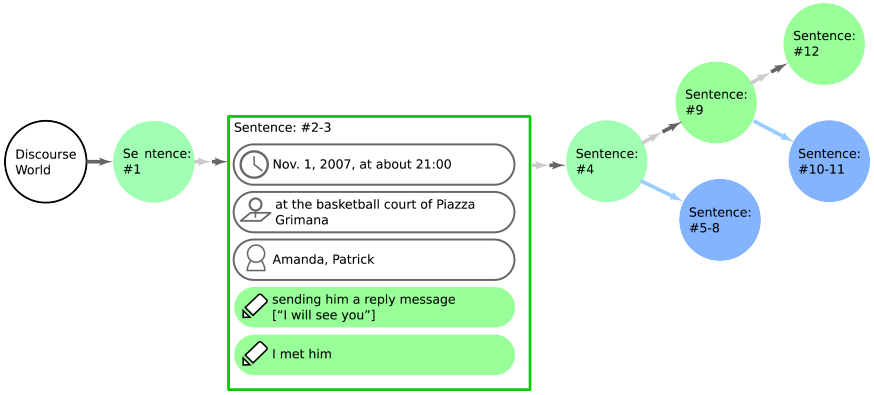

Figure 7b TWT Cognitive diagram of Knox's statement 2 (S2)

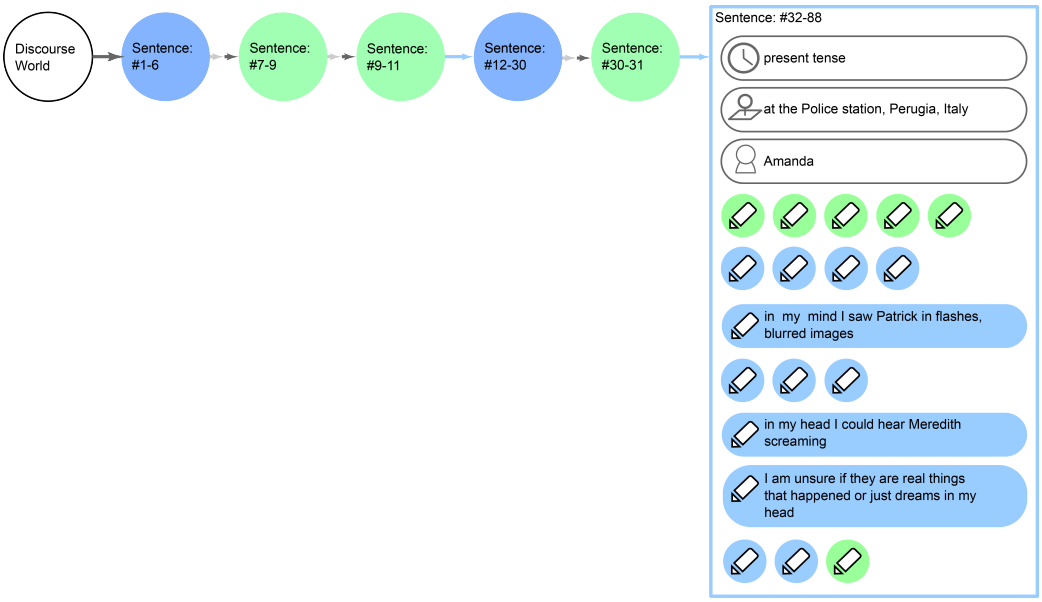

Figure 7c TWT Cognitive diagram of Knox's statement 3 (S3)

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