Validación de un modelo cognitivo basado en M ++ para la generación de preguntas Factoid-Wh

Validation of a Cognitive Model Based in M++ for Factoid–Wh Questions Generation

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Resumen Una pregunta Factoid-WH es una pregunta que comienza con una palabra interrogada WH (What, When, Where, Who) y requiere un hecho como expresado en el cuerpo del texto. Un modelo cognitivo es una especificación teóricamente fundamentada y guiada de las representaciones mentales y los procesos involucrados en una función cognitiva dada. Este artículo tiene como objetivo la representación en M++ del Modelo Cognitivo para la generación de preguntas Factoid-WH. La metodología de este trabajo se presenta en cinco pasos: Selección de la Tarea Cognitiva, Obtención de Información para Describir la Tarea Cognitiva, Descripción de la Tarea Cognitiva en Lenguaje Natural, Descripción de la Tarea Cognitiva en GOMS, Codificación del Modelo Cognitivo de GOMS a Lenguaje M++ y finalmente, se implementó una prueba de validación la cual muestra resultados satisfactorios.

Palabras Claves: Modelo Cognitivo; Preguntas Factoid-WH; Lenguaje Visual de Dominio Específico: M++.

Abstract A Factoid-WH question is a question, which starts with a WH-interrogated word (What, When, Where, Who) and requires as an answer a fact expressed in the text body. A cognitive model is a theoretically grounded and empirically guided specification of the mental representations and processes involved in a given cognitive function. This paper aims the representation in M++ of the cognitive model for the generation of Factoid-WH Questions. The methodology of this paper is presented in five steps; Selection of Cognitive Task, Obtaining Information for describing the Cognitive Task, Description of Cognitive Task in Natural Language, Description of Cognitive Task in GOMS, Codification of Cognitive Model from GOMS to M++ Language. Finally, a validation test was implemented with satisfactory results.

Keywords: Cognitive Model; Factoid-WH Question; Domain-Specific Visual Language: M++.

1 Introduction

A Factoid-Wh question is a question which starts with a Wh-interrogative word (What, When, Where, Who) and requires an answer as a fact expressed in the text body (Kolomiyets & Moens, 2011). A wide number of researchers have focused on the importance of questions for language learning and social interaction (Garvey, 1975; Hart & Risley, 1999; Holzman, 1972; Hung, Stark, & Eykhoff, 1977; Palinscar & Brown, 1984; Siller & Sigman, 2002; Taylor & Harris, 1995).

Question generation has been defined as the task of automatically generating questions from some form of input (Rus & Arthur, 2009). This input is a written sequence resulting from a voice recognition system or obtained from a keyboard or even from a written document (Ramos, Augusto, & Shapiro, 2008).

Factoid-Wh question generation process consists in receiving a text source as input, in order to automatically parsing the sentences and transforming these sentences into Factoid-Wh questions (Ramos *et al*., 2008). A fair amount of researches has been deepen studied different areas on Factoid-WH question generation system, making emphasis in the generation of Wh- question and have worked on specific aspects such as: sentence parsing, extracting simplified sentences from appositives, subordinated clauses, question from sentences, questions from dialogues, question generation from paragraphs, question-answering systems, multiple-choice question generation (Kalady, Elikkottil, & Das, 2010), (Kalady *et a*l, 2010) (Rus *et al*., 2012), (Ali Addaibani, 2017). While much attention has been paid to the studies previously mentioned, little attention has been devoted on the design of Factoid-Wh question generation systems using Cognitive Modeling.

Cognitive modeling is a research methodology of cognitive science, resulting in theories that are formulated as computer programs (Strube, 2001). The central goals of cognitive modeling are: describe, predict and prescribe human behavior (Marewski & Link, 2014; Ziefle *et al*., 2011) through computational models of cognitive processes commonly called Cognitive Models (Fum, Del Missier, & Stocco, 2007). The Cognitive Models are a computational models of some internal information processing mechanisms of the brain for the purposes of comprehension and prediction (Jerónimo, Caro, & Gómez, 2018; Kopp & Bergmann, 2017). Cognitive Models Construction Process needs firstly an analysis of the structure of the cognitive task (Taylor & Harris, 1995).

This type of analysis uses methodologies that allow describing events that occur in a specific order when a cognitive task is developed, M++ is one of these methodologies. M++ is a Domain-Specific Visual Language (DSVL) for modeling metacognition in intelligent system; in M++, the abstract syntax is specified with MOF-based metamodels and the concrete syntax is expressed by some mapping of the abstract syntax elements to visual constructs. The main artifacts of M++ are models specified in a visual manner (Caro, Josyula, Jiménez, Kennedy, & Cox, 2015).

A cognitive model of a task constructed in a cognitive architecture is runnable and create a sequence of behaviors (Jacko, 2012). A cognitive architecture is a general-purpose control system inspired by scientific theories developed to explain cognition in animals and humans (Langley, Laird, & Rogers, 2009). This have been used to create cognitive models of a variety of intelligent systems (Forstmann & Wagenmakers, 2015). The Computational Metacognition allows to an intelligent systems to monitor and control their own learning and reasoning processes (Caro, Gómez, & Giraldo, 2017).

CARINA is a metacognitive architecture for artificial intelligent agents, derived from the MISM Metacognitive Meta model, and is composed of two cognitive levels named object-level and meta-level (Caro, Josvula, Gómez, & Kennedy, 2018).

This paper focuses on the representation in M++ of the cognitive model for the construction of Factoid-WH questions. The motivation of this work is the creation of a cognitive model for the construction of Factoid-WH questions in order to create educational resources, in the future which help to enrich the teaching – learning process.

The development and implementation of this kind of cognitive educational resources based on models that represent cognitive processes have become the latest educational trend in Latin America (Gómez, Caro, Solano, & Vega, 2018). This is because the principles and notions that are part of educational theories are used in the engineering process of this type of cognitive educational resources to design the reasoning and decision-making mechanisms on which these intelligent systems are based (Gómez & Caro, 2018).

Chapter II represents the structure, characteristics, essential components and the syntactic representation of Factoid-Wh questions. In chapter III the steps for the Question Generation are defined. Chapter IV describes the metacognitive architecture in which the cognitive model is housed. Chapter V discloses the methodology used. Chapter VI describes a cognitive model for Factoid-Wh Question in M++. Chapter VII represents the M++ model validation and finally, the conclusions are described remarking the results generated from the representation in M++ the cognitive model created for the Factoid-Wh Questions construction.

2 Features of Factoid-WH Questions

A Factoid-Wh question is a sentence starting with an interrogative pro-form -what, where, when, who, why and how- that expects an answer which is a noun phrase that corresponds to a fact (Waraporn & Ahamed, 2006). According to i Cherta (1993) and Ali Addaibani (2017) Factoid-Wh questions are composed of the following structure: Wh-word + auxiliary verb + subject + main verb.

Start with an interrogative pronoun reversing the order between subject and operator and pronounced with descending intonation. If there is no assistant, it is entered as an operator, usually is structured with an auxiliary verb (be, do, have or a modal verb) that must go according to the subject and the time of the sentence, see the example as follow (Fig. 1)

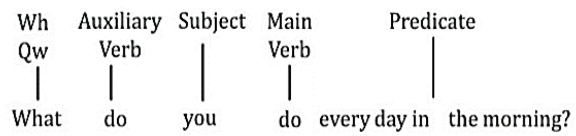

Fig 1. Example of Factoid-WH Question

3 Question Generation

According to applied linguistics, Question Generation is an important comprehension-fostering and self-regulatory cognitive strategy (Palinscar & Brown, 1984). Question Generation facilitates students to carry out higher-level cognitive functions for themselves (Garcia & Pearson, 1990; Scardamalia & Bereiter, 1985).

The following approaches (Heilman & Smith, 2010; i Cherta, 1993; Valin, 1998) are used for this Question Generation cognitive model, which is structured in three stages: i) *Content selection*: In the content selection stage, all the pieces of text in the clause over which the question has to be asked are identified (Boyer & Piwek, 2010).

This research will use a single clause as an input, which will be the context to finally build a syntactic tree in order to identify not only the core and Periphery but Noun Phrase, Verb Phrase and Preposition in the clause; ii) *Selection of question type*: the most appropriate type of question will be chosen depending on the selected content and context (Rus *et al*., 2012).

This step focuses on how to ask the question; iii) *Question construction:* a question is formed over each of the texts picked in the previous stage (Boyer & Piwek, 2010). Taking into account that a Wh-question appears with a Wh-word at the beginning of the sentence, question construction process will use the Wh-movement Mechanism proposed by Van Der Lely & Battell (2003).

Wh-movement is a syntactic operation in English which refers to elements that are often produced in a different position from the one they originate (van der Meulen, Bastiaanse, & Rooryck, 2011). In order to apply the Wh-movement in the question construction stage we will identify the relationship between subject and object and prepositions on the clause to finish with the generation of possible Factoid-Wh Questions related with the input clause.

4 Carina Metacognitive Architecture

CARINA is a metacognitive architecture for artificial intelligent agents; is derived from the Master of Information Systems Management (MISM) Metacognitive Metamodel. CARINA integrates self-regulation and metamemory with support for the metacognitive mechanisms of introspective monitoring and meta-level control; in this sense CARINA assumes a functional approach to philosophy of mind (Caro *et al*., 2018). According to several authors Memory System in CARINA is structured as follows: Sensory Memory, Working Memory and Long-Term Memory (Perlis, Cox, Maynord, & others, 2013; Piccinini, 2010; Shah & Miyake, 1999)

The Information flow through the memory system in metacognitive architecture CARINA is shown as follows (Fig. 3): The input information flow remains in the sensory memory waiting to be attended by the attention system. The attention system selects the input information according to the goals, the problem and the current state of the world then a new episode is generated. The episode is extracted from sensory memory to working memory, where procedural and semantic knowledge is processed.

CARINA represents the problems that intend to solve through Mental States. A Mental State is a representation that is able to build a plan for executing tasks in order to accomplish a goal (Isern, Gómez-Alonso, & Moreno, 2008). These Mental States are stored in its working memory structure called "model of the world". To achieve these Mental States CARINA generates a series of Goals stored in its motivational system. Goal are objectives that drive, a task or process (Caro, Josyula, Cox, & Jiménez, 2014).

These Goals point towards Mental States of working memory in order to modify them through a plan composed of actions located in its procedural memory. Action is a class of events; viewed intuitively, those that result from the activity of some agent or agents in accomplishing some goal (Georgeff, 1988). Below, the cognitive model is presented to generate Factoid-WH Questions in the CARINA Metacognitive Architecture represented in M++.

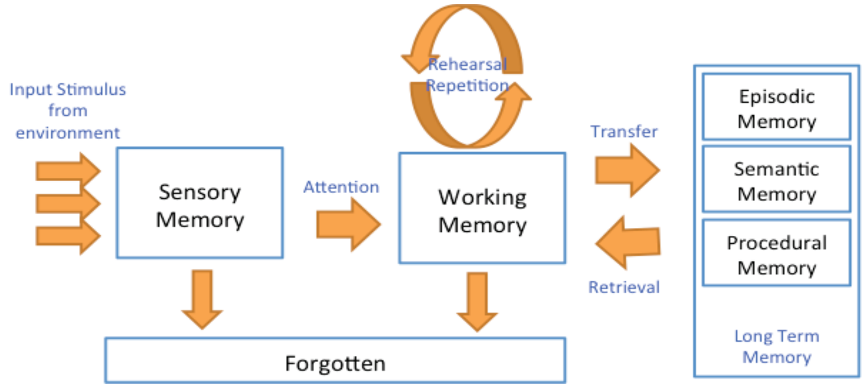

Fig 2. Memory System in CARINA. Copyright 2018 for Caro *et al*. Introduction to the CARINA metacognitive architecture. ResearchGate Conference Paper July 2018.

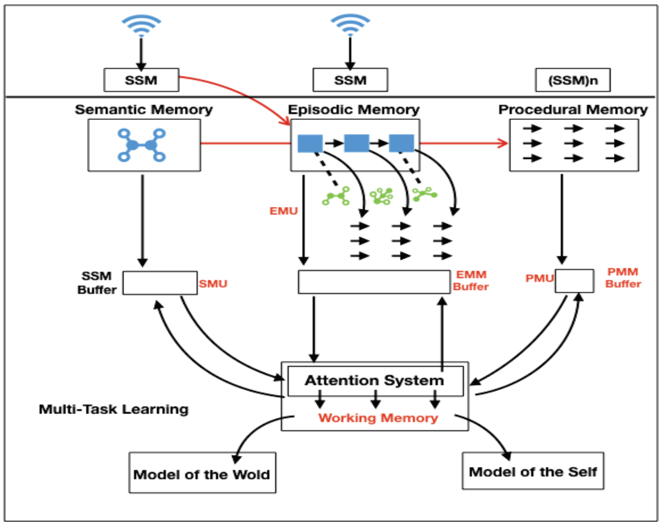

Fig 3. Information flow through the memory system in CARINA architecture. Copyright 2018 for Caro, Gomez, Madera. Integrating Semantic Memory into the CARINA Metacognitive Architecture. CAVA

5 Methodology

The methodology used in this paper is proposed by Olier, Gómez, & Caro (2018) from which the first five steps were chosen since the research process is still in process.

5.1 Selection of Cognitive Task

The problem is stated in terms of cognitive task using natural language.

5.2 Obtaining Information for describing the Cognitive Task

The cognitive modeler selects information sources in order to describe the cognitive task. The Information can be obtained from experts, users or document sources.

5.3 Description of Cognitive Task in Natural Language

The prerequisites to solve the problem stated and the cognitive functions used by each individual or group of people who develop the Cognitive task are explained in in natural language.

5.4 Description of Cognitive Task in GOMS

In this phase, GOMS Model is used as a structured natural language notation in order to represent the first version of the cognitive model.

5.5 Codification of Cognitive Model from GOMS to M++ Language

In this step, the Cognitive Model is translated into a visual language to model metacognition, called M++.

6 Cognitive Model for Factoid-WH Questions in M++

The cognitive model is composed by the following elements: goals, actions and mental states. The cognitive model has a main goal called Input Processing which is structured by various sub-goals that allow to achieve the construction of Factoid-WH questions step by step. These goals are presented below. (Fig 4).

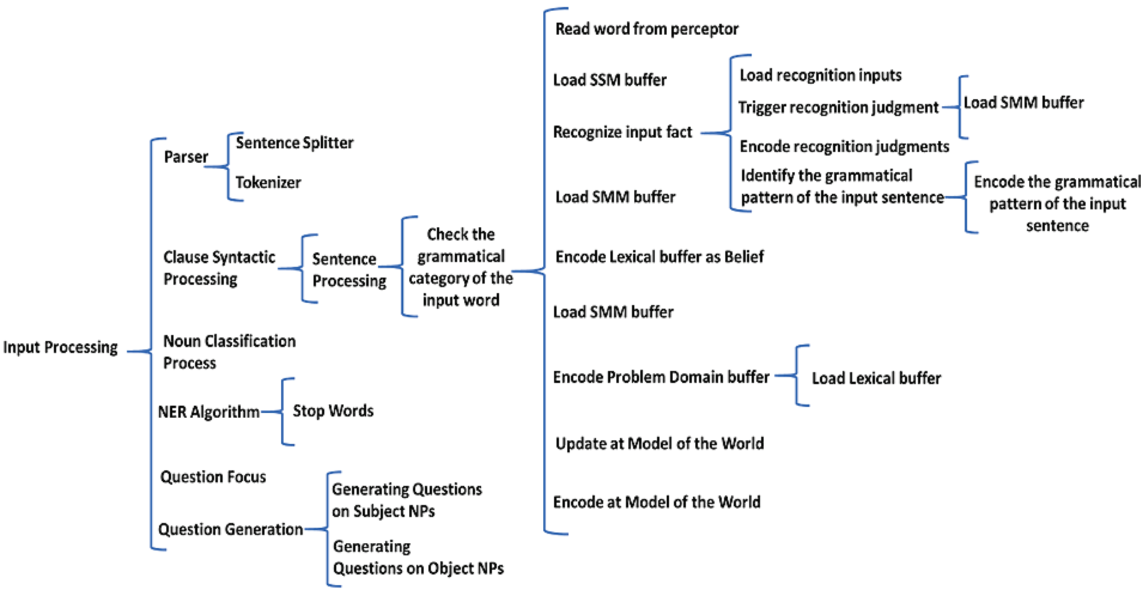

Fig 4. Goals Representation of the Cognitive Model for the Construction of Factoid-WH Questions.

The representation of the Cognitive Model in M++ notation language is described below. M++ is a DSVL for modeling metacognition in intelligent systems and incorporates two meta-reasoning mechanisms, introspective monitoring and meta-level control. The main artifacts of M++ are models specified in a visual manner. In figure. 5, section (A) shows the icons used to represent object-level tasks and section (B) displays icons representing elements that interact with the tasks at the object-level. (Caro *et al*., 2015)

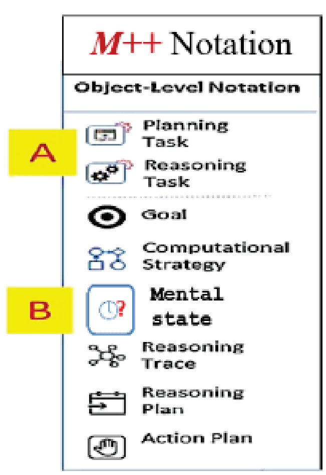

Fig 5. Main elements in M++ notation. Copyright 2015 for Caro, *et al.*

In M++ the Question Generation is viewed as a three-step process: content selection, question type selection and question construction (Rus & Arthur, 2009). These three processes are represented in M++ in the following way.

The model of the environment in Carina is represented in the working memory by the mental states, therefore, for each action Carina maintains a mental state. In M++ (Fig. 6) mental states are represented and shown in the center of the cognitive model and then associated with the actions that modify each of the mental states. The actions have preconditions that evaluate if some mental states have been fulfilled in order to be executed. The actions also have the postconditions that our mental states which are affected and their value changes from false to true after executing the Action; The Goals point to the mental states and these are considered complete when the mental state to which it points become true. The reasoning process of CARINA object level looks for those actions that are capable of modifying a problem from a set of initial states to a set of final states.

Below are all the Actions and Goals of the cognitive model represented in M++.

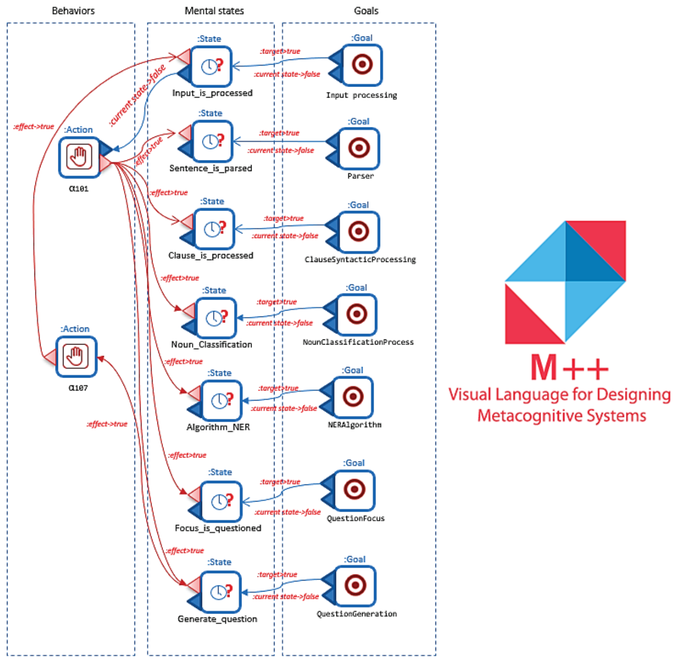

Fig 6. Representation of Mental States, Actions and Goals in M++.

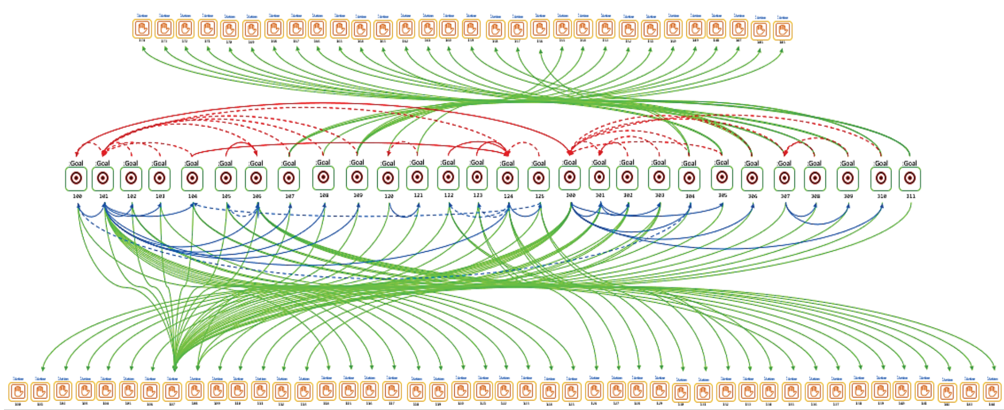

Fig 7. Representation of Goals and Actions in M++.

7 Validation of the Model M++

M++ validation process encompassed just the main aspects of the cognitive model design in M++ and it was performed on two specific dimensions: Readability and Potential Usefulness. For this validation process, the method called empirical study based on user perception was implemented in regard to the quality of the M++ notation was measured (Sargent, 1998). The experimental study was developed based on the designed parameters of the software engineering experiments, all described in the works of (Molina, Gallardo, Redondo, Ortega, & Giraldo, 2013; Sjøberg *et al*., 2005; Wohlin *et al*., 1999).

The objective of the experiment was to evaluate the M++ notation with respect to the readability and usefulness of the M++ based cognitive model. The variables used for measuring the user perception with regard to the quality of the notation are represented on (Abrahão, Insfran, Cars'i, & Genero, 2011), (Wohlin *et al.*, 1999). (i) Perceived ease of read: This variable represents a perceptual judgment of the effort required to read M++ based cognitive models; (ii) Perceived of usefulness: This variable expresses the degree to which a person believes that the use of M++ will achieve its intended objectives regarding the appropriate representation of goals, mental states and actions the cognitive model represented in M++.

The experiment was conducted with the followings two research questions: RQ1: "Is the cognitive model represented in M++ perceived as easy to read allowing to identify the behaviours that belong to this cognitive model and their respective relations?"; and RQ2: "Is the cognitive model represented in M++ perceived as useful to represent appropriated goals, mental states and actions that belong to cognitive model?". The experiment was carried out with 11 experts from the Degree in Computer Science and Audio-visual Media at the Universidad de Córdoba. Initially, participants were asked about their preferences regarding the use of texts or graphical representations for specifying software systems. 91,1% of the experts prefer the graphic notations in comparison with the 9,0% that prefer the textual notations.

The variable perceived ease of read was measured by the opinion of the participants about how easy or difficult they found the M++ represented cognitive models. The subjects rated the "perceived ease of read" on a scale of 1 (very easy to read) to 5 (very difficult to read) according to the perceived use of M++, Table 1 shows the mean of the scores assigned by participants (expert teachers) to M++.

Table 1. Reading Perception

Graphical specification	Professionals
Usability of M ++ to read cognitive models	Mean 1,4

Regarding the usefulness of the notation of M++, 90,1% of the experts considered useful the notation as compared to 9,0% who did not consider it. (Fig. 8)

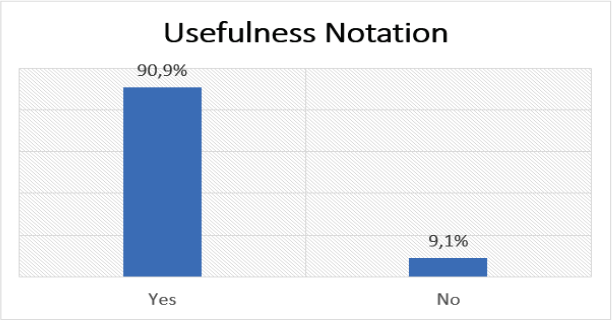

Fig 8. Result of the Usefulness notation.

8 Conclusions

In this paper, the cognitive mechanisms in the Factoid-WH questions generation process when learning English as a foreign language is explained through a cognitive model represented in M++.

For this research a type of validation was performed to prove the notation and the consistency to read the models generated using M++. In this validation process, the experts only evaluated the cognitive model design. The validation of the M++ notation was carried out by an experiment. From the results, it can be concluded that the cognitive model represented in M++ is easy-to-read and allows understanding the relations among different elements of a cognitive model.

Finally, with the development of this research, the M++ representation of cognitive models of Factoid-WH questions generation process when learning English as a foreign language allows an advance from the cognitive informatics to education.

Future Work. This research will continue with the development of a cognitive model performable to let the design of a cognitive agent that uses the process of generating Factoid-WH Questions inside of its inner process of performing.

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