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CARINA based Cognitive Agent for Factoid Wh-Questions Generation in EFL

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***Abstract*— The Metacognitive Architecture CARINA is used to execute cognitive agents. CARINA is defined as a metacognitive architecture for artificially intelligent agents and is derived from the MISM Metacognitive Metamodel. A Factoid WH- question (FWhQ) is an interrogative statement that begins with a WH word (when, what, where, who, which) and gives a fact as answer reflected in the text. A Cognitive Agent is an entity of software that perceives stimulus from its external environment to achieve its goals selecting actions from its internal knowledge rationally. The problem which is tackled in this research is the need to offer and develop educational resources enabling foreign language learners to better cope with this type of questions, problem perceived as a priority in the Foreign Language Program at Universidad de Cordoba. This paper aims at reporting the design of a Cognitive Agent-based on Metacognitive architecture CARINA for the generation of Factoid WH- Questions. The methodology used in this study involved the cognitive modelling designed for this purpose, which consists of seven steps and the application of a test for validation based on 2 research questions focused on two specific dimensions: Readability and Potential Usefulness. Results showed that cognitive models based in M++ are easy to read and allows understanding the relations among different elements of a cognitive model. This allowed a cognitive agent to be developed to answer Factoid questions in English.**

***Keywords*— cognitive agent; factoid-WH question; CARINA.**

I. INTRODUCTION

A cognitive agent is a software entity perceiving stimulus from its external environment to rationally reach its goals by selecting actions from his internal knowledge [1], [2]. The Metacognitive Architecture CARINA is used to execute cognitive agents [3]. CARINA is defined as a metacognitive architecture for artificially intelligent agents and is derived from the MISM Metacognitive Metamodel [3],[4]. A metacognitive architecture provides a concrete framework for mechanisms modeling to an intelligent agent that develops on itself for a high-level reasoning process [3].

CARINA provides cognitive modeling for developing Cognitive Agents [5]. Cognitive Modeling (CM) is a research methodology from cognitive science, producing theories expressed as computer programs, through computational models of cognitive processes commonly called Cognitive Models [6], [7]. A Cognitive Model is a theoretical foundation and empirically specification of mental representations and processes involved in cognitive functions [6], [8].

Question Generation is widely implemented in different research fields such as learning environments, information seeking systems, and multiplicity applications [9]. The process of generating questions is seen as an activity where questions are automatically formulated from an input. The Question Generation is a three-step process: content selection, selection of question type, and question formulation [10].

A Factoid Wh- question (FWhQ) begins with a Wh word (who, which, when, what, where,) that requires a fact as an answer reflected in the text [11]. Learners who are repeatedly exposed to FWhQ generation during didactic activities of learning English as a Foreign language (EFL) produce new FWhQs with a diversity of lexical expressions and Wh-question words [12].

A wide number of researchers have focused on the scope of questions for language study and social interaction [13], [14]–[19]. FWhQ is a prerequisite to deeper conceptual or information questions [20]. According to the National Academy of Sciences is very important to promote the building of a strong and deep foundation of factoid knowledge in learners through these types of questions [21].

FWhQ Generation Process consists of receiving a text source as input, to automatically parsing the sentences and transforming them into FWhQ [22].

Different authors have researched the most common areas on the FWhQ generation system. They have focused mainly on Wh-questions formulations and on working about specific aspects such as sentences parsing, extracting simplified sentences from appositives, subordinated clauses, a question from sentences, questions from dialogues, question generation from paragraphs, question answering systems, multiple-choice question generation [23]–[26]. The studies mentioned above have been thoroughly researched, but the interest in designing FWhQ generation systems using cognitive models has been limited.

This paper focuses on the design of Cognitive Agent based on the metacognitive architecture CARINA for generating FWhQs in EFL using the cognitive modeling methodology. With the completion of this research, it is possible to demonstrate the progress of cognitive computing science applied to education. The motivation of this research is the construction of a cognitive agent to develop educational resources enabling foreign language learners to better cope with this type of question and to enrich their teaching-learning process for language learners at Universidad de Cordoba in the future.

The structure, characteristics, and categories of the FWhQs are described in section II. In section III, the authors present CARINA metacognitive structure. In section IV, the authors describe the CARINA's cognitive modeling as well as the steps needed to build the cognitive model for FWhQs. In section V, the authors present the validation of the M++. Ultimately, the authors provide a conclusion in section VI.

II. Material and Method

A. Factoid-WH Question Generation

According to applied linguistics, Questions Generation is a cognitive strategy that self-regulates and fosters understanding. The action of formulating questions concentrates the student's interest in the content, allowing them to consolidate the main ideas while checking whether the content is understood or not [19]. The question generation process enables students to perform high-level cognitive functions [27], [28].

An FWhQ is an interrogative statement that begins with a Wh word (when, what, where, who, Which) and gives a fact as the answer [29]. FWhQs are structured as follows: Wh-word + an auxiliary verb + subject + main verb [30], [26]. An FWhQ is pronounced with descending intonation when asking the question; it also starts with an interrogative word changing the common order that the subject and operator have in an affirmative noun phrase. If there is no assistant, an auxiliary verb (be, do, have or a modal verb) must be used depending on the subject and the time of the sentence, see the example as follow (See Fig. 1.):

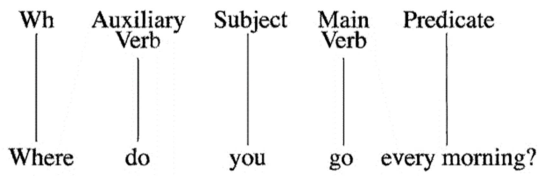

Fig. 1. Example Structure Factoid-Wh Question

FWhQs have some characteristics as follows [30]:

- Begin with an Interrogative Pronoun (IP) inverting the order between the subject and the operator, and it is pronounced with falling intonation.
- If there is no auxiliary verb, "do" is introduced
- "Be" and "Have" as lexical verbs had the same function as the yes/no questions formulation statements.

Learners who are repeatedly exposed to FWhQs generation during didactic activities of EFL classes produce new FWhQs with a diversity of lexical expressions and Wh words (who, when, what, which, where) [12].

When generating FWhQs, in a foreign language, English, for example, learners can formulate questions even when there is an absence of a speech model to be exposed to [31], [32]. The conception of Role and Reference Grammar (RRG) Theory, [33] establishes that learners produce grammar of their language based on their initial cognitive assignment, which does not incorporate an Autonomous Language Acquisition Device or Universal Grammar and the evidence they were exposed.] In RRG Theory, Grammar is constituted in a syntactic and semantic representation [33.

This study is mainly based on the syntactic representation when generating an FWhQ. According to RRG Theory, essential components of a sentence are: (i) the nucleus, which contains the predicate, (ii) the core, which contains the nucleus plus the arguments of the predicate in the nucleus, and (iii) the periphery, which contains the adjunct modifiers of the core. This theory states that in FWhQs in EFL, the WH-expression occurs in a position called the pre-core slot [33]. In Fig. 2, it is shown Essential Components of Factoid WH- Question according to the RRG Theory.

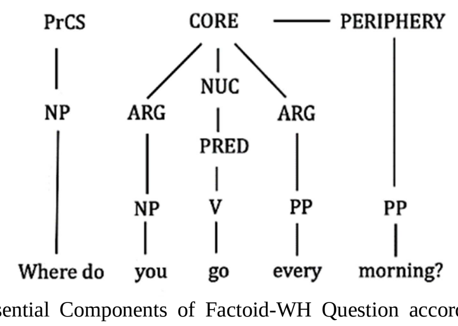

Fig. 2. Essential Components of Factoid-WH Question according to the RRG Theory.

Furthermore, in RRG theory, the syntactic representation of a clause is structured by two main components [34] that consist of A-Parser and a Syntactic Inventory. The Parser split the clause in each component already described. The Syntactic Inventory helps in the categorization process of each word that structures each clause (See Fig. 3.)

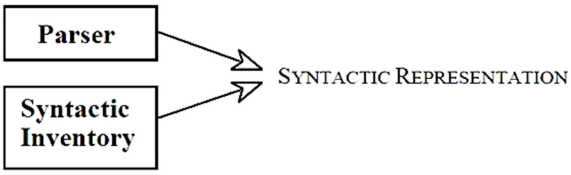

Fig. 3. Syntactic Representation Main Components of a clause according to RRG Theory.

Some approaches were used to design the model of the cognitive agent developed for the FWhQs generation [24], [30], [33]. The approaches are structured in three stages, as follows:

- Content selection: This step aims at choosing what is relevant to ask about a specific context. For this, an identification process of all the elements in the text must be applied [35]. This research uses a single sentence as input and describes the context. It also allows a syntactic tree to be created to identify the core and Periphery as the NP, VP and PP in the statement.
- Selection of question type: This step selects the questions depending on the question type, considering appropriate content and context [25]. FWhQ is the type sentence that will be developed through an input clause categorization process. These categories are (Person, Organization, Location, Entity).
- Question construction: the question will be formulated by using each one of the selected elements in the previous step [35].

The Wh-movement Mechanism will be used in this question formulation process [36]. Wh-movement deals with the syntactic function of the language, English, and involves elements of the sentence often produced differently to the original sentence [37]. The relationship between object, subject and prepositions in the produced clause apply the Wh-movement for the question formulation step to generate the possible FWhQs linked to the input clause.

B. *Metacognitive Architecture CARINA*

CARINA is defined as a metacognitive architecture for artificially intelligent agents and is derived from the MISM Metacognitive Metamodel [3]. CARINA incorporates self-regulation and meta-memory with support to the introspective monitoring metacognitive mechanisms and meta-level control. Therefore, CARINA assumes a functional approach to the philosophy of mind [38]–[40].

CARINA is divided into two cognitive levels: object-level and meta-level. The object-level encompass the artificial intelligent agent model for reasoning about the world and solving problems [4], and the meta-level encompass a dynamic model of the object-level [3].

Memory System in CARINA is constituted as follows [41], [42]:

- Sensory Memory constitutes a momentary buffer which stores information that has not been attended immediately [3], [43].
- Working memory comprises a memory space used for temporary information storage during the developed of different cognitive tasks types such as: perception, reasoning, planning, etc. [44], [45].
- Long-Term Memory function to encode information semantically stored (stores information over the time) [3], [46].

A cognitive model in CARINA is loaded in the attentional system, performing each one of the cognitive functions that run in the object-level. When the cognitive model has achieved all the planned goals without any reasoning failure, the cognitive model is stored in CARINA's semantic memory in the form of belief.

CARINA represents the problems to be solved through the Mental States. A mental state is a representation able to build a plan for task execution in order to accomplish a goal. The mental state responds to environmental events [47]. These Mental States are stored in its working memory structure called “model of the world”. To achieve this Mental States CARINA generates a series of Goals stored in its motivational system. Goals are objectives that intensify a task or process [48]. These Goals point towards Mental States of working memory in order to modify them through a plan composed by actions located in its procedural memory. Actions are a type of situation; viewed intuitively, those resulting from the activity of some agent or agents in accomplishing some goal [49]. A production rule is a statement of logic programming that details the execution of one or more actions when its condition is satisfied [50]. Production Rules structure the Procedural Knowledge in CARINA. [51]

C. *Cognitive Modelling for CARINA*

The methodology implemented in this research is based on the Cognitive modeling from the Metacognitive Architecture CARINA [5]. Cognitive Modelling is a research methodology of cognitive science, producing theories expressed as computer programs [6]. The central goals of cognitive modelling are described, predicted, and prescribed by human behavior [52], [53] through computational models of cognitive processes commonly called cognitive models [54]. CARINA’s Cognitive modelling is presented below:

1) Cognitive Task Selected: The problem is established as a cognitive task using natural language [5]. The cognitive task to be modelled is Factoid-WH Question Generation developed by a cognitive agent.

2) Information Obtained to detail the Cognitive Task: In this stage, the information sources are selected (obtained from experts, users, or documental sources) in order to describe the cognitive task. The information describing the cognitive task was obtained from two experts and some documentary sources.

3) Cognitive Task in Natural Language: At this stage, in a natural way, the necessary requirements to solve the problem are specified. In this research the cognitive task expressed in natural language is presented below:

- The input is gotten, and a Parsing process is developed.
- Each sentence is syntactically processed word by word verifying the grammatical category of each detected word.
- The lexical buffer is loaded.
- The buffer of the problem domain is encoded.

- The Belief β de Buffer / Campo in Model of the World (MoW) is retrieved.
- The Belief β is copied in Short Term Memory (STM) Lexical in MoW.
- The word node is updated in the MoW.
- Word Node is encoded in MoW.
- The classification of nouns is processed.
- Recognized Algorithm of Nominated Entities is executed.
- Connector words are chosen.
- The question is focused.
- The question is generated.
- If the question Factoid-Wh Question is subject NP is attached to the main verb of the sentence and is identified.
- If it is FWhQ is NP objects are attached to the front of the sentence, and the NP object is identified.

TABLE I
FORMAT TO SYNTHESIZE THE COGNITIVE TASK DESCRIPTION WHEN THE INFORMATION SOURCE COMES FROM EXPERTS. COPYRIGHT 2018 FOR ESPINOSA ET AL.

Experts	**X**
Knowledge Area	Cognitive Computing and Applied Linguistics
Number of Experts	1 MSc. in Technology of Information Applied to Education 2 Lic. in English
Synthesis of Cognitive Task Description	Cognitive modeling is a research methodology of cognitive science, which produces theories that are expressed as computer programs. The central goals of cognitive modeling are: (a) describe (b) predict, (c) and prescribe human behavior through computational models of cognitive processes commonly called Cognitive Models.

4) *Cognitive Task in GOMS*: In this phase, the first version of the cognitive model is produced using a structured natural language notation to represent GOMS Models [55]. In this research a variation of GOMS is used, called NGOMS-L. This, NGOMS-L, is defined as a structured Natural Language Notation to present GOMS models and a method to build those [56]. Below, the main Goals are presented to construct the Factoid-WH question.

Method for goal γ_{300}: Input Processing

Step 1. (α^{c}_{101}) Accomplish goal:γ_{301} # *Parser*
Step 2. (α^{c}_{102}) Accomplish goal:γ_{304} # *Clause Syntactic Processing*
Step 3. (α^{c}_{103}) Accomplish goal:γ_{310} #*Noun Classification Process*
Step 4. (α^{c}_{104}) Accomplish goal:γ_{306} # *NER Algorithm*
Step 5. (α^{c}_{105}) Accomplish goal:γ_{305} # *Question Focus*
Step 6. (α^{c}_{106}) Accomplish goal:γ_{307} #*Question Generation*
Step n. (α^{c}_{107}) Return with goal accomplished.

Fig. 4. Main Goals to construct the Factoid-WH question.

5) *Systematization of Cognitive Model from GOMS to M++ Visual Language:* In this step, the cognitive model is turned into a visual language representation based on the Domain Specific Visual Language (DSVL) that enables modelling metacognition in intelligent systems integrating two meta-reasoning mechanisms, introspective monitoring, and meta-level control. The artefacts of M++ are models established in a visual manner [57]. In Fig. 5, group A shows the icons to represent object-level tasks and group B displays icons representing elements that interact with the tasks at the object-level [57].

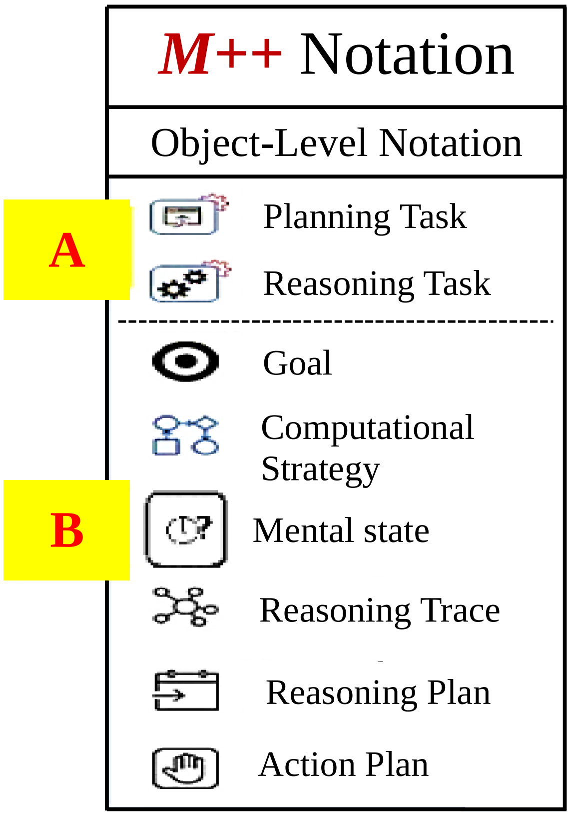

Fig. 5. Main elements in M++ notation

Questions Generation Process is a three-step process that consist of content selection, question type selection and question construction [10]. These three processes are represented in M++ in the following way.

The environment model in CARINA is represented in the working memory through the mental states and actions where each mental state corresponds to an action. A cognitive model represented in M++ shows in its center the mental states associated with the actions which modify them and are located on the left part of the model figure. Actions have post-conditions that are affected by mental states after an action is executed, changing their value from false to true. In Fig 6, just two actions are shown, which fulfil the function of completing the mental states and returning to the goal if the condition is met.

The Goals are in the right part of the model and point out to the mental states. The Goals are achieved when the related mental state becomes true. The actions have pre-conditions that evaluate if some mental states have been achieved in order to be executed, these conditions are: i) the current state of the mental state and the goal; ii) and the desired state which verifies whether the desired condition was fulfilled or not. The reasoning process of the CARINA´s objects level searches modify a problem from a set of initial states to a set of final states.[47].

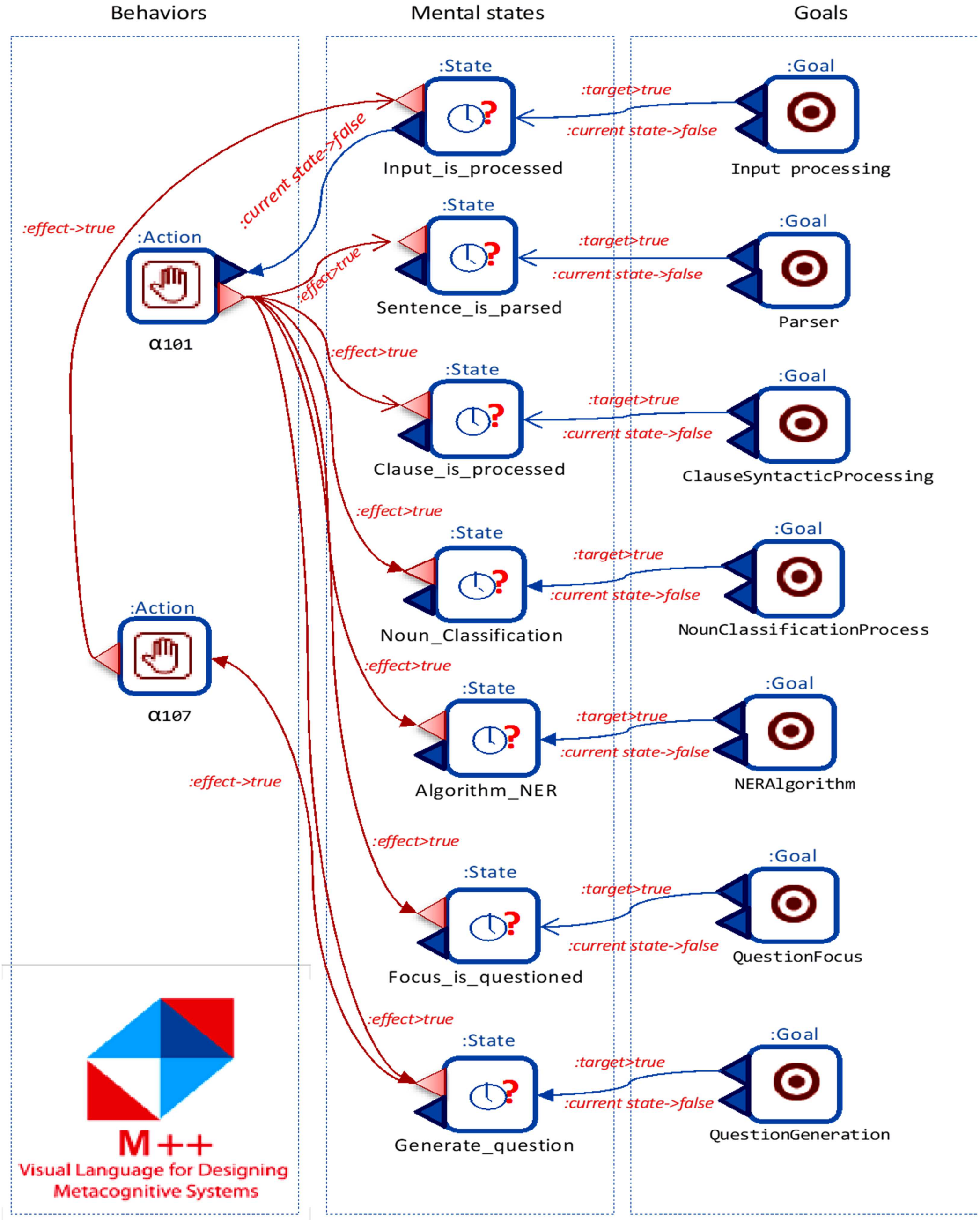

Fig. 6. Representation of Mental States, Actions and Goals in M++

In Fig. 6. Representation of just the main goals for the construction of the cognitive model is shown.

6) Runnable Cognitive Model in Carina: The cognitive model exported in the previous step is saved in CARINA to be executed. FWhQs cognitive model was made in an executable code called, JSON, explained and presented below. Mental states indicate CARINA how to do a specific task. Mental states are composed by a system identifier, a name, a type, a system unique identifier and a cognitive model identifier in the cognitive model. The cognitive model starts with the mental states, which are the objectives that are wanted to change from a false state to a true state.


```
[
  {
    "_id": "5becc375fa3c95fda65b7572",
    "name": "Translate User Response to SDG",
    "type": "CMEC",
    "ius": "5becc3751ff39189340f3274",
    "cm": "5becc3755bbc4254e5c674d8",
    "mentalStates": [
      {
        "name": "stimulus_from_environment_is_read",
        "state": false
      },
      {
        "name": "Translate User Response to SDG",
        "state": false
      },
```


Fig. 7. Mental State in Cognitive Model for Factoid-Wh Question

The goals are needed to reach and change each mental state. In the goals, the reference, the mental state, the current state, corresponding to false or true, and the description are found.

```
{
  "goal": {
    "_id": "5becc3758cdc20aea06fbd62",
    "name": "Translate User Response to SDG",
    "currentValue": false,
    "targetValue": true,
    "description": "Translate User Response to SDG"
  }
```

Fig. 8. The goal in Cognitive Model for Factoid-Wh Question.

The production rules must have a condition to be achieved so that the conclusions can be executed [1]. The condition of the following aspects is described: cognitive model is to solve the problem and the goal is affected at the same time. Mental states are the cognitive model tasks to solve the problem.

```
],
"productionRules": [
  {
    "rules": {
      "_id": "5becc37552accf1704e02dfa",
      "condition": {
        "reasonState": {
          "cm": "5becc3755bbc4254e5c674d8",
          "goal": "5becc3758cdc20aea06fbd61"
        }
      },
```

Fig. 9. Rules of production in Cognitive Model for Factoid-Wh Question

In the conclusion, the actions found: a name, a function identifier module that detects where the function is coming from, a function identifier (an action that is executed); the function identifier points out when the action is executed. At the end all the actions are executed as well as the rules dealing with mental state. When all the mental states are true, it can be said that the problem is solved.

```
"conclusion": [
  {
    "action": "accomplishGoal",
    "module": "carinaModules",
    "idFS": "5becc3754579f6751b5c4341",
    "params":{
      "goal":"5becc3758cdc20aea06fbd62"
    },
    "accomplish": false
  },
  {
    "action": "returnWithGoalAccomplished",
    "module": "carinaModules",
    "idFS": "5becc3754579f6751b5c4341",
    "params":{
      "goal":"5becc3758cdc20aea06fbd62"
    },
    "accomplish": false
  }
]
```

Fig. 10. Conclusion of production in Cognitive Model for Factoid-Wh Question

7) Testing and Maintenance of the Cognitive Model: In this step, the performance, response time and compliance with the requirements of the Cognitive model are evaluated. The designed cognitive model for the Factoid-WH questions in EFL was initially tested with a cognitive agent that answers Factoid questions in Spanish. The results of the cognitive agent TOOLKIT are shown below. TOOLKIT is an Artificial Intelligence designed agent to answer factoid questions in a specific domain of knowledge.

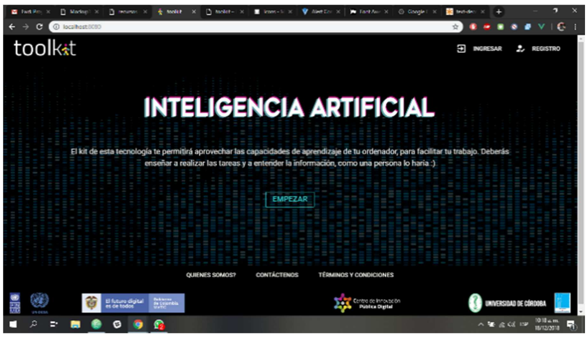

Fig. 11. Login and registration in the Toolkit agent

Fig. 12. Interface to create the factoid questions.

III. Results and Discussion

M++ validation process coped with key components of the cognitive model design in M++ and it was proposed based on two dimensions: Readability and Potential Usefulness. The Empirical study method was used for this validation process. This was based on the method called empirical study based on the expert perception about the quality of the M++ notation [58], [59]. A practical test was used to verify and evaluate the readability and usefulness of M++ based cognitive model. The variables used to calculate the user perception in terms of the M++ effectiveness [58], [60] are as follows:

- Easiness to read perceived: this variable represents a perceptual judgment to read M++ represented cognitive models.
- Usefulness Perceived: This variable declares the degree a person believes in the use of M++ to adequately represent Goals, the Mental States and Actions of the cognitive model represented in M++.

The experiment was conducted with the following two research questions:

- RQ1: "Is the cognitive model represented in M++ perceived as easy to read for the identification of behaviors that belong to this cognitive model and their respective relations?"
- RQ2: "Is the M++ cognitive model perceived as a usefulness to represent appropriated goals, mental states and actions belonging to a cognitive model?". The experiment was carried out with 11 experts from the undergraduate program in Computer Science and Audiovisual Media at the Universidad de Córdoba.

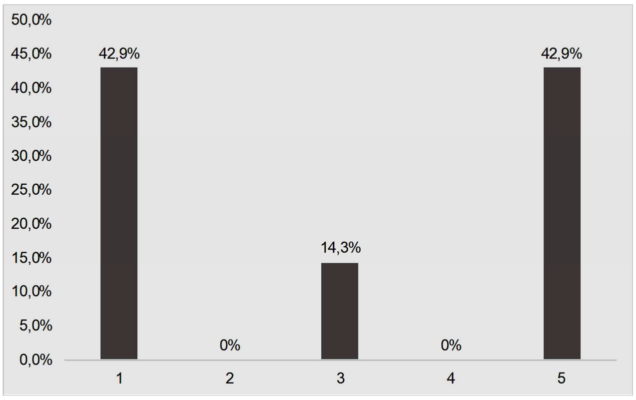

Fig. 13. Result variable perceived ease of reading.

The easiness to read perceived variable was measured by the expert judgment about how easy or difficult they perceived the M++ represented cognitive model to read was. The experts rated the "easiness to read perceived "on a scale from 1 to 5, where 1 is very easy to read, and 5 is very difficult to read. Fig. 13 shows the expert answers. The relationship the usefulness of the notation of M++, 90,1% of the experts considered useful, as compared to 9,0% who did not.

IV. Conclusion

This research describes the design of a CARINA-based Cognitive Agent for the generation of Factoid-Wh Questions in EFL using a cognitive modelling methodology. In this study, the cognitive model was tested for Factoid WH-questions in English with a cognitive agent to answer Factoid questions in Spanish in a specific knowledge domain.

For this purpose, a cognitive modeling methodology for the metacognitive architecture CARINA proposed by [5] was used. Also, the cognitive model algorithm of generation was presented through the cognitive task, where its main characteristics are presented: the mental states, the goals, production rules and actions.

A type of validation was performed to prove the M++ notation and the coherence to read the produced models using M++. In this validation process, the experts only evaluated the cognitive model design in M++ through an experiment. Results evidenced the property of being easy to read that the M++ based-cognitive models have and how they enable the understanding of relations among different elements of a cognitive model. This research presents a new application field of the cognitive informatics and cognitive computing, language use, which facilitates the construction of educational resources based on cognitive process simulated in the Metacognitive Architecture CARINA.

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