The Role of Mental Elaborations in Making Counterintuitive Ideas Memorable

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Abstract

Previous work has suggested that concepts that are only slightly counterintuitive are more memorable than concepts that are intuitive or overly counterintuitive (Boyer, 1994; Boyer and Ramble, 2001) even though causes for this memory advantage have been debated (Barrett, 2008; Upal, 2009). This paper presents four studies conducted to better understand the cognitive processes that underlie memory for counterintuitive concepts. They suggest that elaborative processing of counterintuitive concepts may be the primary driver of the MCI effect rather than domain violation.

Keywords: time, elaborative processing, MCI hypothesis.

Introduction

One important question in the field of cognitive science is why certain concepts enjoy a memory advantage over others. Indeed, a considerable amount of research has been conducted in an effort to answer this question. The results of this research indicate that two primary factors facilitate memory performance: elaboration of a concept by a learner (Anderson & Reder, 1979; Hamilton, 1989), and distinctiveness of the concept in the given context (Eyesenk, 1979; Hunt & McDaniel, 1992; Hunt & Worthen, 2006; von Restorff 1933). More recently, Boyer (1994; Boyer & Ramble, 2001) proposed the minimal counterintuitiveness (MCI) hypothesis. According to this hypothesis, concepts that are slightly "counterintuitive" to real-world (i.e., violate one or two features of the ontological category to which the item belongs e.g., a tree that talks) are more likely to be remembered than those that can occur in the real world or those that are maximally counterintuitive (e.g., an invisible tree that talks and can see things thousands of miles away). Boyer argued that this is the case for two reasons: 1.) such concepts attract attention, increasing the likelihood of encoding in long-term memory, and 2.) minimally counterintuitive concepts are easier to categorize than maximally counterintuitive events. This hypothesis explains how the nature of a stimulus influences memory performance and in turn results in the concepts becoming cultural; that is, they remain across time and space. In particular, the minimal counterintuitiveness hypothesis has been applied to the resilience of religious concepts in various cultures.

An alternative explanation suggests that concepts are only counterintuitive in a given context (Upal, 2009). This "context-based" perspective proposes that when individuals encounter expectation-violating ideas, they struggle to comprehend the information. In such cases, they make use of the surrounding episodic context or their general world knowledge to interpret the violation. Therefore, counterintuitive concepts experience a memory advantage because they result in additional elaborative processing.

The purpose of the present set of experiments was to investigate the hypothesis that elaborative processing results in a memory advantages observed for minimally counterintuitive concepts.

Experiment 1

The purpose of Experiment 1 was to investigate the nature of the relation between reading time and recall rate of intuitive and counterintuitive ideas. Counterintuitive ideas were divided into two categories: those with only one feature-violation (low-CI) and those with two feature violations (high-CI). Both the concept-based view and the context-based view predict recall should be higher in both CI conditions compared to the intuitive condition. However, only the context-based view predicts reading times to be longer in the two counterintuitive conditions compared to the intuitive condition.

Participants

32 Providence College undergraduate students participated. Participants were compensated $5.00 for their time.

Materials

The materials included two stories titled "Jon's Travels" and "Nigel's Dream (see Appendix for sample story). Each story began with an introduction, followed by three sets of

three intuitive statements, three sets of three minimally counterintuitive, and three sets of three maximally counterintuitive ideas. The three conditions were presented in a mixed order. Each concept was specified using two sentences. The first sentence introduced the concept and the second sentence simply repeated the idea without adding any new information. All sentences were approximately the same length (between 63 and 69 characters). Intuitive ideas did not specify any feature violations, while minimally counterintuitive concepts specified one feature violation, and maximally counterintuitive concepts specified two feature violations. Both stories ended with a brief conclusion.

Procedures

Participants read the two stories on a computer screen, one sentence at a time. They were allowed to take as much time as they needed to process each sentence. After reading each sentence they were instructed to press the space bar to continue to the next sentence. Reading time for each sentence was recorded as the time between key presses. After reading the two stories, participants were presented with two pieces of paper. Each sheet of paper had the title of the story written across the top. The participants were instructed to write down as much as they could remember about each story.

Results and Discussion

All analyses were significant by the .05 level unless otherwise indicated. The subject responses were coded for recall by assigning the value 1 if the gist of the concept was thought to have been recalled by the subject. A score of 0 was assigned otherwise. The proportion of recall was measured by dividing the number of concepts recalled by subjects by the total number of concepts of that type embedded in the story. The reading time and proportion of recall for each statement are shown in see Table 1. For reading time, there was a significant main effect $F(2,62) = 19.04$, $MSE = 150473.86$. Planned comparisons revealed that reading times were significantly longer in the low – counterintuitive (L-MCI) condition and high counterintuitive (H-MCI) condition compared to the intuitive (INT) condition $F(1,31) = 37.35$, $MSE = 167396.84$, and $F(1, 31) = 26.19$, $MSE = 64610.75$, respectively. However, the difference between these two conditions was insignificant, $p > .05$. There was also a significant main effect for recall, $F(2,62) = 7.10$, $MSE = .018$. Recall rate was significantly higher in the L-MCI condition compared to the INT condition $F(1,31) = 74.42$, $MSE = .101$, and was also higher in the MXCI condition compared to the intuitive condition $F(1,31) = 7.04$, $MSE = .038$. However, the difference between the L-MCI and H-MCI conditions was insignificant, $p > .05$.

Table 1. Reading time and recall rates for Experiment 1

	INT	L-MCI	H-MCI
Reading Time	3182	3750	3624
Proportion Recall	.18	.30	.27

The results of Experiment 1 lend support to the context-based view as reading times on statements containing counterintuitive concepts were in fact longer than intuitive statements. In addition, recall rates were also higher for counterintuitive concepts compared to intuitive concepts. The pattern of results indicates that the additional time spent processing material facilitates memory performance. However, another possibility is that counterintuitive ideas take longer to process and they are also more memorable but the longer processing time does not cause them to be more memorable. Since Experiment 1 did not have a control group of non-counterintuitive sentences that also took longer to process, we cannot discount this possibility. The second experiment addressed this shortcoming.

Experiment 2

Past work has shown that negated sentences take longer to read (Sherman, 1976). Given the results of Experiment 1, the increased processing time should facilitate memory performance for such concepts as well. The purpose of the second experiment was to examine memory performance for counterintuitive concepts that were negated. Participants read the same stories from Experiment 1. However, the high-counterinituitive condition was replaced with a negated condition in which a counterintuitive concept was negated. For instance, consider the following statements:

He came upon a man who was not able to figure out how to fly.
He would jump off a roof and flap his arms but it didn't work.

In these sentences the counterintuitive concept of a man flying is negated, thus the concept is entirely intuitive. Given that previous work has shown that negated sentences take longer to read, it is likely that reading times will be longer for these sentences. According to the context-based view, the additional processing time should result in better memory performance for such statements. However, the traditional content-based version of the MCI hypothesis (Boyer & Ramble 2001; Barrett & Nyhoff 2001; Barrett 2008) predicts that minimally counterintuitive ideas enjoy a memory advantage over intuitive ideas. Because the negated statements are intuitive, memory performance for the negated statements should be the same as the intuitive statements.

Participants

Participants were 30 Providence College undergraduate students who were compensated $5.00 for their time.

Materials

The materials were the same as Experiment 1 with one modification. The H-MCI statements were replaced with negated statements. The first sentence introduced a counterintuitive concept that was negated. The second sentence elaborated on the first. Again, all statements contained 63-69 characters.

Procedures

The procedures were the same as Experiment 1.

Results and Discussion

Average reading time and recall rates are presented in Table 2. There was a main effect of condition, $F(2,58) = 10.59$, $MSE = 113352.88$. Reading times were longer in the MCI condition compared to the negated condition, $F(1,29) = 15.22$, $MSE = 161829.76$, $p < .05$ and the intuitive condition $F(1,29) = 14.77$, $MSE = 301027.99$. Reading times in the negated and intuitive conditions did not differ significantly, $p > .05$. The fact that reading time was shorter in the negated condition was inconsistent with previous work (Sherman, 1976). Therefore, we decided to look at average reading for the first and second sentence in each condition. For the first sentence, there was a main effect of condition, $F (2,58) = 5.38$, $MSE = 170471.57$. Reading times in the MCI and negated conditions were significantly longer than the intuitive condition, $F(1,29) = 5.60$, $MSE = 411986.44$ and $F(1,29) = 12.53$, $MSE = 250368.30$. However, the difference between the MCI and negated conditions was insignificant $p > .05$. For the second sentence, there was also a significant main effect, $F(2,58) = 21.39$, $MSE = 145250.52$. Reading times were longer in the MCI condition compared to the negated condition, $F(1,29) = 53.07$, $MSE = 233154.06$, and intuitive condition, $F(1,29) = 12.19$, $MSE = 314394.66$. Interestingly, reading times were significantly faster in the negated compared to the intuitive condition $F(1,29) = 7.51$, $MSE = 232951.40$.

There was also a significant main effect for recall, $F(2,58) = 16.75$, $MSE = .015$. Recall rates were significantly higher in the MCI condition compared to the intuitive condition, $F(1,29) = 45.97$, $MSE = .02$, were higher in the negated condition compared to the intuitive condition, $F(1,29) = 14.09$, $MSE = .04$. The difference between the MCI and negated conditions was insignificant, $p > .05$.

Table 2. Reading time and recall rates for Experiment 2

	INT	MCI	NEG
Reading Time			
Sentence 1	3453	3730	3776
Sentence 2	3208	3565	2923
Both Sentences	3347	3732	3445
Proportion Recall	.13	.31	.27

The pattern of reading time paired with recall mirrors Experiment 1. In conditions where we observed longer reading time, we also saw better memory performance. This is especially interesting in the negated condition as those concepts are actually intuitive. The fact that recall was significantly higher in the negated condition than in the intuitive condition contradicts the concept-based view of the MCI hypothesis. However, the results are consistent with the context-based view; increased reading time results in additional elaboration of the material, in turn, facilitating memory performance.

Experiment 3

The purpose of Experiment 3 was to examine whether the memory advantages observed in Experiments 1 and 2 results from time spent with the material or elaborative processing which involves successful resolution of an inconsistency (or expectation violation), as hypothesized by the context-based view. Participants read the same stories from Experiment 1. However, the low-MCI statements were replaced with statements that were nonsensical. For instance:

One woman he met was able to cut swimming with midnight cues.

She was in the process of carving as he watched her for some time.

If time alone facilitates memory performance, then recall for such statements should be high. However, according to the context-based perspective, it is the successful resolution of expectation-violating or inconsistent material that enhances memory performance, as it results in a more integrated memory trace. In the case of the nonsensical material, resolution of the expectation violations is very unlikely, if not impossible, for most readers. Thus, although reading times should be longer for such statements compared to intuitive or counterintuitive statements, recall should be lower compared to the other conditions.

Participants

Participants were 30 Providence College undergraduate students who received $5.00 for their time.

Materials

Materials were the same as those from Experiment 1 except that the low-MCI statements were replaced with statements that were nonsensical (see appendix).

Procedures

Procedures were the same as Experiments 1 and 2.

Results

The average reading time and proportion of recall for each condition are presented in Table 3. For reading time, there was a significant main effect, $F(2,58) = 61.72$, $MSE =$

127689.28. Planned comparisons revealed that reading times were significantly longer in the counterintuitive (H-MCI) condition and nonsense condition compared to the intuitive (INT) condition $F(1,29) = 66.69$, MSE = 281880.26 and $F(1, 29) = 128.07$, MSE = 214729.79, respectively. Although the difference between the high MCI and nonsense conditions was insignificant, there was a trend, $F(1,29) = 3.14$, MSE = 269525.66, $p = .08$. One likely reason there was not a significant difference between the two was that the second sentence in the nonsense condition made logical sense. Therefore, it is likely that reading times were quite long on the first sentence, but not on the second sentence. In order to address this, we analyzed reading time for the first and second sentence across all conditions. There was a main effect for the first sentence, $F(2,58) = 40.06$, MSE = 679873.13. Reading times were significantly longer in the nonsense condition compared to the MCI condition, $F(1,29) = 14.62$, MSE = 1306316.78 and the intuitive condition $F(1,29) = 56.49$, MSE = 1912418.71. In addition, reading times were significantly longer for the MCI statements compared to the intuitive statements, $F(1,29) = 42.18$, MSE = 860503.29. There was also a main effect for the second sentence, $F(2,58) = 12.36$, MSE = 393050.17. Reading times in the nonsense condition were significantly longer than the intuitive condition, $F(1,29) = 22.40$, MSE = 391610.96. Reading times in the MCI condition were also longer than the intuitive condition, $F(1,29) = 17.02$, MSE = 1091012.88. However, reading times on the second sentence were not significantly different in the nonsense and MCI conditions, $p = .16$.

There was also a significant main effect for recall, $F(2,58) = 32.83$, MSE = .011. Recall was significantly higher in the MCI condition compared to the INT condition, $F(1,29) = 11.66$, MSE = .029 and was also higher in the MCI compared to the nonsense condition, $F(1,29) = 89.40$, MSE = .02. Finally, recall was higher in the INT condition compared to the nonsense condition, $F(1,29) = 18.39$, MSE = .02.

Table 3. Reading time and recall rates for Experiment 3

	INT	High-MCI	Nonsense
Reading Time			
Sentence 1	3520	4620	5417
Sentence 2	3142	3928	3682
Both Sentences	3293	4084	4253
Proportion Recall	.16	.27	.04

Although participants took more time to read the nonsense statements compared to the INT and nonsense statements, recall was significantly worse for those concepts. It is very likely that the fact that the statements were nonsensical prevented resolution. In other words, because the material was largely incomprehensible, readers were either unwilling or unable integrate the information coherently. This resulted in an impoverished memory trace in which concepts from those statements were not integrated with one another or with the context, making retrieval of the ideas more difficult.

Experiment 4

The fourth experiment compared processing of maximally counterintuitive (MXCI) statements with minimally counterintuitive and nonsensical statements. Participants read statements that were either nonsensical (from Experiment 3), minimally counterintuitive (the H-MCI items from Experiment 1), or maximally counterintuitive (containing three feature violations, consistent with Barrett, 2008). Both the concept-based and the context-based views predict that reading time for maximally counterintuitive statements will be longer than minimally counterintuitive statements, but memory performance will be lower for maximally counterintuitive concepts compared to minimally counterintuitive concepts.

Participants

30 Providence College students participated and were compensated $5.00 for their time.

Materials

The materials included the nonsensical concepts from Experiment 3, the minimally counterintuitive (H-MCI) statements from Experiment 1, and maximally counterintuitive statements containing three ontological domain/feature violations.

Procedures

The procedures were the same as Experiments 1-3.

Results

The average reading times and proportion of recall for each condition are presented in see Table 4. For reading time, there was a significant main effect, $F(2,58) = 24.08$, MSE = 1175771.96. Planned comparisons revealed that reading times were significantly longer in the nonsense condition compared to the maximally counterintuitive (MXCI) condition and minimally counterintuitive (H-MCI) condition, $F(1,29) = 15.07$, MSE = 2100332.65and $F(1, 29) = 29.27$, MSE = 3864886.12, respectively. Reading times were also significantly longer in the MXCI condition compared to the H-MCI condition, $F(1,29) = 23.04$, MSE = 1089412.99. We also analyzed the data for the first and second sentence. There was a significant main effect for the first sentence, $F(2,58) = 49.10$, MSE = 1152799.28. Reading times on the first sentence were significantly longer in the nonsense condition compared to the MXCI condition, $F(1,29) = 20.80$, MSE = 2776862.60 and were also significantly longer in the nonsense condition compared to the MCI condition, $F(1,29) = 66.03$, MSE = 3429027.57. In addition, reading times were significantly longer for the

MXCI statements compared to the MCI statements, F(1,29) = 78.00, MSE = 710905.48. There was no main effect for the second sentence, p = .85. Planned comparisons revealed no significant differences between the three conditions.

There was a significant main effect for recall, F(2,58) = 40.57, MSE = .008. Recall rate was significantly higher in the H-MCI condition compared to the nonsense condition F(1,29) = 70.29, MSE = .019 and was also higher in the H-MCI compared to the MXCI condition F(1,29) = 25.56, MSE = .023. Finally, recall was higher in the MXCI condition compared to the nonsense condition, F(1,29) = 16.45, MSE = .009.

Table 4. Reading time and recall rates for Experiment 4

	MCI	MXCI	Nonsense
Reading Time			
Sentence 1	3366	4725	6113
Sentence 2	3379	3313	3378
Both Sentences	3372	4019	4745
Proportion Recall	.25	.11	.04

The pattern of reading time suggests that participants struggled with the information in the MXCI condition more than in the MCI condition, even though there was only one additional counterintuitive feature. This finding is important for two reasons. First, it is consistent with Barrett's (2008) operational definition of MXCI and thus lends support to his coding scheme. Second, it suggests that MXCI material is, in fact, more difficult to process than minimally counterintuitive statements. However, processing of that material was not as difficult as in the nonsense condition. Reading times were significantly longer in the nonsense condition compared to the MXCI condition, suggesting the nonsensical material resulted in more serious comprehension difficulties. This hypothesis is supported by the recall data – recall was significantly worse in the nonsense condition compared to the MCI and MXCI conditions.

General Discussion

Why certain concepts enjoy a memory advantage over others is an interesting question for cognitive science because it furthers our understanding of how certain cultural ideas became widespread (Boyer, 1994). This paper documents the results of a number of novel experiments conducted to better understand cognitive processes that underlie memory for various types of concepts. This is the first study to compare reading times for intuitive, minimally counterintuitive, and maximally counterintuitive concepts. It is also the first study to measure recall rates for maximally counterintuitive concepts embedded in narratives while systematically comparing those recall rates with intuitive and nonsensical concepts. Our results indicate that minimally counterintuitive concepts enjoy a memory advantage because such ideas require additional elaborative processing, resulting in a more integrated memory trace. However, Experiments 3 and 4 indicate the additional processing doesn't always improve memory performance, likely because in some cases the additional processing does not result in successful interpretation and/or integration of the material in memory.

These results along with a growing set of experimental findings (see review in Upal, 2009) lend support to the context-based view of the MCI hypothesis, which argues that counterintuitiveness is not a property of the concepts alone, but rather it is a property of the concepts along with the context in which they are embedded.

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Appendix

Sample Story: Jon's Travels

Introduction
Jon is a trader who has been to many places. One day, after he had come back from a journey to distant places, he told his friends about the people he had seen. Some of those people are like you and me and others are different. Jon met a lot of interesting people.
Low-MCI (Experiment 1 and 2)
One girl was interesting because she could be in two places at once.
He could see her talking to two different people in different rooms.
Intuitive (Experiment 1)
There was also a man who could recognize people he had met before.
If he met someone once he was able to easily remember that person.
Negated (Experiment 2 only)
He was introduced to a boy who was unable to radiate blue light.
No matter how hard he tried, he just could not manage to do it.
High-MCI (Experiment 1, 3, and 4)
One boy radiated blue light and turned to stone if you touched him.
The people he stood next to glowed while keeping a safe distance.
Nonsense (Experiments 3 and 4)
One girl was interesting because she colored sleep into purple ideas.
He spent an entire hour observing and analyzing her unique skill.
MXCI (Experiment 4 only)
One boy radiated blue light, shed his skin, and saw through walls.
The men he stood next to were afraid of him and kept their distance.
Low-MCI (Experiment 1 and 2)
One woman he met was able to cut metal with only her pinky finger.
She was carving a doorway and a window near the back of the room.
Intuitive (Experiment 1 only)
There was another person who could accurately predict the weather.
She could tell you if it was going to thunderstorm the next day.
Negated (Experiment 2 only)
He then came upon a statue of a woman that was unable to cry.
He looked very closely but saw no tears upon her cold, stony face.
High-MCI (Experiment 1, 3, and 4)
There was a man who had large gills and turned into a bear at night.
Strangely, he breathed through his nose and always walked upright.
Nonsense (Experiments 3 and 4)
One woman he met was able to turn on swimming through midnight cues.
She was in the process of working and he watched her for some time.
MXCI (Experiment 4 only)
One man cut glass with a finger, cast spells, and saw invisible people.
Strangely, he didn't brag about the incredible things he could do.
Low-MCI (Experiments 1 and 2)
He also met another person who was taller than a two-story house.
He was so tall that he had trouble getting into buildings and cars.
Intuitive (Experiment 1 only)
There was another person who seemed to be screaming all the time.
He was standing in front of a group of children yelling at them.
Negated (Experiment 2 only)
One young woman he met was unable to make herself breath fire.
He watched her inhale deeply but was only able to exhale air.
High-MCI (Experiments 1, 3, and 4)
One woman had a long white tail and she could also breathe fire.
She reminded him of a big rat and always seemed to be smoking.
Nonsense (Experiments 3 and 4)
He met another person who believed sparkles underneath cunning grace.
The man was willing to discuss his beliefs with anyone that listened.
MXCI (Experiment 4 only)
One woman floated in space, could spit fire, and breath under water.
Her special powers frightened him and he kept his distance from her.
Conclusion
Jon had finished telling people what he had seen in these far-away places. He told them that after he had traveled to those places he had felt homesick, and that was why he had come back to be with his family.