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# MEXICA: A computer model of a cognitive account of creative writing

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*Abstract*. MEXICA is a computer model that produces frameworks for short stories based on the engagement-reflection cognitive account of writing. During engagement MEXICA generates material guided by content and rhetorical constraints, avoiding the use of explicit goals or story-structure information. During reflection the system breaks impasses, evaluates the novelty and interestingness of the story in progress and verifies that coherence requirements are satisfied. In this way, MEXICA complements and extends those models of computerised story-telling based on traditional problem-solving techniques where explicit goals drive the generation of stories. This paper describes the engagement-reflection account of writing, the general characteristics of MEXICA and reports an evaluation of the program.

*Keywords:* engagement, reflection, creativity, computerised storyteller

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## 1. Introduction

Traditionally, computer models in AI have been developed either with the goal of producing programs that perform a task in the same way as human beings, or with the goal of producing programs that perform a task in any way that meets objective criteria of effectiveness, independently of how human beings do it. In this paper we present a model that stands at a point between these two positions: an automated story-teller based on a cognitive account of writing. The cognitive account provides a set of requirements that correspond to mental constraints and the observed behaviour of writers. In this way, the computer model obtains completeness and rigour from the cognitive account. The program produces examples of computational creativity that can be matched against human writing, demonstrating the plausibility of the cognitive account through the quality of its productions, and producing insights into the adequacy and completeness of the cognitive model of writing. MEXICA is a computer

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program, based on the engagement-reflection account of writing, which produces novel and interesting story frameworks about the Mexicas, the old inhabitants of what today is México City. We refer to MEXICA outputs as 'story frameworks' rather than stories, since the system is not capable of producing full natural language. Figure 1 shows an example of a story framework created by the system.

The paper is organized as follows. We describe the main aspects of the cognitive account of writing: the role of internal and external constraints, how memory is probed and, the cycle of engagement and reflection. We then present a description of the MEXICA model: its general architecture, how structures representing knowledge are created, and the way events are retrieved from memory. Since one of the main characteristics of the system is the production of material guided by constraints rather than explicit goals, a section is devoted to explain how internal constraints are represented in the computer model. Next, we give an explanation of how the whole system interacts to develop a new story framework. Finally, we present an evaluation of outputs from the program.



## 2. How we write

The design of MEXICA is informed by an account of writing as design (Sharples 1999) and it implements a core part of that account, in which the activity of creative writing is conceptualized as a cycle of cognitive engagement and reflection. An episode of writing begins with a set of internal and external constraints that provide a context for linguistic creativity. External constraints include the writing task, the tools available for writing and the surrounding world of human and physical resources. The internal mental constraints consist of content constraints (what to write) and rhetorical constraints (how to compose the material in order to satisfy the audience and purpose). These act as the tacit knowledge that guides the composing process.

A writer probes long term memory to retrieve ideas that conform to the constraints and expresses these as written prose. The current context triggers further probes of memory to continue the process. This engagement with the emerging text may be interrupted when the probe fails to elicit new ideas, when the writer senses that the emerging text has departed from the constraints, or when the writer decides to explore a conceptual space to create new content or rhetorical constraint. At that point the writer will stop and bring the current state of the task into conscious attention, as a mental representation to be explored and transformed. This may involve reviewing all or part of the written material, conjuring up memories, forming and transforming ideas, and specifying what new material to create and how to organize it. The process of mental engagement and reflection forms a productive cycle (figure 2) whereby a writer forms and explores ideas and conceptual spaces; these provide constraints for the writer to specify and organize the ideas into a linguistic form; the language is expressed as written text; the writer reviews and interprets the written material which provokes new ideas and cognitive transformations. The cycle may be short, such as when a writer generates and reviews a text sentence by sentence, or longer, when a writer creates a productive space of constraints that leads to a prolonged bout of engaged writing followed by a period of review and revision.

The MEXICA system is an attempt to model the cycle of engagement and reflection. Thus it both demonstrates the adequacy of the model as a general specification for

generating frameworks of literary text, and it provides a test-bed for investigating a cognitive account of the writing process. Since MEXICA is a software system not an embodied being, it is restricted to simulating the mental processes and constraints and contains no representation of a writer's external resources or constraining influences. Throughout this paper the internal processes of the program are described in cognitive terms ('reflection', 'long term memory', etc.). This is necessary in order to make clear the relationship between the cognitive account and the computer implementation, however it is not intended to imply that the computer is a cognitive or self-aware agent nor that the computational processes are direct representations of human mental activities. MEXICA is not a model of a human writer, but a tool for exploring a cognitive account of writing.



***Jaguar_knight was an inhabitant of the great Tenochtitlan. Princess was an inhabitant of the great Tenochtitlan. From the first day they met, Princess felt a special affection for Jaguar_knight.*** Although at the beginning Princess did not want to admit it, Princess fell in love with Jaguar_knight. Princess respected and admired Artist because Artist's heroic and intrepid behaviour during the last Flowery-war. For long time Jaguar_knight and Princess had been flirting. Now, openly they accepted the mutual attraction they felt for each other. Jaguar_knight was an ambitious person and wanted to be rich and powerful. So, Jaguar_knight kidnapped Artist and went to Chapultepec forest. Jaguar_knight's plan was to ask for an important amount of cacauatl (cacao beans) and quetzalli (quetzal) feathers to liberate Artist. ***Princess had ambivalent thoughts towards Jaguar_knight. On one hand princess had strong feelings towards Jaguar_knight but on the other hand Princess abominated what Jaguar_knight did. Suddenly, the day turned into night and after seconds the sun shone again. Princess was scared. The Shaman explained to Princess that Tonatiuh (the divinity representing the sun) was demanding Princess to rescue Artist and punish the criminal. Otherwise Princess's family would die. Early in the Morning Princess went to Chapultepec forest.*** Princess thoroughly observed Jaguar_knight. Then, Princess took a dagger, jumped towards Jaguar_knight and attacked Jaguar_knight. ***Jaguar_knight was shocked by Princess's actions and for some seconds Jaguar_knight did not know what to do.*** Suddenly, Princess and Jaguar_knight were involved in a violent fight. In a fast movement, Jaguar_knight wounded Princess. An intense haemorrhage arose which weakened Princess. Jaguar_knight felt panic and ran away. Thus, while Tlahuizcalpantecuhtli (the god who affected people's fate with his lance) observed, Princess cut the rope which bound Artist. Finally, Artist was free again! ***Princess was emotionally affected and was not sure if what Princess did was right. Princess was really confused.*** The injuries that Princess received were very serious. So, while praying to Mictlantecuhtli (the lord of the land of the dead) Princess died.

Figure 1. A story framework generated by MEXICA in ER2 operation mode (text in italics shows those parts produced in 'reflection' mode).

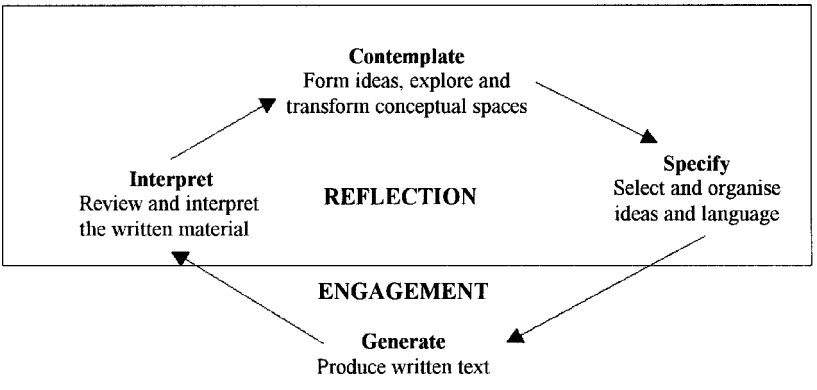


Figure 2. The cycle of engagement and reflection in writing.

## 3. General aspects of MEXICA

MEXICA (Pérez y Pérez 1999) is divided in two main parts: the engagement state and the reflective state. During engagement MEXICA generates material driven by content and rhetorical constraints avoiding the use of explicit goals or story-structure information. This characteristic contrasts with previous systems which employ explicit goals or story-structure information to generate their outputs (e.g. Pemberton 1989, Turner 1993). During reflection MEXICA breaks impasses, modifies the story in progress to satisfy coherence requirements, and evaluates the novelty and interestingness of the story in progress. As a result of this evaluation MEXICA can modify the constraints that drive the production of material during engagement. Thus, the stories produced by MEXICA are the result of the interaction between engagement and reflection.

The system employs a database to create in long-term memory (LTM) a group of structures representing the content and rhetorical knowledge necessary to construct stories. Such a database is called Previous Stories and is formed from a set of stories. Stories in MEXICA consist of two different kinds of components. The first is formed by the explicit elements described in the narrative, i.e. concrete story-actions such as *princess went to the forest*. The second is formed by tacit elements (they are never explicitly shown in the story) that represent emotional links between characters and the dramatic tension produced in the story. These tacit components are stored in a structure called a story-world context. This is used as a cue to probe LTM during engagement and retrieve into working memory (WM) subsequent next actions for the story in progress. Story-world contexts are dynamic structures that can be modified during the probe of LTM in order to retrieve novel and interesting actions.

To evaluate novelty the system compares the story in progress against the previous stories in terms of significant differences in content. To evaluate interestingness MEXICA compares patterns of change in dramatic tension from the sequences of actions in previous stories. MEXICA includes a group of parameters that can be adjusted to control and modify the writing strategy in the system. In this way, the user can experiment with different aspects of the computer model.

### 3.1 *How MEXICA works*

MEXICA performs two main processes: the first builds in LTM the knowledge necessary to produce a story; the second triggers an engagement-reflection cycle in order to develop a new story. As mentioned above, MEXICA builds its knowledge from a set of pre-defined stories called *previous stories*. Previous stories are kept in a program's archive and can be written or modified by a user of MEXICA. The process of analysing the previous stories to build schemas representing content and rhetorical knowledge in LTM simulates the human writing process in that 'from reading ... you acquire basic knowledge of the structural and rhetorical devices that belong to a particular genre or form of writing' (Lodge 1996: 171). A language (resembling a simple computer language) called the Previous Stories Definition Language (PSDL) was developed to allow the user of the system to specify the set of previous stories, and therefore to control the type of content and rhetorical knowledge in the system. Figure 3 shows an example of a previous story defined with the PSDL.

In MEXICA, a story is defined as a sequence of actions. Thus, before a user can define the previous stories it is necessary to establish a set of valid story-actions. A language, called Story Action Definition Language (SADL), was developed to allow

specifying story actions. Figure 4 shows a typical example of an action defined through the SADL.

In this way, the general steps to create stories in MEXICA are the following:

- The user defines a list of all possible story-actions.
- The user defines a set of previous stories.
- MEXICA reads the story-actions and previous stories to build in LTM schemas representing content and rhetorical knowledge.
- MEXICA generates new stories through an engagement-reflection cycle.

Since the set of previous stories represents examples of well-constructed stories, all structures in memory represent correct rhetoric and content knowledge. In MEXICA, actions have associated with them a set of consequences (or post-conditions) that modify the story world each time an action is performed. Post-conditions are referred to as tacit elements because, by contrast with story-actions, they are never explicitly shown nor mentioned in the story. MEXICA works with three types of post-conditions: emotional links between characters, situations that produce tension (see section 4 for an explanation of tensions) and changes in the physical position of a character in the story-world. For example, the action *princess cures jaguar knight's injuries* produces as a consequence that *the knight is grateful towards the princess* (an emotional link between characters). MEXICA works with three types of emotional links: type 1 is brotherly love, type 2 is amorous love, and type 3 can be defined by the user. Emotions of type 1 represents a continuum between love and hate while emotions of type 2 represent a continuum between being in love with and feeling hatred towards another person.



**Scenery City**
**Princess Went_Popocatepetl_Volcano**
**Hunter Kidnapped Princess**
**Farmer Found_By_Accident Hunter**
**Farmer Realised Hunter Kidnapped Princess**
**Hunter Attacked Farmer**
**Farmer Fought Hunter**
**Hunter Wounded Farmer**
**Hunter Ran_Away**
**Princess Did_Not_Cure Farmer**
**Princess Went_Tenochtitlan_City**
**Farmer Died_By_Injuries**

Figure 3. An example of a previous story defined with the PSDL.

```
ACT
Attacked 2
PRE
E a b -2 *      ; A(-2,*):B
POS
E b a -3 1      ; B(-3,1):A
E Lb a % 1      ; Lb(%,1):A
TEN
T Lr b a +      ; Lr(b):a+
TEXT
@A thoroughly observed @B. Then, @A took a dagger, jumped towards @B and attacked @B.
@A's frame of mind was very volatile and without thinking about it @A charged against @B.
```

Figure 4. A story-action defined with the SADL.

MEXICA creates for each character in the story a structure called story-world context where post-conditions are registered. Thus, continuing with the example below, the princess' story-world context and the knight's story-world context are formed by the emotional link established between the knight and the princess. The purpose of story-world contexts is to constrain the possible directions that the story in progress can take. For instance, since *princess cures jaguar knight's injuries* produces a context where the knight is grateful towards the princess, the story might continue with an action where the knight rewards the princess. The same context restricts the possibility that the story continues with an action where the knight tries to cause damage to the princess. Each character has its own story-world context. This situation allows the development of stories where different characters register different events in the story world. The following paragraph illustrates this situation (the text in brackets represents actions' post-conditions):

> At the Sunday market, a farmer tries to kill jaguar knight [The knight hates the farmer] In response, the knight thrashes the farmer [The knight hates the farmer. The farmer also hates the knight]. In that moment, the princess arrives to the market and sees the knight beating the farmer…

Since the princess is not located in the market when the farmer tries to kill the knight, her story-world context does not register the consequences of this action, i.e. she is not aware of the killing attempt; she only sees a knight taking advantage of his position and thrashing a farmer without any reason. This situation permits driving the story in different directions: for example, from the perspective of the princess' story-world context, the story might continue with an event where she punishes the knight; such an action can trigger a resentment feeling in the knight that would lead to a revenge action towards the princess, and so on. From the perspective of the knight's story-world context, the story might continue with an event where the knight kills the farmer as a punishment and offers his heart to the Gods. Story-world contexts are not only an accumulation of post-conditions. They are dynamic structures that change according to the different events occurring during the development of the story in progress. For instance, MEXICA incorporates a set of post-conditions—named inferred post-conditions—that are triggered when it detects pre-defined situations. Thus, if MEXICA detects in the story in progress that two different characters are in love with the same woman, the system triggers in the characters' story-world contexts an inferred post-condition representing a love competition between them. If during the development of the story one of those characters should die—which implies the end of the love competition—the system eliminates from the story-world contexts the inferred post-condition.

Story-world contexts play an important role in the production of material during engagement. They act as cues to probe LTM and retrieve sets of possible next actions into working memory in order to continue the story in progress (see figure 5). That is, LTM is organized in groups of schemas representing story-world contexts. Each of them has associated a set of possible next actions to be executed in the story in progress. When an action in a story in progress is performed, it modifies the actual story-world context of the characters participating in the action. MEXICA utilizes those contexts to probe LTM. When MEXICA finds a schema that matches any of the story-world contexts it retrieves the actions associated with that schema into working memory. Then, one of the possible next actions retrieved is selected at random to continue the story in progress. When this action is performed it modifies characters'

context and the cycle starts again. Whenever it cannot match a schema in LTM, MEXICA declares an impasse and switches to reflection to break such an impasse.

Once the system switches state, it starts to perform the reflective processes. To break an impasse, MEXICA analyses the previous stories to find alternatives to continue the story in progress. This simulates the process where some human writers—in order to break an impasse—study how other authors have sorted out similar situations and try to apply the same strategy. MEXICA evaluates novelty by comparing the content of the current story against the content of previous stories. MEXICA evaluates interestingness by comparing changes in the dramatic tension of the story in progress against changes in the dramatic tension of previous stories. As a result of these evaluations MEXICA sets some guidelines to constrain the production of material during engagement and in this way to improve the quality of the story in progress.



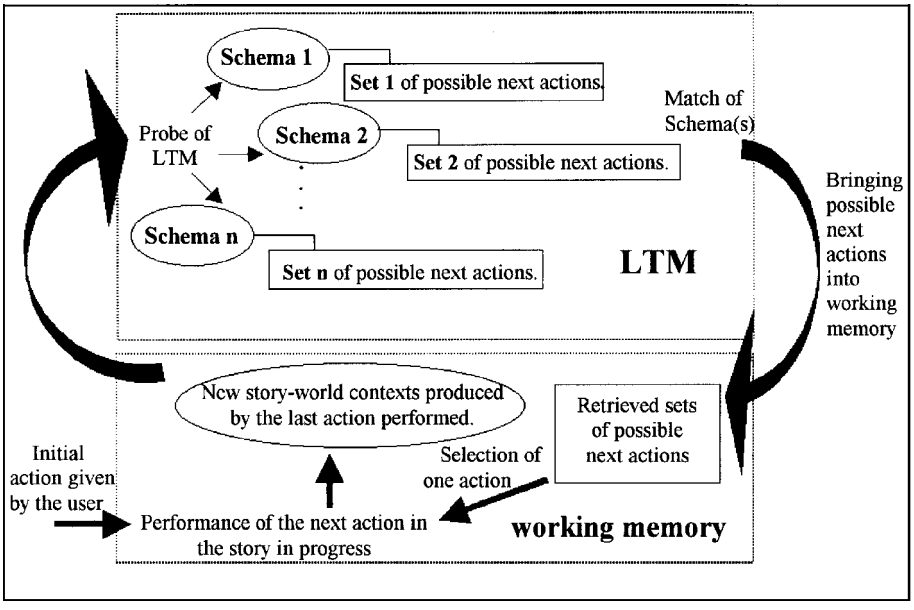


Figure 5. Retrieval of actions during engagement.

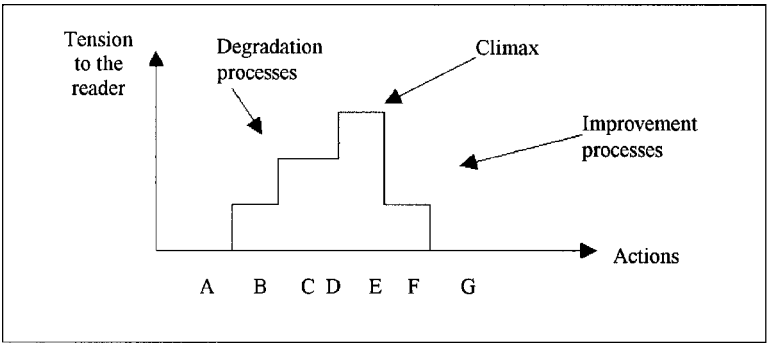


Figure 6. Representation of a story in terms of the Tension to the Reader.

## 4. Analysis of constraints

Constraints are the core element for the production of material. In MEXICA, the knowledge representing content and rhetorical constraints has been organized in four types: context constraints, knowledge constraints, guidelines constraints and general constraints.

- 'Context constraints or story-world contexts' encode the emotional links and dramatic tensions produced in the story in progress. That is, they register the consequences of all actions performed so far in the tale.
- 'Knowledge constraints' represent writer's experience, knowledge and beliefs about writing goals, the writing topic and world in general. They apportion the structures necessary for retrieving logical following actions from LTM during the development of a tale, as well as for producing novel and interesting stories. Knowledge constraints are constructed from tacit information in the previous stories when the system starts (i.e. before MEXICA begins to develop a new story).
- 'Guidelines' constrain the production of material to satisfy requirements of novelty and interest. They are updated during reflection each time an evaluation of the story in progress takes place.
- 'General constraints' include the knowledge necessary to assure that the events in the story in progress satisfy basic beliefs about the world, and to assure that the story flows. They are established by the programmer as part of the code and never changed.

Context constraints can be seen as structures representing the story-world state of affairs. There is a story-world context for each character in the story. They are created each time a new character is introduced in the story in progress and updated after an action is executed. MEXICA only updates the story-world context of those characters that are located in the same place as the characters that perform the action.

Knowledge constraints are divided into three classes: the Abstract Representation, the Tensional Representation and the Concrete Representation. The *abstract representation* is formed by structures in LTM representing story-world contexts—where characters are not instantiated—extracted from the previous stories. Each of these structures is linked to a set of possible next actions to be performed in the story in progress (see figure 5). During engagement MEXICA tries to match these structures and retrieve their associated events into working memory. In this way, the abstract representation embodies all possible occurrences that MEXICA can retrieve during the developing of a story.

The *tensional representation* encodes the dramatic tension in the story in progress. Bremond (1996) describes the sequences of events in a narrative as processes leading towards either an improved or degraded state, which can or cannot be reached. During a degradation process a state of tension is created by introducing forces or obstacles that oppose a more satisfactory state. During an improvement process an obstacle that stands against such a more satisfactory state is eliminated. In MEXICA, a story is classified as interesting when it includes degradation-improvement processes. Thus, the tensional representation encodes part of the knowledge necessary to create sequences of events that combine degradation-improvement processes.

In MEXICA it is assumed that a tension in a story arises when a character is murdered, when the life of a character is at risk, when the health of a character is at risk (i.e. when a character has been wounded), when a character is made a prisoner,

when a character feels clashing emotions towards another one, when a character is involved in a situation of potential danger and when two different characters are in love with a third one producing a love competition. MEXICA can trigger a tension as a direct consequence of an action (e.g. if an enemy attacks the princess, as a consequence a tension will be produced because her life is at risk), or as an inferred post-condition (e.g. if the system detects that jaguar knight and eagle knight are both in love with the princess, a tension due to love competition is triggered). Different tensions can be active at the same time. Tensions have associated a value between zero and fifty; such a value is modifiable by the user of the system. Each time an action is performed MEXICA calculates and stores the tension produced in the story in a variable called Tension to the Reader. An array named Tensional Representation records the different values over time of this variable. In this way, it is possible to obtain a graphical representation of the story in terms of the Tension to the Reader. For example, figure 6 shows a story formed by seven actions: actions A to E represent degradation processes where the tension to the reader increases. Action E represents the climax of the story where the highest tension is reached. Actions F and G represent improvement processes where the tension decreases, i.e. the resolution of the story. During reflection MEXICA evaluates the interest of the current story by comparing its tensional representation against the tensional representation of the previous stories. This evaluation sets some guidelines that contribute to creating interesting stories (see setting of guidelines below).

The *concrete representation* is a copy in LTM of the stories defined in the file of previous stories. It is used during reflection to break impasses. The abstract and tensional representations are formed from tacit information in the previous stories, while the concrete representation comes from explicit information. The abstract, tensional and concrete representations are structures that represent different aspects of the previous stories at different levels of abstraction.

MEXICA develops a story as a result of an engagement-reflection cycle. Each time MEXICA switches to the reflective state it evaluates the novelty and interest of the story in progress. As a result of such an evaluation a group of guidelines are set to constrain the production of material during engagement. For example, if the system detects that the current story lacks improvement-degradation processes (i.e. that the story is boring) guidelines requiring interesting actions become active. Thus, when MEXICA switches back to engagement, a group of routines called filters eliminate from the set of possible next actions those that do not satisfy the guidelines' requirements; in this case, those actions that do not contribute to making the story more interesting. Filters do not perform any evaluation, their only function is to constrain the universe of actions that can be brought into working memory. This situation seems to agree with human behaviour in employing schemas to constrain the generation of ideas. For example, if a person is asked to write a Sherlock Holmes story, he probably will retrieve events related to detectives, gangs, bad and good boys, etc. That is, the universe of possible actions available in his head to continue the story is constrained to those events that satisfy the task requirements.

The general constraints are requirements that have two purposes: to prevent the story from including events that do not satisfy basic beliefs about the writing topic and world in general, and to assure the flow of the story in progress. In MEXICA a story flows when the post-conditions of the last action performed modify the story-world context of at least one character. In this way, it is assured that either the story develops in terms of improvement-degradation processes (modification of tensions) or the

emotional links between characters change. It is important to have dynamic emotional links and tensions because a story becomes interesting when degradation-improvement processes arise. Tensions increase or decrease either as direct consequences of actions or as a product of inferred post-conditions, i.e. as a result of combinations of emotional links between characters, such as tension due to love competition. In this way, if story-world contexts change over time the story is forced to move forward. This procedure alone does not guarantee that the story is moving in the right direction. All constraints working during engagement, together with the procedures that operate during reflection, contribute towards developing a coherent and interesting story. There is also a technical problem related to the flow of a story. MEXICA employs the story-world context as cue to probe LTM and retrieve the subsequent action in the current story. If an action that does not modify the story-world context is selected as the next event MEXICA might retrieve the same action again, which would not modify the story-world context with the result that MEXICA might retrieve the same action again, and so on. Thus, the flowing of the story prevents the system from being caught in a loop. As in the case of the guidelines, filters are in charge of eliminating those actions that do not satisfy the general constraints.



## 5. Generation of a story

Stories in MEXICA are the result of an interaction between engagement and reflection. The system allows the user to experiment with different writing strategies. MEXICA can work in four different modes of operation (see table 1):

1. Engaged State 1 (E1).
2. Engaged State 2 (E2).
3. Engaged and Reflective States 1 (ER1).
4. Engaged and Reflective States 2 (ER2).

When MEXICA works under the E1 and E2 operation modes all the routines related to the reflective state are deactivated. That is, all stories developed by MEXICA are the result of an engagement process. When the system works under the ER1 and ER2 operation modes both states are active. Thus, stories are developed as a result of an interaction between engagement and reflection. During the E1 operation mode the system disables all filters (and therefore the guidelines). During the E2 operation mode the filters are set as active and the guidelines are set to a fixed value; i.e. since the reflection state is not active, the guidelines cannot be updated and therefore they retain a fixed value. During the ER1 operation mode the filters and guidelines are deactivated. Finally, during the ER2 operation mode all the routines in the system work together to develop a new story.

To create a new story the user specifies an initial action, the initial location and the characters participating in the event. The initial action produces story-world contexts that are employed to probe LTM. MEXICA switches from engagement to reflection after a particular number of events have been generated in the story in progress (by default this number is set to three although it can be modified by the user) or when an impasse is declared. An impasse is declared when MEXICA cannot match any of the story-world contexts in the current story with a structure in LTM, or when all possible next actions retrieved from memory do not satisfy constraints (e.g. novelty requirements established by the guidelines) and therefore are removed by the filters.

Table 1. Operation modes in MEXICA.

| | | |
|---|---|---|
| Engaged State 1 (E1) | No Filtering Process | No guidelines. |
| Engaged State 2 (E2) | Filtering Process | Guidelines set by default. |
| Engaged and Reflective States 1 (ER1) | No Filtering Process | No guidelines. |
| Engaged and Reflective States 2 (ER2) | Filtering Process | Guidelines set during the Reflective State |



5.1. *Engagement*

During the retrieval process MEXICA follows three strategies to bring into working memory possible next actions. The first is called the exact-strategy. MEXICA attempts to find structures in LTM that are identical to any of the story-world contexts, i.e. they are formed by exactly the same elements (the same emotional links and/or tensions). When the system finds such a structure, it brings into working memory the possible next actions associated to that structure.

The second is called the inclusive-strategy. It consists of searching LTM for structures that include, as part of its organization, the story-world context. For example, if a story-world context is formed by an emotional link representing two characters in love (1 element), and MEXICA finds in LTM a structure formed by the same emotional link and a tension representing that the life of one of the characters is at risk (2 elements), MEXICA assumes that they are similar enough to be matched with each other. Thus, the system brings into working memory the possible next actions associated to the matched structure. When using this strategy the system assumes that the structure in LTM cannot contain more than twice the number of elements found in the story-world context (in this example the structure in LTM contains two elements while the story-world context includes one) but this parameter can be modified by the user. The third strategy, named the dynamic-strategy, consists of modifying the organisation of the story-world context and triggering a new search in LTM. The logic behind this strategy is that as long as the essential features of the story-world context are conserved, it can be modified to establish new ways of matching structures in LTM.[1] In the MEXICA prototype two transformations of the story-world context can be executed before an impasse is declared. Initially, MEXICA applies the first transformation; if it does not work the system applies the second transformation. In order to illustrate how these transformations work, the reader can think of a story-world context that belongs to character A (remember that each character in the story has its own story-world context). The first transformation consists of eliminating all the emotional links where character A does not participate, and all tensions where character A does not participate except life at risk and health at risk. In other words, this new structure contains all emotional links where character A participates, all tensions where character A participates, and all life at risk and health at risk tensions independently of which character participates in them. The second transformation consists of eliminating from the story-world context all emotional links; i.e. it retains only those tensions where character A participates, and

all life at risk and health at risk tensions, independently of who participates in them. Once a transformation has been executed, MEXICA tries again to apply the exact and inclusive strategies. Notice that MEXICA is not transforming a conceptual space (typical reflective process) but modifying the cue. Thus, the process for retrieving possible next actions from LTM work as follows:

1. An action is performed and story-world contexts are updated.
2. MEXICA applies the exact-strategy.
3. If no structure is matched, MEXICA applies the inclusive-strategy.
4. If no structure is matched:
   If the second transformation has been already performed an impasse is declared, otherwise, MEXICA modifies the story world context (performing the first or second transformation) and goes back to step 2.

Once the possible next actions are brought into working memory, a complex instantiation process to assign the right characters to the retrieved actions takes place. This process is important since the same action can take a completely different connotation in the story depending on who participates in it and how. For example, if the system retrieves *A punched B*, it is not the same to instantiate this action as *princess punched jaguar knight*, or as *jaguar knight punched princess* or *as jaguar knight punched enemy*. Also, this instantiation process establishes when to introduce a new character in the story or when to employ an old one, which is important to keep the coherence of the story (chaos would ensue if after every performed action a new character were introduced).

The ability to transform the story-world contexts and the inclusive strategy provide the system with an important flexibility during the retrieval process. Notice that the dynamic strategy is not relaxing constraints but transforming the story-world context. In this way, constraints, the retrieval strategies and the instantiation process form the core elements to create novel and interesting stories in MEXICA.

### 5.2. *Reflection*

The reflective state performs three main processes: it verifies the coherence of the story in progress, evaluates its novelty and interest, and breaks impasses.

In MEXICA, a story's coherence relies on an element that has not yet been introduced in this paper: an action's preconditions. Each story-action has associated a set of preconditions, defined by the user, that help to assure logical sequences of actions. For example, to perform the action *princess cured jaguar knight* it is necessary to satisfy the precondition of jaguar knight being ill or wounded. During reflection MEXICA analyses action by action the story in progress. When it finds an action with some unfulfilled preconditions an event to satisfy such preconditions is inserted. For example, the action *jaguar knight twisted his foot* can be inserted to satisfy the preconditions of the action *princess cured jaguar knight*. Now, this new action might also have unsatisfied preconditions. For example, there is a precondition that every event in MEXICA must satisfy: all characters participating in an action must be in the same location. Thus, it is necessary to insert a new event—e.g. *jaguar knight invited the princess for a walk to the forest*—to locate both characters in the same place and in this way satisfy this precondition. MEXICA can insert a full new episode to satisfy

Table 2. Possible values for the novelty guideline based on the classification of the current story.

| Classification of the current story | Novelty guideline |
|---|---|
| Adequate | Normal |
| Similar to a previous story | High |
| A copy of a previous story | Strict |



preconditions. It is necessary to check preconditions because during engagement the system generates material without verifying preconditions, therefore, sequences of not very coherent actions might be produced. During reflection MEXICA checks that each action's preconditions are satisfied.

To evaluate novelty, MEXICA compares the content of the current story against the previous stories. As a result of this evaluation MEXICA classifies the story in progress as adequate, similar to a previous story, or as a copy of a previous story, and sets the novelty guideline to normal, high or strict (see table 2).

MEXICA records the number of times that an action has been employed in the previous stories. In this way, the system detects which are the most utilized actions, which are the regularly used actions, and which are the most unused actions. Thus, if the novelty guideline is set to Strict, MEXICA employs in the story in progress only those actions classified as the most unused, i.e. all other actions are eliminated by the filters. If the novelty guideline is set to High, the system employs in the story in progress either those actions classified as regularly used or most unused. Finally, if the guideline is set to Normal, there is no constraint to employ any action.

MEXICA evaluates interestingness by comparing the tensional representation of the story in progress against the tensional representations of the previous stories. For instance, if MEXICA detects that most of the tensional representations of the previous stories tend to increase their values of tension after the first actions have been performed, the system verifies that the current story follows the same pattern. If it is the case that there is a difference between them, MEXICA sets the interestingness guideline to generate material that fulfils this tendency. To illustrate this situation, the reader can think of a story formed by the actions *princess went to the market*, *princess bought a nice blanket*, *princess met jaguar knight*. Clearly, it does not follow this pattern (the tension never increases), so MEXICA evaluates the story as boring and sets the interestingness guideline to 'increment tension' in order to reject all those retrieved actions that do not increase the tension to the reader. Thus, actions like *princess went back home and had a nap* are not produced any more, while actions like *suddenly the enemy arrived to the market and kidnapped the princess* are encouraged. The interestingness guideline can be set to increment tension, keep the same tension, or decrement tension.

MEXICA breaks impasses with the help of the concrete representation. An impasse is declared when the system cannot match a structure in LTM and bring into working memory actions to continue the story in progress. MEXICA explores the concrete representation to find an action that in previous stories has followed the action that triggered the impasse. The logic behind this process is that, if in previous stories this sequence of events worked, it might also work for the current story.

5.3. *Interaction between states*

By default the system starts in the engaged state, although through a parameter controlled by the user the system can start in the reflective state. Once the system triggers an engagement-reflection cycle, it only stops (i.e. the story is finished) when:

1. All characters in the story are dead.
2. When an unbreakable impasse is declared.
3. When the number of actions in the story in progress is bigger than the number of actions in the previous stories (this condition is necessary because MEXICA employs the previous stories to set the guidelines).
4. When the maximum number of actions allowed in a story is reached. The maximum number of actions allowed in a story is a parameter definable by the user called Maximum Actions.

Optionally, the user can set the system to stop when a degradation-improvement process is completed. In this way, it is possible to force the system to create stories either with one degradation-improvement process or with several degradation-improvement processes. Table 3 shows the relation between each of the processes performed during an engagement-reflection cycle and the type of constraint employed in such process.

After the engagement-reflection cycle ends MEXICA performs what is called the 'final analysis'. Its purpose is to insert events in the current story to make explicit and clearer the behaviour of the characters. This process helps to produce more coherent and well structured outputs. MEXICA accomplishes this objective by inserting actions that represent explicit character's goals or tensions. For example, the reader can picture a story with the following events: *eagle knight went to the forest for a walk*, *suddenly the enemy appeared between the bushes and attacked the knight*, *the enemy ran away leaving the knight wounded*, *the princess decided to go to the forest for a walk*, *suddenly she found the wounded knight*, *the princess looked for some curative plants to heal the knight*.... At the beginning of this story an enemy wounds an eagle knight and some events later the princess cures the knight saving his life. When MEXICA detects this situation it inserts an action, just after the princess realizes about the wounded knight, where the princess' goal of curing the knight is set: *eagle knight went to the forest for a walk*, *suddenly the enemy appeared between the bushes and attacked the knight*, *the enemy ran away leaving the knight wounded*, *the princess decided to go to the forest for a walk*, *suddenly she found the wounded knight*, *she knew that it was her duty to help her people: the knight's life was at risk and she had to save him*, *the princess looked for some curative plants to heal the knight*... (the new action is underlined). In this way, by inserting an explicit goal, the robustness of the story improves. MEXICA applies this procedure when it detects that the life of a character is at risk, the health of a character is at risk, or a character is a prisoner and another character saves, heals or rescues the first character. A similar procedure is performed when the system detects a tension due to love competition or clashing emotions between characters.

The last step is to print the final story. As part of the definition of actions, a user of MEXICA can specify one or several texts associated with each story-action. When the system ends a story, it employs these texts to print the final output. Figures 1 and 7 show complete and unedited outputs from the MEXICA program.

Table 3. The different processes performed during an engagement-reflection cycle and the constraints employed in each of them.

| | Process | Constraints employed |
|---|---|---|
| Engagement | Performing of an action in the story | Story-world contexts |
| | Retrieval of actions | Story-world contexts<br>Abstract representation |
| | Elimination of no useful-actions (filters) | Guidelines<br>General constraints |
| Reflection | Verification of coherence | Concrete representation |
| | Breaking of an impasse | Concrete representation |
| | Evaluation of the current story | Tensional representation<br>Guidelines (update) |



## 6. Evaluation

MEXICA was evaluated by means of an Internet questionnaire. Fifty subjects from twelve different countries answered it: 38% of them were Americans (from Brazil, Canada, México and the USA) and 62% Europeans (from Austria, The UK, The Netherlands, France, Germany, Greece, Norway and Poland). Of them 92% were graduates, 68% possessed postgraduate degrees and 6% did not answer this question (see table 4).

The subjects were asked to rate four stories created by MEXICA on a five-point scale (from 'very poor' to 'very good') for narrative flow and coherence, narrative structure, content, suspense, and overall quality. One each of the stories was generated under the E2 operation mode (engaged mode only with filters), E2-boring (engaged mode only with filters and with the variable 'tension to the reader' forced to have low values), ER2 (the complete model with engaged and reflective mode and the full set of constraints, see figure 1), and ER2-boring (engaged and reflective mode with the variable 'tension to the reader' forced to have low values, see figure 7).

It was hypothesized that ER2 would gain the highest rates while E2-boring would gain the lowest rates. No prediction was made about the order of the ratings for E2 and ER2 boring. For comparison, two stories created by published story generation programs were included in the questionnaire: a story framework created by GESTER (Pemberton 1989) and a story created by MINSTREL (Turner 1993). Finally, a framework of a human-generated story using the same type of 'computer-story language' but aiming to satisfy requirements of originality and interest was also included in the questionnaire. The results are shown in table 5.

ER2 obtained the highest rates in all categories. The ER2 and the human stories got the highest rates in the suspense category while the ER2-boring and E2-boring stories

Table 4. Nationalities and educational level of the subjects that answered the questionnaire.

| Nationality | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| British | Mexican | German | Brazilian | Polish | Norwegian | Greek | US | Austrian | Canadian | Dutch | French |
| 20% | 20% | 16% | 12% | 10% | 6% | 4% | 4% | 2% | 2% | 2% | 2% |

| Education | | | | | |
|---|---|---|---|---|---|
| Unknown | Diploma | Bachelor | Master | MPhil | PhD |
| 6% | 2% | 24% | 46% | 4% | 18% |

obtained two of the lowest rates. These results suggest that the degradation-improvement process employed by MEXICA to produce interesting stories works adequately. In the same way, the results regarding the narrative structure suggest that the interaction between reflection and engagement produces more robust stories than the engagement state alone. It is interesting to notice how the human-generated story was rated lower than the ER2 story in the overall quality category. From these results it is not possible to conclude that MEXICA is a better storywriter than a human author, but perhaps that the human was less effective in accomplishing the task of creating a successful and somewhat contrived story framework.

In MEXICA a story is considered novel when it is different in content to the previous stories. To test MEXICA, six stories were introduced as the set of previous stories. Table 6 compares the themes that form the previous stories with the themes of two stories created by MEXICA. As can be observed, MEXICA is capable of producing novel stories.



## 7. Conclusions

MEXICA is a computer program based on a cognitive model of how humans write. The engagement-reflection account of writing supplies a general framework to build the computer system while the development of the program provides insights into the adequacy and completeness of the cognitive model of writing. The main objective of MEXICA is the production of novel and interesting stories as a result of the interaction between engagement and reflection. During engagement MEXICA generates material guided by rhetoric and content constraints, while during reflection the system evaluates—and when necessary modifies—the story in progress to satisfy requirements of consistence, novelty and interest. A story is considered consistent when all its preconditions are satisfied. A story is considered novel when it is not similar to any of the previous stories. A story is considered interesting when it includes degradation-improvement processes.

MEXICA includes four types of constraints:

- Context constraints or story-world contexts. They register the consequences of the events in the story in progress. Each character has its own story-world context and all they are used as cues to probe LTM.
- Knowledge constraints. They are built from the previous stories and encode the main content and rhetorical knowledge in the system. They are formed by the abstract representation, tensional representation and concrete representation.
- Guidelines. They are updated during reflection according to the results of the evaluation of the story. Their purpose is to influence the production of material during engagement.
- General Constraints. They encode the knowledge necessary to assure that the story flows and that basic beliefs about the world are satisfied.

These constraints proved to be adequate when driving the production of material during engagement. The MEXICA model shows:

- the plausibility of combining, on one hand, traditional problem solving techniques—represented in MEXICA by the reflective state—where the system focuses on reaching explicit goal-states, and on the other hand what might be called the 'engagement technique', where the system focuses on the production of material driven by constraints and avoids using explicit goal-states.

- how to use the previous stories as a way to produce novel outputs.
- the importance of flow in a story. Since the production of material is not guided by explicit goals that push the story towards a particular goal-state, it is necessary to establish a method that assures that the story would move forwards and would not get trapped in a loop.
- the importance of instantiation. The way that actions are instantiated and the decision of when to introduce new characters and when to re-introduce characters already in use, play an important role in the generation of logical and interesting stories.

MEXICA allows the user to define the primitive actions, their preconditions and post-conditions, and the set of previous stories. In this way, the user can control the knowledge stored in LTM. Furthermore, the system includes more than 20 different parameters modifiable by the user that permits applying different strategies of writing (e.g. operation modes). As far as the authors of this work know, no other system offers this flexibility to experiment with a computer model.

An evaluation of MEXICA suggests that the system is capable of producing frameworks for short stories that are similar to those produced by a human and by other story-writing programs. The use of the tension to the reader appears to be an appropriate method of producing interesting stories. The retrieval strategies, together with the use of constraints, produces stories that satisfy the established requirements of novelty. MEXICA thus demonstrates the plausibility of implementing computer models of creativity in writing in terms of engagement and reflection.

A final thought. Some readers may wonder why story generation programs are so far behind human-level ability. Why are programs that write in a human-like style so difficult to build? We have two answers to this question. Creativity is a process which has not yet been fully understood. This situation limits the construction of any model. Thus, it is necessary to continue the research into this area in order to be able to develop more powerful creative computer systems. Furthermore, current explanations of this phenomenon are so complex that it is difficult to represent a whole theory of creativity in computer terms, limiting the power of the resulting systems. MEXICA is an example that illustrates this situation: it only includes part of the engagement-reflection account of writing. All aspects involving the effects of environment on a writer's work are not represented in the computer model and to include them may require many years of research. We find similar problems when picturing in computer terms other theories of creativity; for example Boden's (1990) ideas on creativity, where she points out the importance not just of exploration of conceptual spaces but also of the transformation of these spaces, suggests that it is necessary to represent detailed general world knowledge, knowledge of the particular context of the writing



Jaguar_knight was an inhabitant of the Great Tenochtitlan. Princess was an inhabitant of the Great Tenochtitlan. Jaguar_knight was walking when Ehecatl (god of the wind) blew and an old tree collapsed injuring badly Jaguar_knight. Princess went in search of some medical plants and cured Jaguar_knight. As a result Jaguar_knight was very grateful to Princess. Jaguar_knight rewarded Princess with some cacauatl (cacao beans) and quetzalli (quetzal) feathers.

Figure 7. A story generated in ER2-boring operation mode.

Table 5. Results of MEXICA's evaluation on a 5 point scale from 'very poor' to 'very good'.

| | ER2 | Human | MINSTREL | ER2-boring | E2 | E2-boring | GESTER |
|---|---|---|---|---|---|---|---|
| Narrative flow | 3.8 | 3.5 | 2.9 | 3.5 | 2.2 | 2.8 | 2.1 |
| Narrative structure | 3.7 | 3.7 | 3.2 | 3.2 | 2.6 | 2.7 | 2.1 |
| Content | 4.1 | 3.7 | 3.6 | 2.8 | 2.8 | 2.4 | 2.6 |
| Suspense | 3.8 | 3.8 | 3.3 | 2.3 | 2.3 | 2.0 | 2.1 |
| Overall quality | 3.8 | 3.6 | 3.3 | 2.9 | 2.6 | 2.5 | 2.4 |

Table 6. Relation of the themes in the Previous Stories and two tales created by MEXICA.

| Story | Topic |
|---|---|
| Previous Story #1 | Love and Disloyalty. This story is about a knight who falls in love with his brother's girlfriend and decides to kidnap her. |
| Previous Story #2 | Love and Obsession. This story is about a princess who falls in love with a knight. When she realizes that he is in love with another woman, the princess decides to kill her rival. |
| Previous Story #3 | Envy. This story is about a prince who envies his father's position. The prince's ambition is so great that he abandons his father in the forest after he suffers an accident. |
| Previous Story #4 | Love and Obsession. This story is about a knight who is in love with a woman who is attracted to a different man. The knight decides to attack his rival. |
| Previous Story #5 | Valour. This story is about a kidnapped princess who is rescued by a farmer. The farmer is wounded during the rescue and dies. |
| Previous Story #6 | Gratitude. This story is about a hunter who saves the life of a Tlatoani (a Mexica King), and later the Tlatoani does the same for the hunter. |
| The princess who cured the Jaguar Knight | Love and Revenge. This story is about a kidnapped princess who is rescued by a knight. The princess falls in love with the knight. However, she realizes that the knight murdered her father and decides to kill him. |
| The lovers. | Love and Values. This story is about a princess who is in love with a man whose values clash with the princess' values. Thus, she has to decide between following her values or following her man. |



and of the anticipated audience, in order to be able to constrain the transformations of the conceptual space to ones that are believable and acceptable to the reader. These types of representation present a fundamental problem to AI. Another example is given by Gelertner who describes emotions 'as the glue of thought' during the creative process (1994, p. 5). Or in words of the poet Wordsworth, creativity is 'emotion recollected in tranquillity':

> The emotion is contemplated till, by a species of reaction, the tranquillity gradually disappears, and an emotion, kindred to that which was before the subject of contemplation, is gradually produced, and does itself actually exist in the mind. In this mood successful composition generally begins, and in a mood similar to this it is carried on. (Wordsworth, cited in Sharples 1999, 48)

To successfully carry out this type of creative process, it has been argued, it is necessary to be an embodied human being— to recount authentic human experience. Even if this were not the case and it were possible to simulate the effects recounted experience, we are far from being able to produce a complete computational account of emotion.

Computer models of creativity have proved to be useful tools in the research of human cognition. It is necessary to continue exploring new ways of tackling the problems described in this section in order to develop more powerful systems. This

work is one step towards a better understanding of creativity. It is hoped that it will encourage research into computer models based on cognitive accounts.

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## Endnote

1. This strategy seems to agree with some general theories that explain how concepts are retrieved from LTM. Following Torrance (Torrance *et al.* 1996) a retrieval process initiates with a memory probe in working memory that activates concepts in LTM susceptible to be retrieved. Raaijmakers and Shiffrin (1981, cited in Torrance *et al.* 1996) suggest that these probes are formed by permanent and nonpermanent cues. The former remain unchanged during the retrieval process, while the latter are constantly modified. If after several attempts a probe is unsuccessful in retrieving something from LTM, the nonpermanent cues are substituted and a new attempt is performed.

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