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An Ontology-based Question System for a Virtual Coach Assisting in Trauma Recollection

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Abstract. Internet-based guided self-therapy systems provide a novel method for Post-Traumatic Stress Disorder patients to follow therapy at home with the assistance of a virtual coach. One of the main challenges for such a coach is assisting patients with recollecting their traumatic memories, a vital part of therapy. In this paper, an ontology-based question system capable of posing appropriate and personalized questions is presented. This method was tested in an experiment with non-patients ($n = 24$), where it was compared with a non-ontology-based system. Results show that people take more time answering questions with the ontology-based system and use more words describing properties, such as adjectives. This indicates that the ontology-based system facilitates more thoughtful and detailed memory-recollection.

Keywords: Virtual coach, PTSD, Dialogue system, Ontology, Memories

1 Introduction

Post-Traumatic Stress Disorder (PTSD) is a mental disorder caused by one or more traumatic experiences [1]. Several treatments for PTSD are available, with the most common element being exposure, which is the process of exposing patients to their traumatic memories [10]. One problem for PTSD treatment is that there is often a barrier to talk about problems and a stigma on seeking help from the mental health-care system. One new method for exposure treatment for PTSD which addresses this issue is a self-therapy system with a virtual coach [9, 21]. With such a system, patients follow their therapy at home behind their computer with the assistance of a virtual coach and a human therapist is only remotely involved. One of the main challenges for a virtual coach in such a self-therapy system is providing the assistance PTSD patients need for exposure sessions. PTSD patients often have fragmented memories of their trauma and are very reluctant to recall them, requiring detailed questions to stimulate memory retrieval. To provide this assistance, a virtual coach should therefore be able to

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communicate with the patient and have an understanding of the topic, namely the traumatic experience. Further, because every trauma is unique, it needs some understanding of the patient to personalize the communication. It is also important to get it right, because the topic is highly sensitive and difficult for patients to re-experience. To solve this problem, we propose an ontology-based conversational system with minimal natural-language processing with which a virtual coach can pose relevant and personalized questions to assist individuals with memory recollection.

For our system to be effective, we envision that a virtual coach is able to assist the human patient in a similar manner as a human therapist. Virtual avatars have been around for some time, and are being used more and more in health-care applications. These applications rely on the anthropomorphism of these characters. Even though people know they're interacting with a digital agent, they will still behave as if the avatar were human [18]. This means virtual characters can follow the same methods for motivation and behavioral change as human therapists and coaches would. Blanson-Henkemans et al. [8] showed that a virtual coach with emotional facial expressions can motivate and support people to live a healthier life, and Bickmore et al. [5] showed the effectiveness of an application with virtual character to elicit healthier behavior in older adults. For mental health-care, virtual characters have been employed for complex user groups such as people suffering from depression [14]. For PTSD, Rizzo et al. [19] developed the SimCoach, a virtual coach guiding veterans who potentially have PTSD towards treatment. Even though virtual avatars have some limitations compared to human coaches, such as the lack of full language abilities, they also have their own advantages, like full-time availability. Moreover, the anonymous nature of a virtual character can increase self-disclosure by patients, which is crucial in many health-care applications [13].

Despite a lack of full natural language capabilities, virtual agents which can communicate with humans in a meaningful way have been developed. One example is by Qu et al. [17], who showed that the answers of the human conversational partner can be steered through priming with images or video. Similarly, Ter Heijden and Brinkman [12] proposed a system in which the agent steered the conversation and used limited speech recognition, providing a low-level method to understanding responses. The draw-backs of these systems is that they do not interpret input from users or store patient information in a meaningful way, while both are required for a more meaningful conversation [6]. One study which addresses this was done by Schulman et al. [20], who developed a conversational agent using Motivational Interviewing (MI, [15]) for health-behavior change. Their method relied on multiple-choice and free text input based on which specific dialogue acts for MI were selected. Also considering MI, Friedrichs et al. [11] developed a system which repeats back utterances of the user and employs multiple-choice input to personalize the content. Both these systems have been evaluated with users, showing that even without natural language understanding a system can hold a personalized and meaningful dialogue with a user and elicit behavior change.

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Ontologies are often used in dialogue systems to add additional meaning and world knowledge. For example, Bickmore et al. [7] developed an ontology-based counseling framework which described a patient's mental states and therapist's actions affecting these states. The use of ontologies was also shown by Beveridge and Fox [4], who employed an ontology to formulate the high-level representations in their dialogue system. These systems show that an ontology is a helpful tool which can be used to go from user input to a response which serves a certain goal. Another possible use of ontologies is to add meaning to the speech of the agent itself, something often used for chatbots. For example, Al-Zubaide et al. [2] used ontologies to form a relational database which could be used to drive chat interactions. The advantage of this system was that the ontology behind it could be changed for different domains without any other adaptations being necessary. Similarly, Augello et al. [3] employed an ontology to add world knowledge and flexibility to a chatbot. Both these studies show that ontologies can be used in dialogue systems to add knowledge and meaning. In this paper, we propose to use ontologies in such a way that they assist in interpreting the user input, to steer the conversation towards its goal, and giving meaning to the dialogue of the virtual agent.

2 Ontology

Several definitions of the term *ontology* have been proposed. In this paper we use the working definition as formulated by Noy & McGuiness [16], where an ontology is *a formal explicit description of concepts in a domain of discourse (classes) properties of each concept describing various features and attributes of the concepts (slots), and restrictions on properties.* When these classes and properties are instantiated, a knowledge base is formed. Ontologies give meaning to words, making them to some extent understandable to machines. They also enable a structured knowledge base of a domain. For trauma, this means that the ontology allows a system to have an understanding of traumatic events. Through this understanding, which information is still unknown and should therefore be asked for can be determined. For instance, whenever an abuse victim never mentions a perpetrator, something is missing from the discourse and the system should ask an appropriate question.

The first thing to consider when designing an ontology for a question system is the modularity of the expected answers. For this paper, we consider the possibilities of the self-therapy Multi-Modal Memory Restructuring system (3MR) [9]. This system allows users to employ different types of media, namely text, images, music, video, google maps, websites, and emotion labels. For a user, all these modularities are available to expose them to their memory and a question system can employ these as possible answers. An example would be the question *Where did this happen?*, which might be answered in the form of text, but also through adding a map. Because this is one of the unique characteristics of the 3MR system, the ontology is based around these modularities.

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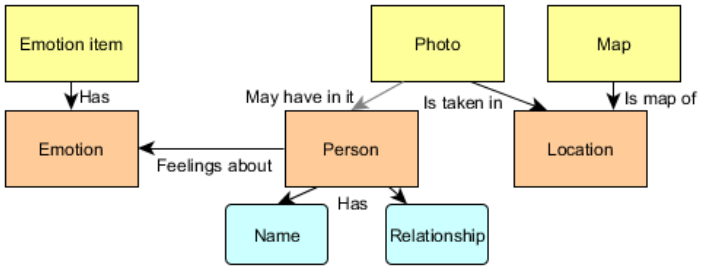

Fig. 1. Section of an ontology based on diary items in the 3MR system.

Figure 1 shows a section of an ontology, based on the modularities Emotion, Photo and Map. A photo has two links in this example, namely the people on the photo and where it is taken. People have three properties, namely their name, their relationship to the person filling in the diary, and how this person feels about them. This last property is an instance of the Emotion class, and can therefore be represented by an emotion item. The location of a photo is an instance of the Location class, which can be represented by a map item. In this way, every diary item has certain properties, which can again be instances of other classes again having their own properties. Which classes and properties these are is determined by the type of memory one wants to retrieve. For a war veteran, the location of the trauma in a foreign country is very relevant, while for abuse victims this might be the type of room they were in.

3 Question System

Together with the ontology, a question dialogue based on this ontology needs to be in place. For this study, the ontology led the design of the natural language questions. Whenever a specific item was entered, such as a photo, the resulting questions could be derived from the ontology. Whenever the ontology was not specific enough to decide on the order of the questions (for instance which type of item to start with), a basic *when, where, who, what*, paradigm was employed. We furthermore decided to ask for two types of memories, those relating to a general time period and those relating to a specific moment in time. For PTSD patients, both types are an important aspect of exposure therapy and with the 3MR system, the therapy follows a gradual exposure paradigm in that people first confront their general memories before working on the trauma itself. These types of memories call for slightly different types of questions and therefore ontologies. In Figure 2 and 3, an outline is given of both conversations. An example of the difference between those conversations for war veterans would be that in the general conversation the *where* question would be *Where was your mission?*, while in the specific conversation this would be *At which exact spot were you in that moment?*

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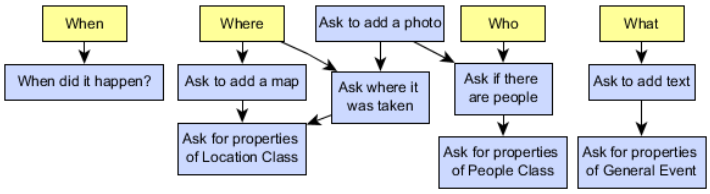

Fig. 2. Outline conversation general period

Although these outlines are based on an ontology, a dialogue without ontology could follow the exact same pattern. Personalization begins when the ontology is filled in and specific questions are asked. This could happen for instance, by knowing if a photo was taken in an inside or outside location. These two location types have different properties and only those properties for the correct type of location would be asked. While a system not based on an ontology could still ask for properties of the location, it could only ask for those applying to all locations and give examples. To illustrate this concept, Figure 4. shows a section of an ontology of a location of a holiday memory. Figures 5. shows the dialogue based on the ontology in Figure 4. The corresponding dialogue not based on the ontology would be the question *Can you describe your location? If you were outside, think of what your surroundings looked like and what the weather was like, and if you were inside, what type of place you were in and what it looked like?* followed by *If google streetview is available for this spot, could you find it and add it to the diary?* In this example it is clear that the non-ontology based conversation consists of fewer, more general and longer questions.

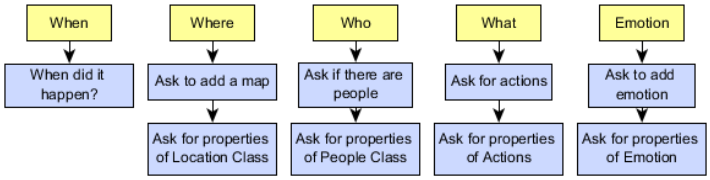

Fig. 3. Outline conversation specific moment

Figure 5 shows that the addition of an ontology allows for asking questions which are much more in-depth and specific. Another advantage is that with an ontology, one has a clear overview of all the topics of the questions. If the ontology contains classes and properties for every concept in a certain memory, so if it is complete, we can state that the resulting question dialogue is also complete. Another expected advantage of such an ontology-based question dialogue is that it is more personal. It can be expected, therefore, that such a system also assists

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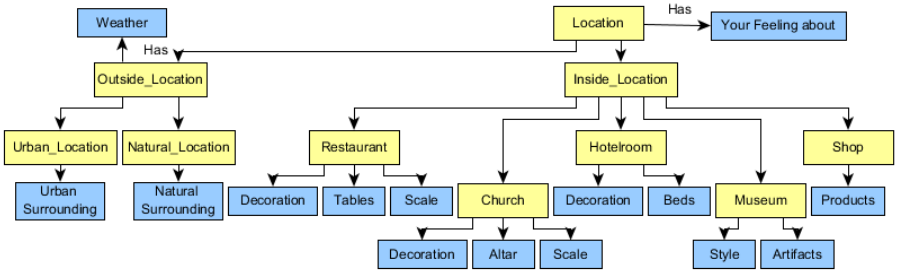

Fig. 4. Ontology of holiday moment locations. The light boxes are the classes, the darker ones their properties.

people better when recollecting memories than a non-ontology based system. To test this hypothesis, an experiment was set up comparing an ontology-based to a non-ontology based question dialogue.

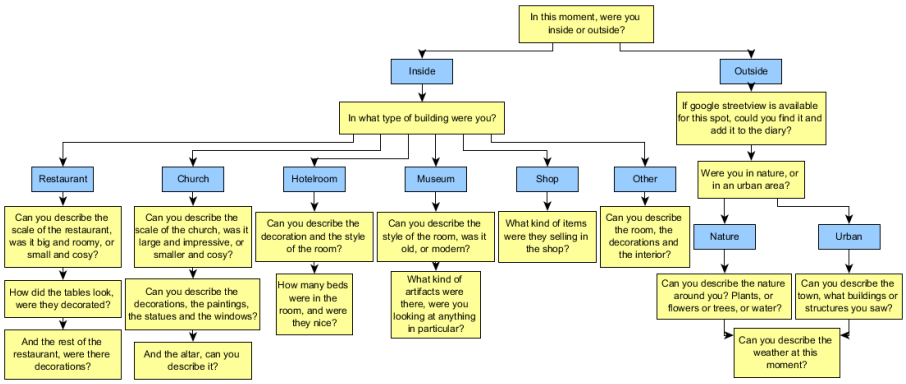

Fig. 5. Dialogue tree on location of an experience using an ontology. The large boxes are the questions, the small ones are multiple-choice answer options.

4 Experiment

A within-subject experiment with two conditions was conducted. We wished to know if an ontology-based system would allow people to recollect their memories better. For this purpose, our ontology-based system was compared with a non-ontology-based question system with the same topics and order of questions, but without any of the personalization. The effect this difference had on people's

opinions and experiences with the system was tested, as well as the effect it had on the level of detail with which the questions were answered.

4.1 Participants

Giving exposure sessions to PTSD patients without providing a full treatment was not considered ethically appropriate. For this reason 24 healthy participants (10 female, mean age 28.4, SD 3.1) were recruited from the University staff and student population. Eight Participants performed the experiment in their native language (English or Dutch), all others in their second language (English). Because the participants did not have traumatic experiences, the memories they had to recollect were holiday memories. This topic was chosen because it was universal for this sample and could be modelled with an ontology quite well. Furthermore, in exposure treatment PTSD patients would also start with a positive memory to get familiar with the system.

4.2 Question System

The question system was based on two ontologies, one for a general holiday memory and one focusing on a specific moment within that same holiday. For the non-ontology based system, the questions followed the exact same order and topics as the ontology-based system, such as destination and travelling companions. An example of the ontology and the difference between the systems can be seen in Section 3. Figure 5 also shows a number of multiple-choice options the participants could choose from. This use of multiple-choice answers ensures that the ontology-based system could react to answers appropriately. The non-ontology based system did not include any multiple-choice options. Finally, in the ontology-based system it was possible to pose a constraint on the type of answers possible, in this case the length of the answers. For the questions asking for descriptions, the answer needed to be at least six words long. Whenever this was not the case, a follow-up question would ask the participant to tell more.

4.3 Wizard of Oz & Procedure

A Wizard of Oz procedure was followed. The full dialogue of questions was written in advance and the procedure was fully specified to avoid any influence from the human wizard on the dialogue. The order of the questions was set and participants could signal they were finished answering through a button. The wizard was in the same room as the participants, but they could not see the wizard controlling the system. All questions appeared on the screen of the participant as typed text. The whole question would appear at once, along with multiple-choice options if applicable.

Prior to the experiment, all participants were asked to bring media (photos, video and music) from four holidays. The two holiday memories which were used in the experiment were randomly chosen from this set. All participants started

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with a small introductory exercise to get familiar with the system. After this, the agent posing the questions gave a short introduction, in which it explained its function and that it could communicate through text only. After this, two dialogue sessions followed in which participants were asked to describe two holiday memories, once with the ontology-based and once with the non-ontology based question system. The order of the two dialogue sessions was counter-balanced. Each dialogue session consisted of 10 minutes of questions on the general experience and 10 minutes of questions on a specific moment. Participants had the option to take a short break between the two dialogue sessions. The experiment was approved by the University ethics committee.

4.4 Measures

Both subjective experience and the amount of detail in participant's answers were studied. The subjective experience was examined in three ways. The first was the emotion experienced when thinking back to the memory. In particular, if the subjective feeling changed when the memory was recollected. Pre and post-measures were taken with the 5-point Self-Assesment Manikin scale (SAM) scale (Lang, 1980) of Arousal and Valence for both memories recollected. The second subjective measure was how well people felt the system helped them in recollecting their memory. The third way was how people experienced the conversation with the system. These two measures were examined with 6 questions each in a questionnaire answered on a 7-point Likert scale. Examples of these questions are *The questions assisted me well in recollecting my memory* for the memory recollection and *The conversation did not run smoothly* for the conversational experience. This questionnaire was presented directly after each dialogue session. Finally, each participant answered four questions on their overall preference of one system over the other. The first was on which system helped recollect the memory best, the second which system was most pleasant to work with, the third on which asked the best questions to trigger the memory and the fourth on which system they would use again. The objective measure considered was the amount of detail in the answers of the patients. On a general level, the number of words typed and the number of question topics posed were checked. The number of question topics could differ per participant because the dialogue sessions had a fixed time, i.e. some participants would answer only questions about location and travel, while others were quicker and would also answer questions on travel companions. To consider the amount of detail present in the texts, all answers were annotated and the number of objects, people, descriptives, feelings and time references were counted. The description of the categories in this annotation can be found in Table 1. A second annotator annotated 1235 words to ascertain reliability of the rating. Interrater reliability was assessed with Cohen's Kappa and showed a good agreement between annotators $\kappa = 0.86$, $p<0.0001$.

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Table 1. Annotations and definition

Annotation	**Consists of**
Objects	All nouns, except those referring to a person (or multiple, such as *people*), and those referring to a period of time (e.g. *day* or *moment*).
People	All nouns referring to people (e.g. *girl, tourists*) and names of people.
Descriptives	Adjectives (including terms as *very* and *three*), as well as words describing aspects of something (e.g. *cold*, in *the room is cold*). Excluding adjectives of feelings. Double adjectives were counted apart (*a very cold room*, and *a large cold room* both counting 2 descriptives)
Feelings	All words referring to feelings (e.g. *excited*), including *looking forward to* and *tired*, as well as all adjectives of feelings (*very excited* counting both words).
Time	All nouns referring to time, such as *month* or *period*.

4.5 Data preparation & Analysis

Two questionnaires were designed specifically for this experiment, namely the one measuring how well people felt the system helped them in memory recollection, and the one measuring how people experienced the conversation with the system. The validity of these questionnaires was tested with Cronbach's alpha, after which one question was removed from the recollection questionnaire and two from the conversation questionnaire to improve internal validity. Internal validity after this was acceptable to good (α 0.72 to 0.81 for the recollection and α 0.54 to 0.63 for the conversation questionnaire). For objective measures we considered the answers given to the questions. For one of the participants, the answers to the questions were lost due to a technical error. Because of this, the answers of only 23 participants were taken into account. When considering the amount of detail in the answers, we only considered the comparable answers. Here *comparable*, means the answers to question topics which were actually posed and answered in both conditions. This gives a measure where we can compare, as if per question, how detailed the actual answers were. As it is possible that more questions were posed in one condition than the other, comparing all texts could result in comparing answers of, for instance, answers to five questions to answers to three questions. This would give a distorted image of how detailed the response to each question actually was.

5 Results

5.1 Questionnaires

The first questionnaire measured if recollecting a memory changed peoples arousal and/or valence regarding the memory. A doubly multivariate repeated measures was done for both arousal and valence, with moment of measurement (pre/post) and system (ontology/non-ontology based) as within-subject factors. No significant results were found ($p > .05$). For both the recollection and the conversation

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questionnaire, a paired samples t-test was done to compare scores between conditions. Neither of these two questionnaires yielded any significant results between conditions (Recollection: $t(23) = -.38$, $p = .71$, Conversation: $t(23) = -.27$, $p = .79$). On the overall preference, a single-sample t-test showed no significant difference between the result of any of the 4 questions and the middle position on the scale (50), signifying that there was no significant preference for one system over the other (Recollection: $t(23) = 1.26$, $p = .22$, Pleasant: $t(23) = 1.82$, $p = .81$ Questions: $t(23) = 1.17$, $p = .25$ Use again: $t(23) = .1.57$, $p = .13$).

5.2 Answers

A paired t-test was performed on the amount of words typed in answers and the number of question topics answered in both conditions, the results of which are presented in Table 2. The table shows that there is a significantly higher number of total words in the answers with non-ontology based system compared to the answers with the ontology-based system. The result for the number of topics is similar, a significantly higher number of topics was covered with the non-ontology-based system compared to the ontology-based system.

Table 2. Comparison between the number of words and number of topics for the ontology-based and non-ontology-based system.

	Mean(SD)					
Measurement	***Ontology***	***Non-Ontology***	***t***	***df***	***p***	***Cohen's d***
Nr. of Words	237 (114)	285 (11)	-2.37	22	0.027	0.33
Nr. of Topics	8 (3)	10 (4)	-3.98	22	0.001	-0.54

Finally, the amount of detail in comparable texts in the two conditions was considered. An omnibus test was done on the annotations of the total number of comparable texts, showing a trend of a higher number of words in the ontology-based system, but no significant result $F(5, 18) = 23.63$, $p = .084$, $\eta^2 = .87$. Table 3. shows the univariate analysis for the individual annotation categories. Here we see that there was a significantly higher number of descriptive words used in the ontology-based system even after a Bonferroni correction which sets the α level at 0.01. None of the other categories showed significant results.

6 Discussion & Conclusion

The first conclusion we can draw based on the results is that no subjective difference between an ontology-based and a non-ontology-based system was found. This indicates that people have no preference for one type of system over the other. The second conclusion is that people answered the questions more quickly with the non-ontology based system. This is shown by a higher number of topics answered with the non-ontology-based system, while both conditions lasted

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Table 3. Comparison between the ontology-based and non-ontology-based system based on the total number of objects, people, descriptives, feelings and time references in the participants comparable texts.

	Mean(SD)				
Category	***Ontology***	***Non-Ontology***	***F(1,22)***	***p***	η^2
Objects	21 (14)	20 (13)	1.00	0.328	0.044
People	7 (7)	6 (4)	0.66	0.425	0.029
Descriptive	22 (13)	16 (9)	8.91	**0.007**	0.288
Feeling	5 (3)	6 (4)	0.34	0.567	0.015
Time	4 (3)	3 (3)	0.32	0.263	0.057

equally long. This is promising, as it suggests that people put more effort into answering the questions from the ontology-based system. When making statements about effort in memory recollection it is, however, also important to consider the amount of detail in the answers and not just the time taken. Concerning this detail, we see that that there is a significantly higher number of descriptive terms for the ontology-based system. From this we can conclude that people describe memories in more detail with this system. Taken together with the result that people take more time, we can conclude that people recollect their memories in more detail with an ontology-based system. This study also has some limitations, the main drawback being that the participants tested were healthy individuals, and not PTSD patients. We believe, however, that our results do provide a valid insight in memory recollection with an ontology-based system as it shows that such a system can assist in detailed memory recollection. Future work will have to study the effect of an ontology-based system on the recollection of memories which people would rather forget. One contribution of this study has been to show that aside from high-level planning [7], and adding domain knowledge [2], ontologies can also be used to store specific knowledge of the user and steer the conversation based on this. It has also shown that the use of multiple-choice options to personalize the conversation [20, 11] can be combined with such an ontology. Finally, we have shown that an ontology-based question system is effective in assisting users with detailed memory recollection, as necessary in PTSD exposure therapy [10].

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