Role of Context in Memorability of Intuitive and Counterintuitive Concepts

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Abstract

A number of recent studies have shown that minimally counterintuitive concepts are better recalled than intuitive and maximally counterintuitive concepts. This paper presents a computational model that relates memorability of a concept to the amount of new information that the concept provides to a rational agent seeking to build a more accurate model of its environment. Given two different types of concepts (or same type of concepts presented in two different contexts), the model can be used to make strong predictions about which concepts will be better comprehended, remembered, and recalled by people. Free recall experiments with human subjects provide strong support to the memorability hypothesis.
Keywords: Comprehension; memory; concept acquisition.

Introduction and Background

Bartlett (1932) was one of the first to systematically study how concepts embedded in stories are transformed as they pass from person to person. He asked British university students to read passages from various folk tales including the Native North American folk tale "the war of the ghosts" (Erdoes & Ortiz 1984) and retell it to others in writing who then retold it to others. Bartlett analyzed the transformation of various concepts over successive retellings. He concluded that culturally unfamiliar concepts were distorted and replaced by more familiar concepts; for instance, a canoe was replaced by a rowboat. In none of the series of ten reproductions of, "the war of ghosts," did a mention of ghosts remain, even though the story's title mentions ghosts. Bartlett reasoned that culturally unfamiliar concepts such as canoe and ghost are more difficult to represent in human memory and therefore they are more likely to get distorted. Even though, Bartlett did not systematically measure and compare the recall rates of culturally familiar and unfamiliar concepts, he argued that culturally unfamiliar concepts are less likely to be remembered and recalled and hence less likely to be transmitted than familiar concepts.

Kintsch and Greene (1978) selected an Apache tale and a story from Brothers Grimm. Similar to Bartlett, they found that five retellings of the Apache story introduced more severe distortions than the Grimm story. They concluded that this happened because the Grimm story better conformed to the structure expected by their subjects.

Barrett and Nyhoff (2001) also repeated Bartlett's methodology using a larger set of Native North American folk tales from Erdoes & Ortiz (1984). Six stories of about 500 words or less, containing both intuitive concepts such as the river, mountain, and bird and expectation violating counterintuitive concepts such as a talking bird and a walking stone, were chosen. They found that recall rates for counterintuitive concepts were significantly higher than recall rates for intuitive concepts. Barrett and Nyhoff also designed an artificial story to better control for the number of intuitive and counterintuitive concepts, narrative structure, and the amount of repeated exposure to a concept. The futuristic story about a person visiting a museum to see alien beings and artifacts was designed to contain six concepts of each of the following three types:

1. intuitive concepts that conform to expectations such as a being who is aware of its existence
2. minimally counterintuitive concepts that violate one intuitive expectations such as a being who never dies, and
3. bizarre concepts that do not violate any category expectations but have an unusual feature value such as a being who weighs 1000 pounds.

They found that after three retellings, counterintuitive concepts were better recalled than bizarre concepts which were better recalled than intuitive concepts.

Boyer and Ramble (2001) used a variant of Barrett and Nyhoff's (2001) alien museum story but did not use a serial reproduction task. Instead, they had subjects read a story and following a brief distraction task answer a question requiring reproduction of as many intuitive, counterintuitive and bizarre items mentioned in the story as the subject could recall. Their results supported Barrett and Nyhoff's conclusion that minimally counterintuitive items are best recalled and the intuitive items are worst recalled.

Atran and Norenzayan (2005) constructed three lists of intuitive, minimally counterintuitive (such as a nauseating cat) and maximally counterintuitive concepts (concepts that violate two intuitive expectations such as a chattering nauseating cat). Subjects were presented lists of concepts without the narrative structure used by previous researchers. Each subject saw a list containing an equal number of all three types of concepts and was asked to recall as many concepts as he/she could after a brief distraction task. They found that subjects recalled intuitive concepts better than minimally counterintuitive concepts which were better recalled than maximally counterintuitive concepts. Removing the narrative structure used by Barrett

and Nyhoff (2001) and Boyer and Ramble (2001) had resulted in the recall rates for counterintuitive concepts being lowered. Atran and Norenzayan (2005) suggested that recall for counterintuitive concepts increases only when they are mixed in with a larger number of intuitive concepts. This is in accordance with results from a number of studies of visual stimuli that report an enhanced recall for distinct and bizarre stimuli when surrounded by mundane stimuli (see Waddill & McDaniel 1998 for an overview).

A major problem with the Atran and Norenzayan explanation, however, is that it does not explain why the maximally counterintuitive concepts, which are the most distinctive ones, are recalled the least. This present paper outlines a computational model that can explain why counterintuitive concepts are remembered better than intuitive concept when these concepts are embedded in stories but not when they are presented as lists. The proposed model is based on the insights derived from the discourse analysis work on narrative comprehension.

Narrative Comprehension & Memorability

There is overwhelming evidence to indicate that when reading to comprehend stories (as Barrett *et al*., 2001, and Boyer *et al*., 2001, instructed their subjects to do) people primarily attempt to answer 'why' questions as opposed to answering the how, where, when, and what happens next questions (see Graesser *et al*. 1994 for an overview). People create such justifications to explain why the author mentions a particular piece of information in the text[1]. These explanations help people integrate disparate textual units into coherent higher level representations; the highest level representation being an overall coherent theme for the story. The more disparate a textual unit, the more cognitive effort is required to process it. Following Kintsch (1980), I define *postdictability* of a textual unit as the ease with which a concept's inclusion in the text is justified after the textual unit containing that concept has been read. This can be contrasted with the *predictability* of a textual unit as the ease with which the occurrence of the concept can be predicted prior to the concept having been read. Clearly, the two are not completely independent of each other. Let us define the *prior context* of a concept as the text that precedes the occurrence of a concept and the *posterior context* of a concept as the text that immediately follows[2] the concept. While posterior context has no impact on the predictability of a concept, both prior and posterior context affect a concept's postdictability. Prediction and postdiction seem to require two different reasoning processes. The ability to predict what comes next seems to require the ability to generate expectations about the future (Schank & Abelson 1977) using a generative process similar to problem solving and planning (Newell & Simon 1972) while the ability to find justifications seems to imply an abductive process (Ng & Mooney 1990). In most situations, predicting an outcome before its occurrence is more computationally challenging than justifying an outcome after it has happened. This is because in most common sense reasoning situations, the space of possible worlds one has to search through starting from a given state of the world to find the state that is most likely to occur next is larger than the space of explanations one has to search through to find a justification that can explain an outcome that is already known to have occurred.

The Memorability Hypothesis

If cognitive processes underlying comprehension of narratives are similar to the cognitive processes underlying comprehension of everyday world events (as Kintsch 1998 and others argue) then it makes sense for an intelligent agent with limited cognitive resources (Simon 1982) inhabiting a dynamic world to devote more cognitive resources (including memory) to comprehending those objects whose existence it cannot predict using its existing knowledge as these objects provide the agent with valuable learning opportunities. Indeed, Schank (1979) and Kintsch (1980) argue that people find the low predictability concepts more interesting than mundane everyday concepts that are easily predictable and hence convey little new information. However, if a concept is too hard i.e., one cannot explain it even after having seen it then one may not find that concept very interesting either. In a chaotic world where (a) accidents, i.e., truly random events, seem to happen every now and then, and/or (b) the possibility exists that a message may have become corrupted or distorted during communication or reception (e.g., due to noisy sensors), it is rational to ignore concepts that have low postdictability i.e., concepts that are so counterintuitive that they are very hard or impossible to justify even post hoc. Similar to high predictability concepts, low postdictability concepts do not add much to an agent's understanding of the world. This paper argues that an agent's memory should evolve to preferentially process those concepts that add most to an agent's understanding of the world. If we define gain in understanding as the difference between postdictability and predictability of a concept then memorability of a concept should be directly proportional to the gain in understanding i.e.,

$$Memorability \propto (postdictability - predictability)$$

The hypothesis that memorability of a concept is directly proportional to the difference between its postdictability and predictability explains a number of seemingly contradictory findings. Intuitive concepts embedded in narratives have low memorability because they

[1] Various theories differ on the mechanisms of generating such explanations and on the extent of inferences that are generated online.

[2] At this point, it is not clear to me what that immediate context is. Clearly, it must include the rest of the sentence that the concept is a part of but it is not clear whether it should also include the rest of the paragraph or not?

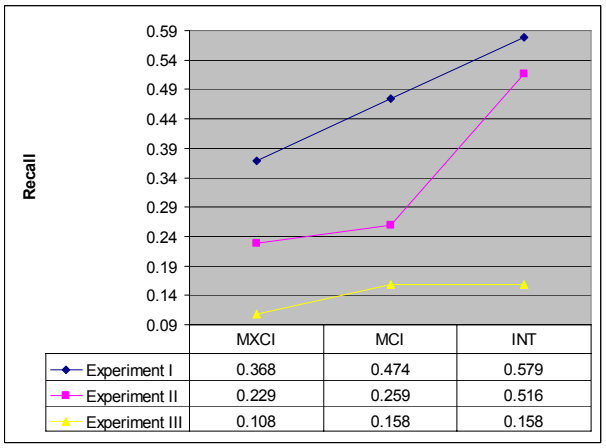
have high predictability while the maximally counterintuitive concepts are less memorable because they have low postdictability. The minimally counterintuitive concepts are a cognitive optimal because they have high postdictability and low predictability. An important contribution of the memorability hypothesis is that it allows us to understand that there is nothing inherently magical about minimally counterintuitive concepts. Minimally counterintuitive concepts only have a higher (*postdictability – predictability)* value than intuitive and maximally counterintuitive concepts in a given context. Indeed, our hypothesis predicts that memorability for various concepts (whether they are minimally counterintuitive, maximally counterintuitive, or intuitive in the Barrett *et al.* 2001 and Boyer *et al.* 2001 sense of violating or following some intuitive expectations) can be increased or decreased by varying their postdictability and predictability. This can be done by changing the context in which these concepts are embedded, by varying the amount of time subjects have to devote to processing each concept, or by directly instructing them not to comprehend a story. Our hypothesis predicts that if all else remains the same and

1. if a concept is made more predictable (e.g., by changing its prior context) then its memorability should decrease,
2. if a concept is made less predictable (e.g., by changing its prior context) then its memorability should increase,
3. if a concept is made more postdictable (e.g., by changing its posterior and prior contexts but without affecting its predictability) then its memorability should increase, or
4. if a concept is made less postdictable (e.g., by changing its posterior and prior contexts but without affecting its predictability) then its memorability should decrease.

A number of experiments have been carried out to test various predictions of our hypothesis (Owsianiecki, Upal, Slone, & Tweney 2005; Upal, Owsianiecki, Slone & Tweney 2005). Using concepts similar to those previously employed by Atran and Norenzayan (2005), Owsianiecki *et al.* (2005) conducted a series of experiments to study the impact of varying context on recall of maximally counterintuitive (MXCI), minimally counterintuitive (MCI), and intuitive (INT) concepts. Unlike Atran and Norenzayan, however, posterior context was added to each concept in order to vary the concept's postdictability. Two types of posterior context were added to obtain items with different amounts of postdictability: *supportive context* that attempted to make counterintuitive concepts more believable in order to increase their postdictability, and *contradictory context* that attempted to make concepts harder to justify to decrease their postdictability. Two versions of minimally counterintuitive concepts with context were created: S-MCI are the minimally counterintuitive concepts with supportive context added to them and C-MCI are the minimally counterintuitive concepts with contradictory knowledge added to them. For instance, **Figure 1** shows the minimally counterintuitive concept *flying cow* with contradictory and supportive context added. Similarly, S-INT and C-INT items were obtained by adding supportive and contradictory posterior context to intuitive concepts. Only supportive context was added to maximally counterintuitive concepts to obtained S-MXCI concepts.

Contradictory Context	Supportive Context
Flying cow. Flying cow is an example of the empty set, said Professor Pythagoras. Cows cannot fly or even jump very high in the air. Cows are very heavy animals and they do not have strong leg muscles required to jump high like Michael Jordan.	**Flying cow.** The old Lapp goddess Mittshwafen is also known as the 'flying cow' because of her miraculous ability to fly in the air bestowed by the Lapp's patron Saint, St. Arthur after the cow's generosity in offering the poor free milk during the famine of 1429.

Figure 1: A minimally counterintuitive (MCI) concept with contradictory and supportive posterior context added.

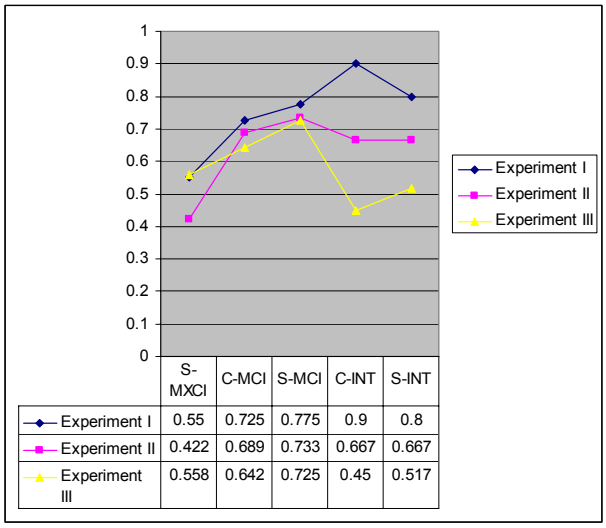


	MXCI	MCI	INT
Experiment I	0.368	0.474	0.579
Experiment II	0.229	0.259	0.516
Experiment III	0.108	0.158	0.158

Figure 2: Mean recall rates of maximally counterintuitive (MXCI), minimally counterintuitive (MCI), and intuitive (INT) concepts presented as lists.

Similar to Atran and Norenzayan (2005), Owsianiecki *et al.*'s results for items without lists (shown in **Figure 2**) indicate that maximally counterintuitive items are least recalled while intuitive items are best recalled. This is what the memorability hypothesis predicts since subjects, readings equal number of different types of randomly ordered concepts without context, do not have any strong expectations about the type of concepts they are likely to see next hence memorability of concepts in such lists depends on postdictability values alone. However, things change when posterior context is added (as shown in **Figure 3**). As expected, supportive context increases the postdictability of minimally counterintuitive concepts causing the recall rates

for S-MCI concepts to be higher than C-MCI concepts in all three experiments. In fact, the minimally counterintuitive concepts with supportive posterior context are best recalled in two out of three experiments. There was no clear trend, however, for the recall rates for intuitive concepts.



	S-MXCI	C-MCI	S-MCI	C-INT	S-INT
Experiment I	0.55	0.725	0.775	0.9	0.8
Experiment II	0.422	0.689	0.733	0.667	0.667
Experiment III	0.558	0.642	0.725	0.45	0.517

Figure 3: Mean recall rates of concepts presented with posterior contexts. S-X denotes X type of contexts in a supportive context and C-X denotes X type of concepts in a contradictory context.

The results of Owsianiecki *et al.*'s experiment support one of the predictions of the our hypothesis, namely, that varying postdictability by changing the posterior context affects the concept memorability in a measurable way. Next section reports on an experiment designed to test another aspect of our hypothesis, namely that varying concept predictability by changing the prior context also affects concept memorability.

Experiment

Variants of two stories used by Barrett & Nyhoff (2001), namely the alien museum visit story and a story about the journey of a brother and sister from school to home, were used in this experiment. The alien museum story called, "the adventures of Mr. Wurg" was rewritten to contain six minimally counterintuitive and six intuitive concepts. The version of the "journey home" story we used contained six minimally counterintuitive concepts and twelve intuitive concepts. Two versions of the stories were created: in the *counterintuitive-concepts supportive version* the prior context of the counterintuitive concepts was modified to make them more predictable while the *intuitive-concepts supportive version* used the prior context employed by Barrett and Nyhoff (2001). In the counterintuitive supportive version, the opening paragraphs of both stories were modified to prepare the reader to expect some of the counterintuitive concepts to follow (as shown in **Figure 4**).

The opening paragraph of the journey home story was modified to add that the narrative to be followed was the boy's dream and that the boy had a history of dreaming about things divorced from reality. The opening paragraph of, "the adventures of Mr. Wurg," was changed to state that the alien galaxy possessed advanced technology to cause the readers to expect to see devices such as intelligent robots on the planet Razon.

Prior context added to "the adventures of Mr. Wurg"	**Prior Context added to "the journey home"**
Razonians love smart object technology. Most Razonian objects have digital sensors and artificial intelligence chips embedded in them to allow them to perceive their environment and act intelligently.	I have always been fascinated by dreams. I have always wondered as to why some of our dreams are so different from our everyday experience; why are the laws of nature violated so often in our dreams even though that never happens when we are awake. I remember that in some of my childhood dreams, our childhood puppy Jack would talk to me. In others, I would fly through the air.

Figure 4: The prior context added to the stories to make the counterintuitive ideas to follow more predictable and thereby decrease their memorability.

Participants

Eighty four University of Findlay students ranging in age from 18 to 35 years, 29 male, and 55 female with a mean age of 20.6 years participated in the study as a part of their undergraduate course work.

Materials and Procedure

Eighty four packets each containing either counterintuitive supportive stories or intuitive supportive stories were designed. "Adventures of Mr. Wurg," was the first story in half of the packages while "the journey home" was the first story in the remaining packages. Four versions of "Adventures of Mr. Wurg" story were designed by changing the order in which Mr. Wurg observes the museum objects to avoid order effects among the objects. Half of the students (42) were randomly selected to receive the counterintuitive supportive version of both stories while the other half received the intuitive supportive versions.

Subjects were instructed to carefully read each story with the aim of comprehending it by trying to imagine each situation described in the story. Once all subjects had read the story, they were given a distraction task involving simple arithmetic for the next three minutes. This was followed by a question asking them to write down as many of the items from the story as they could recall. The whole

process was repeated for the second story. At the end of the study, subjects were told about the aims of the study.

Results and Discussion

Two responses were discarded because subjects were unable to complete the task. The remaining 82 responses were scored by a hypothesis-blind coder. Six counterintuitive and twelve distinct intuitive concepts were identified in the original journey home story. A conservative strategy suggested by (Barrett and Nyhoff 2001) for counting intuitive concepts was used to control the number of intuitive concepts. The coder compared the items recalled by the subjects with the items given in the story and counted the number of intuitive and counterintuitive concepts faithfully recalled by the subjects. This number was then divided by the total number of intuitive and counterintuitive concepts present in the original story to measure the proportion of intuitive and counterintuitive concepts recalled by each participant. The mean proportion of the intuitive and counterintuitive concepts recalled and their variance were calculated and compared using t-tests. Table 3 shows the mean recall rates and associated variances.

Table 1: The mean proportion of counterintuitive concepts recalled when the counterintuitive-supportive and the intuitive-supportive versions of the stories were presented to the subjects. Variance is shown in the parenthesis.

		Adventures of Mr. Wurg	The Journey Home	Total
Counter-intuitive Concepts	*Intuitive-supportive*	0.65.2 (0.07)	0.813 (0.04)	0.733 (0.06)
	Counterintuitive-supportive	0.504 (0.08)	0.723 (0.04)	0.610 (0.07)
Intuitive Concepts	*Intuitive-supportive*	0.599 (0.06)	0.677 (0.05)	0.569 (0.03)
	Counterintuitive-supportive	0.406 (0.05)	0.541 (0.02)	0.474 (0.06)

Similar to Boyer and Ramble (2001) and Barrett and Nyhoff (2001), subjects who read the original intuitive supportive versions of the two stories recalled a significantly larger proportion of counterintuitive concepts than intuitive concepts $t(82) = 4.89$, $p < 0.025$. As predicted by the memorability hypothesis, subjects who read the counterintuitive supportive versions of the two stories recalled significantly fewer counterintuitive concepts than subjects who read the intuitive supported versions, $t(41) = 3.10$, $p < 0.025$. Further, differences between recall rates of counterintuitive concepts for counterintuitive supportive and intuitive supportive versions were statistically significant for both stories. This is what is predicted by the memorability hypothesis.

The results also show that subjects who read counterintuitive supportive versions of the two stories recalled significantly fewer intuitive concepts than the subjects who read the intuitive supportive versions of the two stories, $t(41) = 2.95$, $p < 0.025$. The differences between recall rates of intuitive concepts for counterintuitive-supportive and intuitive supportive versions were significant for both stories. This may indicate that the changes in the prior context, though only intended to increase the predictability of the counterintuitive concepts by prompting the user to expect counterintuitive concepts, also affected the intuitive concepts. The changes may have made have intuitive concepts harder to justify (e.g., the subjects may have found it more difficult to explain the occurrence of, ordinary objects such as, "object made by people as a hobby" in a story about objects belonging to a high tech civilization than they did in the original version of, "the adventures of Mr. Wurg") thereby decreasing the postdictability of intuitive concepts and lowering memorability for these concepts in the counterintuitive-supportive version. This change in prior context may also have decreased the predictability of intuitive concepts somewhat but the memorability hypothesis predicts that if decrease in postdictability was larger than the decrease in predictability then the memorability for concepts embedded the counterintuitive-supportive context should be lower. This hypothesis can be tested by measuring changes in predictability and postdictability of intuitive concepts that result from varying the prior context.

Another result I did not anticipate when designing the experiment is that there is no statistically significant difference in the proportion of intuitive and counterintuitive concepts recalled by the subjects who read the intuitive-supportive version of "adventures of Mr. Wurg." This may mean that counterintuitive concepts I embedded in that story were not as "counterintuitive" as those used by Barrett and Nyhoff (2001) and Boyer and Ramble (2001). This also suggests that results regarding better recall for counterintuitive concepts may not be as robust as originally expected. This is especially noteworthy since the results regarding the impact of context on recall are robust and appeared consistently across all conditions.

The results of the above experiment when considered together with Owsianiecki *et al.*'s experiments, strongly suggest that context in which concepts appear has a significant impact on recall of those concepts. This role is not accounted for by previous theories that attempt to explain better recall for counterintuitive concepts as an intrinsic property of such concepts. The computational model proposed here explains that at least some of that difference between recall is due to the differences in predictability and postdictability of intuitive and counterintuitive concepts.

Conclusion

This paper has presented a computational model that attempts to explain differences in memorability of various

concepts by focusing on the role that the context in which a concept appears plays in making the concept more or less memorable. To the extent that predictability and postdictability of various concepts can be measured reliably, the memorability hypothesis presented here can be used to make precise predictions about the extent to which various concepts will be comprehended, remembered, and recalled by people. Experiments conducted to date provide strong support for the hypothesis. We are currently working to confirm other aspects of this model. This involves designing ways to measure predictability and postdictabilty of various concepts, using the memorability hypothesis to make predictions about recall rates of various types of concepts and comparing them to the actual recall rates observed with human subjects. We are also studying other factors that are known to affect memorability such as imagery, and concreteness (Sadoski and Pavio 2001) and see how they may be impacting memorability of intuitive and counterintuitive concepts. Imagery and concreteness are known to be positively correlated with each other as well as with memorability. However, it is not known as to how these variables relate to counterintuitivess and how imagery, concreteness, and counterintuitivess relate to memorability. Several studies are underway to explore these issues.

Plans are also in the works to instantiate the model presented here in a computer program using a cognitive architecture such as ACT-R (Anderson & Labiere 1998) and to design a multiagent system of cognitively rich agents for simulating the propagation of information through a society of intelligent agents. This will allow us to embed our theory in an overall general unified theory of cognition, further refine the model, and to better understand all its implications. I am keen to understand the implications of the memorability hypothesis not just for the spread of religious ideas but also for marketing, public education, innovation diffusion, and for writing fiction and non-fiction books such as school and college textbooks. It is hoped that this work can lead to techniques for designing more effective strategies for communicating a variety of messages.

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