An Enhanced Mental Model Elicitation Technique to Improve Mental Model Accuracy

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Abstract. The causal mental model representation has been used extensively in decision support. Due to limited information requirements of this representation, that is *concepts* and *relationships*, the users are required to articulate only the mental models, without invoking the corresponding experiential knowledge stored in *associative memory*. The elicitation of mental models without being endorsed by experiential knowledge may lead to inaccurate, invalidated or biased mental models, and espoused theories, being stored for decision making. We introduce *SDA articulation/ elicitation cycle*, which invokes a user's *associative memory* during the articulation/elicitation process to validate mental models. It is argued in this paper that by engaging *associative memory* during the mental model articulation/elicitation process, the accuracy and validity of mental models can be improved, the biases can be reduced, and the theories-in-use can be elicited rather than the espoused theories. A case study is presented to demonstrate the working and contributions of the *SDA articulation/ elicitation cycle*.

Keywords: Mental model representation, mental model articulation/ elicitation, cognitive biases, cognitive decision support.

1 Introduction

The mental models have been used in decision system to understand, predict and solve problems in uncertain and vague situations [1, 2]. They are formed through experience, observation and ongoing learning processes in the human mind, and are the basis for the beliefs and subjective opinions of a person [3]. They provide the knowledge required to do the situation assessment, problem understanding and formulation, problem space identification and problem space segmentation [4,5]. Generally, the mental models used in decision making are represented as causal maps, containing *concepts* and *causal relationships* [2,6].There are inherent limitations, however, to this representation of mental models. In this paper, we will discuss two limitations of the current mental model representation; a) its limited capacity to facilitate elicitation of valid mental models from individuals with accuracy, and inability to store meaningful and contextual information about the mental models [7]; and b) its inability to filter cognitive

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biases during the mental model elicitation [8]. We will explore how these shortcomings can be mitigated to some extent by the *semantic de-biased associations (SDA) model*, which was proposed by Memon et al [9].

The paper is organised as follows. Section 2 gives the overview of the problems at hand and their background from the literature. In Section 3, the SDA model and its basic components are discussed briefly, followed introduction of *SDA-based articulation/elicitation cycle* for mental models, and mitigation of biases. Section 4 presents examples demonstrating the innovation of this cycle. Finally conclusion and future work are presented.

2 Literature Review

Mental models can be a powerful tool in solving complex and vague decision situations [10, 11]. However, there are various issues in the articulation, elicitation, and representation of mental models, which if not addressed, may lead to poor decisions. This paper addresses two issues; a) limited capability of current mental model representation used in DSS, to help articulate, elicit and store knowledge; and b) its limitation to facilitate de-biasing the mental models.

Due to the complex and intuitive nature of mental models, it is difficult to articulate them accurately [6,8]. The articulation of mental models, to some extent, depends upon the intended representation, such as *a causal map*. A person may describe their mental models through various techniques, such as a set of rules, a mind map, or statements [6]. Based on the intended representation, required entities (in the case of *causal maps*, *concepts* and *relationships*) are then elicited from these descriptions [12]. Several elicitation techniques have been proposed to get such as such as 3CM [13], *fuzzy cognitive mapping* [14] and diagrammatic interview method by Dray et al [15]. These techniques assume the mental models to be a network of *concepts* and *relationships*; thus, all that is extracted from the *descriptions* is the *concepts* and *relationships*. However, mental models are much complex structures than merely *causal maps* [16]. They work in conjunction with, and are supported by, our visuals and *associative memory* [8]. Every mental model is formed through an experience, having a historical background in the *associative memory*, which contains the reasons for its existence [17]. Thus its not sufficient to elicit and store the mental models in the form of *concepts* and *relationships*. It is essential to help an individual to remember the historical background (from *associative memory*) as well, and elicit it along with the mental model itself [18]. Engaging *associative memory* allows to avoid the phenomena where people articulate the "espoused theories", rather than the actual "theories-in-use", due to the poor insight into their own mental models [19]. Invoking *associative memory* will help to recall the situations in which the mental models were created, the reasons behind their creation, and their performance in terms of solving a problem. This in turn will give the person a clearer picture of what actually worked and why. Therefore, it is argued in this paper that by

incorporating *associative memory* into the current *causal map* representation for mental models, the following advantages can be achieved:

- Help individuals to articulate their mental models in a better and efficient way, by providing them with a template of what is required to be elicited,
- Improve the accuracy of the mental models by asking critical questions (see Section 3.1 for the details of the questions),
- Mitigate the biases during the elicitation process, as well as the at the time using these mental models, through the *contextual* and *objective information (performance measuring parameters)* extracted from the *associative memory*.

3 Basic Components of SDA Mental Model Representation

The mental model representation proposed in SDA model is comprised of *concepts*, *semantic relationships*, *cases* and performance measuring parameters *weight* and *success factor* [9]. Each link, consisting of two adjacent *concepts* with a *semantic relationship* between them, is named as *association*. Thus, the mental models in SDA are a network of *associations*, where each *association* has *contextual information* attached to it in the form of past *cases*, extracted from the *associative memory* during the *articuation/elicitation cycle* (see Section 3.1 for *SDA articulation/elicitation cycle*).

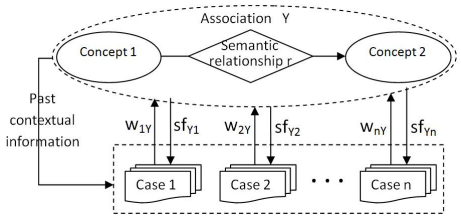

Fig. 1. Fundamental components of SDA-mental model representation

As can be seen from Fig. 1, *association Y* is formed through two concepts *concept 1* and *concept 2* connected with a *semantic relationship r*. The *association Y* has past *cases (1,2, ..., n)* attached to it. These *cases* contain the information about the past experiences, which led to the creation of the *mental model* represented by *association Y*. The information in each case includes:

1. What: The details of the problem/situation;
2. When: Date;
3. Where: Organization;
4. How:
   - The way this mental model (association) helped to solve the problem;
   - The extent to which this mental model (association) was effective in solving the problem *(weight)*;
5. Who: The decision maker (his credibility);
6. Which: (The kind of situations, in which this mental model (association) can be used successfully.

Fig. 2 shows the information contained in a *case* in SDA-based mental model representation [9]. The table contains *case_ID, Association_ID, Case_Details*

(the *what* question), *Case_Year (when), Case_Organisation (where), Future_Use (which) and Weight (how)*. Another important measuring parameter in SDA-based representation is the *success rate*. The success rate is used to measure the usefulness of an *association*). The *success rate* of an *association* is the average of all the *success factors* of that *association* for the corresponding cases (see [9]).

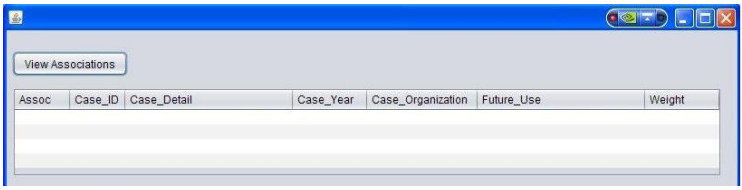

Fig. 2. Implementation of *Case* in SDA-based system

3.1 Articulation Elicitation Cycle in SDA

Mental models can be elicited through *direct* or *indirect* elicitation methods [12]. The direct elicitation allows users to describe main concepts of a domain in the form of words, symbols or pictures, and connect these together according to their understanding. While the indirect elicitation allows to derive mental models from text or the verbal communication with an individual.

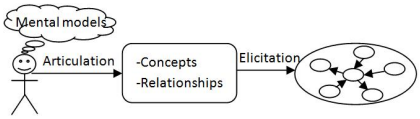

Fig. 3. Conventional articulation/elicitation process

Being direct elicitation approach, SDA model allows participants to view the illustration of their mental models immediately; thus verifying them instantly [12]. Most of the direct elicitation approaches focus on extracting *concepts* and *relationships*, and overlook the contents of *associative memory*, which contain the *experiential knowledge* behind these *concepts/relationships* [8]. As a result, the articulated mental models may be "espoused" or unproven theories, or inaccurate representations [19].

The SDA cycle improves the articulation/elicitation process by asking critical questions about a mental model, thus forcing the user to make a conscious effort to invoke and engage *associative memory*. The questions include:

- why does the user think what they think?
- which decision problem was this mental model used for?
- how helpful their mental model was in that situation?
- how did it solve the problem?
- what were the circumstances surrounding the decision problem?
- when and where did it occur?
- who was responsible for the decision making?
- what was the credibility of the decision maker(s)?
- where can this mental model be applied in the future?

During this process, the users may discover whether their mental models are an espoused theory, inaccurate, unproven or biased [20]; consequently, adjusting their mental models accordingly before the final elicitation. Asking appropriate question can help reduce the cognitive biases as well [8]. Fig 3 and 4 show the difference between the conventional mental model articulation/elicitation process and the SDA-based articulation/elicitation cycle, respectively.

3.2 Role of Associative Memory in Bias Reduction

The SDA model deals with four cognitive biases, *availability, contextual, framing* and *group biases*. However, here we will discuss only the ones affected by the contents of *associative memory*. These are, *contextual* and *framing*. Contextual bias is generated from the circumstances surrounding an experience. Same kind of problem, with different contextual information, may need different solutions [17]. In SDA, the contextual information extracted from the *associative memory* helps a decision maker distinguish between the current decision situation and the past decision cases stored, and determine the suitability of the corresponding mental model for the current decision situation.

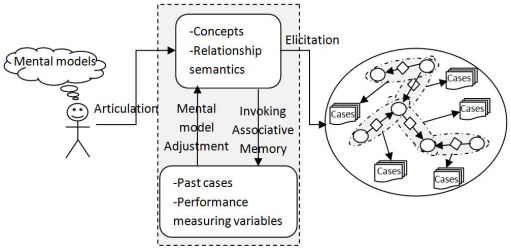

Fig. 4. The proposed technique: *SDA-based articulation/elicitation cycle*

Framing defines the inclinations, developed by the way a decision situation is presented [21]. In SDA, the *framing bias* is handled through various past *cases*, which are attached to certain mental model. These cases come from the *associative memories* of various users. Each case contains a *weight* showing the importance/effectiveness of the corresponding *association* for the case. The *weight*, being the factual data, can assist the user in avoiding framing bias, even if the presentation of decision situation is biased in the *case details (Case_Details in Fig. 2)*.

4 Demonstration of SDA Articulation/Elicitation Cycle

This section walks through the *SDA articulation/elicitation cycle*, demonstrating its effectiveness to facilitate mental model articulation and to improve their accuracy. The specific decision problem is: *How can we increase our sales/clientele?* The participants of this case study were required to articulate possible alternatives/solutions to this decision situation. Following are three selected decision alternatives, articulated by participants from various fields, which demonstrate how the *SDA articulation/elicitation cycle* deals with different scenarios.

Mental Model 1: Offer Incentives. The participant (from fashion industry) came up with the an alternative: "Sales/clientele can be increased by offering incentives". Since SDA model represents mental models in a human-centric manner

by incorporating *semantics*, the conversion of mental model described in natural language into SDA representation was effortless, which is:

Incentives *increase* Sales

Since the SDA model requires the contextual knowledge behind a mental model, the participant was required to recall the previous experience, to store as supporting *case*. The recalled experience (*case 123* Fig. 5) helped them to validate success of the mental model in the domain. This mental model was extracted from a *personal experience* and was validated by the positive outcome (*0.75 weight*) of the decision alternative (*association 012*).

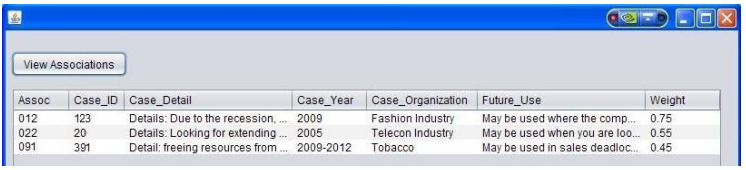

Fig. 5. The *Cases* elicited through the SDA articulation/elicitation cycle

Mental Model 2: Entering New Markets. The participant (from telecom industry) came up with the mental model "Sales/clientele can be increased by entering new markets", converted to SDA-based representation as:

Entering New Markets *increase* Sales

This mental model was based on the participant's observation. They observed a company entering the rural market rather than focusing on urban market, giving that company a big boost in sales. This mental model was validated by the positive results it brought for that company (*Case 022* in Fig 5).

Mental Model 3: Chasing Good Prospects Continuously. The participant (from tobacco industry) came up with the mental model "Sales/clientele can be increased by chasing good prospects (potential customers) continuously", converted into SDA-based representation as:

Pursuing good prospects continuously *increase* Sales

Initially, the participant was confident about pursuing good prospects continuously. But during the *questioning process* of *SDA articulation/elicitation cycle* to invoke *associative memory*, the participant was unable to recall a huge profit gained from long-chased prospects in the past few years. Rather, they realized that their company has gained more sales from pursuing new prospects, after freeing the resources from the long-held ones. As a result of this process, the participant corrected their mental model as: " Sales/clientele can be increased by freeing the resources from long-chased yet unfruitful Prospects". That is:

Sidelining long-chased prospects *increase* Sales

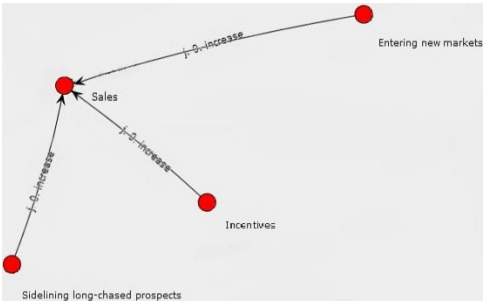

Fig. 6. The three mental models elicited for the domain *Increase in Sales*

Fig. 5 shows the final mental model in *case 091*. The initial mental model in this example was a deep-seated but inaccurate assumption, which was recognized by engaging *associative memory*, as the mental model could not be sufficiently validated by the past experiences of the participant. Rather, the participant developed a new and *validated* mental model by recalling past experiences. This example shows the effectiveness of *SDA articulation/elicitation cycle* in discarding inaccurate mental models. Fig. 6 shows the three mental models presented in this Section.

5 Conclusion and Future Work

This paper discussed the contributions of SDA-based mental model representation towards better articulation, elicitation and accuracy of mental models, in addition to the mitigation of biases. The *SDA articulation/elicitation cycle* for mental models was introduced in this paper. Compared to the conventional mental model elicitation techniques, the *SDA articulation/elicitation cycle* provides an improved way to elicit and validate mental models by engaging associative memory, and ensures their accuracy/validity by asking critical questions during the elicitation process. Furthermore, the SDA-based mental model representation allows the mitigation of *contextual* and *framing biases*.

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