Curiosity and Its Influence on Children's Memory

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Abstract

Curiosity has a tumultuous past. Originally curiosity was considered a vice of excess leading to misconduct and disaster. Recently, curiosity has transformed into a virtue of self-expression resulting in success and better performance. In classrooms, educators try to find ways of eliciting curiosity from their students: allowing them to pick their own research topics and books, including pop culture references in lecture, and many more strategies. Recent adult studies have revealed better memory for trivia facts that elicit more curiosity. The current study modifies the methods used in previous adult studies in order to make them more appropriate for children. Results from a sample of 24 7- and 8-year-olds reveal that by age eight curiosity significantly affects memory for trivia facts. This research may shed light on the cognitive advantages of curiosity and legitimize the encouragement of curiosity in classrooms for school age children.

Keywords: curiosity; children; Information Gap Theory

Introduction

Philosophers and psychologists have attempted to define curiosity for generations with no real consensus. In 1994, George Loewenstein, taking pieces of each previous theories of curiosity, proposed the Information Gap theory (Loewenstein, 1994). Loewenstein saw curiosity not as a drive, reaction or motivation but rather a state of deprivation. Inspired by the idea that curiosity begins with prior knowledge and leads to new knowledge, Lowenstein argues that curiosity is induced by information gaps which can explain the variation in the situational determinants that lead to a state of curiosity. Every one has some prior knowledge that is organized into networks (Chi & Koeske, 1989). When an information gap in a particular knowledge network is made salient, curiosity is induced.

Information Gap theory can explain why curiosity seems to have varied intensity. Loewenstein (1994) believes that the size of the information gap predicts the intensity of the resulting curiosity. Larger gaps lead to low curiosity and small gaps lead to high curiosity. Larger gaps suggest that the knowledge network is not as extensive and therefore probably does not contribute to a person's self-concept, making that piece of information less rewarding. Smaller gaps suggest that the knowledge network is extensive and therefore probably does contribute to a person's self-concept, making that piece of information potentially more rewarding.

Recently, Kidd & Hayden (2015) have argued that we should move beyond a mere definition of curiosity and investigate the behavior in light of Tinbergen's (1963) four questions for explaining the behavior of an organism: (1) what function does the behavior serve?, (2) what is the mechanism or causal explanation for the behavior?, (3)how did the behavior evolve over phylogeny?, (4) how does the behavior develop over ontogeny? Indeed, Loewenstein's Information Gap theory can provide insight into curiosity's function and mechanism.

Once a salient information gap produces curiosity, people engage in exploratory behaviors in order to find the desired information. Exploratory behaviors and the eventual retrieval of desired information will vary depending on the size of the gap, the expected reward of filling the gap and one's perceptions of their ability to fill the gap. If the size of the gap is too large and the reward of filling it is not substantial or important to one's self concept people are less likely to go through with acquiring the desired information. In addition, if someone believes they are unable to acquire the information they will be less likely to do so. If one does eventually obtain the information, she will then put that new information into her knowledge networks and in the process modify them. The filling of the gap or rather the modifying of the network is the reward. Curiosity, therefore, can act as an intrinsic motivation for people to continue to build up and expand their knowledge networks.

Machine learning has been using a process similar to Information Gap theory to create artificial curiosity. In the case of a robotic arm, a reinforcement learner with an adaptive world model uses the expected improvement of the world model as intrinsic motivation and reward (Ngo, 2012). Essentially, the robotic arm has knowledge networks that it aims to improve and experiences reward when that expected improvement, filling of information gaps, is completed. For machine learning, artificial curiosity has been an effective way for machines to learn about the world for themselves, a form of active learning.

Curiosity in fact can be considered a mechanism for active learning since the desire, initiative and execution of learning originates purely from the learner. Active learning has been shown to lead to a better quality of learning (Benware & Deci, 1984). One question remains: can curiosity lead to better learning? Scientists have shown that information itself is rewarding (Marvin & Shohamy, 2016) and that curiosity may lead to better memory retention in adults (Gruber et al., 2013; Kang et al., 2009), however, the mechanism by which it does remains unknown.

Recent research in reward learning may illuminate the process by which curiosity can influence memory retention. Research on reward began with the simple idea that dopamine was the pleasure/reward neurotransmitter (Wise, 1985). It was soon found, however, that rats depleted of dopamine still somehow could feel pleasure (Berridge & Robinson, 1998). Interestingly, dopamine depleted rats do show a decrease in exploratory behaviors (curiosity) in the presence of novel objects and reward seeking (Ungerstedt et al., 1971; Heffner et al., 1972). Dopamine, in recent years, has been shown to regulate reward anticipation rather than reward itself. In reward anticipation it is the predictive cue that leads to a spike of dopamine (Simansky et al., 1985; Philips et al., 1991; Phillips et al., 1992; Phillips et al., 1993, Blackburn et al., 1989; Schultz et al., 1995). The reason curiosity is affected by dopamine depletion might be that curiosity is a form of reward anticipation. The information gap of Lowenstein's theory could act as a predictive cue for reward. Experiments have shown that the indicated level of curiosity induced in participants by trivia questions affected the level of activity in the substantia nigra and ventral tegmental areas (Gruber et al., 2013; Kang et al., 2009), the main centers of reward, before the answer to that question was given. The SN/VTA is potentially highly connected with the hippocampus. Some hypothesize that the VTA and hippocampus form a functional loop and VTA increased activity can lower the threshold needed for a long-term potentiation (Lisman & Grace, 2005). Curiosity, therefore, by activating the reward centers can make later encoding of information easier. Is this true for children as well?

The relationship between curiosity and exploration has been studied extensively. Using a Bayesian perspective, Laura Szhulz and her colleagues (Schulz, 2012) have investigated children's exploratory behavior when confronted with ambiguous evidence (Schulz & Bonawitz, 2007; Gweon & Schulz, 2008; Cook, Goodman & Schulz, 2011;) and when evidence violates their expectations (Bonawitz, van Schijndel, Friel & Schulz, 2012). Yet, most of the research on curiosity and memory has been conducted on adults. This phenomenon has yet to be explicitly studied in children.

In this study a modified form of the Gruber et al. (2013) methods will be used to elicit and measure curiosity as well as measure memory retention in children. Child participants were asked to rank trivia questions based on how much curiosity the questions induce relative to each other on a scale presented on a game board. The game will not use any questions a child determines she knows, therefore all the questions should incite some level of curiosity since every question highlights a particular information gap. After ranking the questions, the children will learn the answers and will then be tested on these questions to see which answers they remember and how those questions relate to the child's curiosity rankings. We hypothesize that children will be more likely to remember questions they ranked on the high end of the scale (i.e., high curiosity questions rather than the questions they ranked as on the low end of the scale (i.e., low curiosity questions). In addition to answering pivotal questions about the development of curiosity, the present study will further emphasize the importance of peaking a student's curiosity in the classroom.

Methods

Participants

Nine seven-year-old children (Mean age = 7.43; SD = 0.22; 4 female) and 16 eight-year-old children (Mean age = 8.43; SD = 0.30; 8 female) participated in this study. Participants were recruited using the Berkeley Early Learning Lab database as well as during testing sessions at the Lawrence Hall of Science. Informed consent was obtained from the participants' parents. Children received a small prize for their participation.

Materials

Thirty-four trivia questions were previously piloted to ensure that on average 60% of children ages 6-7 did not know their answers. The trivia questions included content related to living animals, dinosaurs, astronomy, geography, and miscellaneous (e.g., How big is the brain of a stegosaurus? How many planets are in the solar system?). Questions were printed on 2 inch by 3 inch laminated cards and the answers were printed on the back of each card.

Children were asked to rate 6 randomly-selected questions based on the amount of curiosity the questions elicited. For each question the child was asked if they believed they knew the answer to the question. If the child stated that they did know the answer or if the the child guessed either correctly or incorrectly, the question was discarded and a new one was drawn. This was done in order to insure that any differences in recall were due to curiosity ratings rather than prior knowledge.

The participants were given a board with a scale of 1-6 (1-3 representing no to little curiosity and 4-6 representing substantial to extreme curiosity). On the board above each number of the scale was an associated box where the child could place one question card.

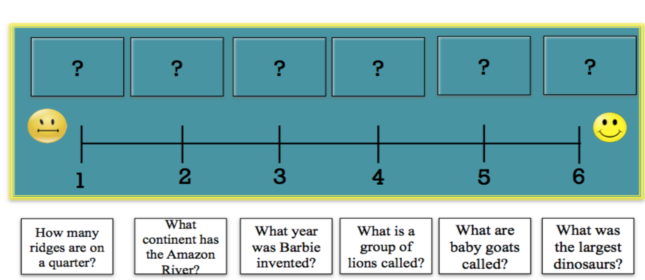

Figure 1: Scale and Questions

Procedure

Each testing session consisted of 4 trials in which the child was presented with 6 questions per trial. Children therefore received a total of 24 questions out of the original 34 questions. Extra questions were included in the case that a child may know some answers to the 24 questions presented to them. Before each trial the experimenter told the child to indicate to the experimenter if she knew the answer to a presented question. If a child thought they knew the answer to a question or if the child guessed either a correct or incorrect answer, a new question was chosen from the top of the deck.

At the beginning of each trial the experimenter shuffled the deck and drew the first 6 question cards from the top of the deck. The experimenter read the cards and placed each question card in front of the child. The experimenter instructed the participant to use the board to rate the questions based on their level of curiosity and guided participants through the rating scale: First the experimenter would ask the child which question they were the most curious to know the answer to and then which question they were the second most curious to know the answer to. Those questions were placed in boxes 6 and 5. The experimenter then asked the child which question she was the least curious about and which question she was the second least curious about. These questions were placed in boxes 1 and 2. For the remaining two questions, the experimenter would ask the child which question she was the most curious about of the two, that question was then put into box 4 and the last question was put in box 3.

After all the questions were rated, the experimenter, starting at one end of the scale, would reread the question and then flip the card over and read the answer. Once all of the answers had been revealed the experimenter put the 6 questions off to the side for later testing. The trial was then repeated and the order of presentation of questions and answers was counterbalanced across trials in order to reduce an possible recency or primacy effects. After two trials, the 6 questions from trial 1 and the 6 questions from trial 2 were combined and shuffled randomly. The child was then asked to answer each question from memory. The child underwent two more trials and one more testing block. All ratings and responses to questions were recorded with a video camera.

Answers were coded as correct if the child provided the correct answer and incorrect if the child did not provide the correct answer or stated that they did not know or that they forgot the answer. Since we used child-friendly trivia questions most of the answers consisted of one word however some of the answers contained two words such as ‘argentine lizzard’ or ‘wild prairie rose’. If a child responded with a key word or phrase such as ‘argentine’ or ‘prairie rose’ the response was coded as correct. However, if the child responded with a word from the answer that was not a key word or phrase such as ‘lizzard’ or ‘wild rose’ the response was coded as incorrect.

Results

Data analysis showed that there was a significant difference in memory retention between age groups with 8-year-olds showing greater recall than 7-year-olds but age was not a significant factor within either of the two age groups. On average, 7-year olds recalled 60.2% (SD = 0.13) of the answers while 8-year-olds remembered 77.6% (SD = 0.13) and this difference was significant ($t = 2.304$, $df = 12.026$, $p = 0.039$).

Generalized Linear Models with Mixed effects (GLMMs) were used to predict recall based on age group and curiosity rating[1]. Since each child rated multiple questions for each curiosity rating participant ID was entered as a random effect in order to control for individual differences in recall. Results from model comparisons revealed that model with the best fit predicted recall from curiosity ratings, age group and the interaction of curiosity ratings and age group. This model outperformed a null model ($\chi^2 = 12.12$, $df = 3$, $p = 0.006$), as well as models using curiosity ratings alone (($\chi^2 = 10.966$, $df = 2$, $p = 0.004$), age group alone (($\chi^2 = 6.009$, $df = 2$, $p < 0.049$), or the combination of curiosity ratings and age group without interactions (($\chi^2 = 4.855$, $df = 1$, $p < 0.028$).

The coefficients provided in the output of the GLMMs are in the form of the logarithm of the odds that a response is correct at a given value or level of the independent variable. By taking the exponent of the log odds we can see the odds ratio of a correct response. Table 1 provides the odds ratio of coefficients for each of the variables in the model as well as their corresponding 95% confidence intervals.

Analyses of the coefficients from the model with interactions revealed that for 7-year-olds the odds ratio of giving a correct answer increased by only 0.156 for each unit increase in curiosity rating while for 8-year-olds, each unit increase in curiosity rating led to a 1.17 increase in the odds of recalling the correct answer. Children’s percentage of correct responses by age group and curiosity rating are presented in figure 2 on the following page.

	Odds ratio	Lower limit	Upper limit
Intercept	1.903	0.0008	4416.062
Curiosity	0.156	0.028	0.864
Age_group	1.015	0.367	2.805
CuriosityXAge	1.288	1.028	1.613

[1] Analyses revealed no significant effects of trial or block order indicating that children in this study did not show an effect of receny or primacy.

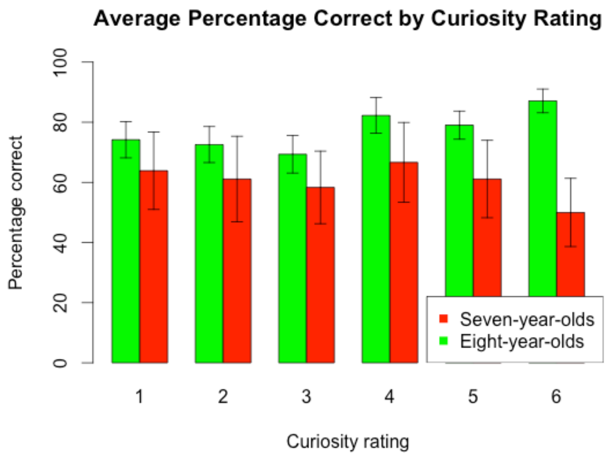

Figure 2: Percentage correct by curiosity rating and age group.

Discussion

Our results showed that by age 8, children's own ratings of curiosity predicted their memory recall. The more curious they are about a trivia fact, the more likely they are to remember the answer. For 7-year-olds, however, no such effects were found. The sample size is small for this study, so we need to interpret our results with caution. On-going work aims to increase the sample size of each age group.

Multiple factors could be causing the difference between the age groups seen in this study. First, memory and attention both improve with age and it is possible that the eight-year-olds' higher performance is due to improvements in these more basic cognitive functions. Secondly, younger children may lack the metacognitive skills necessary for curiosity to effectively influence their learning patterns. Curiosity requires one to first recognize when there is an information gap and then selectively focus attention and use cognitive resources to fill that gap. Although it has been shown that young children have metacognitive skills (Brown, 1977; 1979; Flavell, 1979), they develop with age and therefore, some children may not have the ability to recognize an information gap effectively and then use those metacognitive skills to focus attention on appropriate information. Whatever the reason may be, this experiment while hinting at developmental differences cannot determine the underlying cause of the differences.

In addition, the effect of curiosity on memory may not be very strong due to a variety of other factors. One of them being that children may be more likely to remember answers that have words which are more familiar to them. Some of the questions children are curious about may have answers with words that are not commonly used (for example: argentine lizard), while other less curiosity inducing questions have easier to remember answers (for example: lion). For this reason, future studies will investigate the familiarity of content knowledge as well vocabulary knowledge.

Lastly, some answers to the questions were in the form of numbers. When considering numbers, children are also more likely to forget answers to questions they were highly curious about if the number is hard to remember, such as 119 or 1959. Other answers to lower curiosity questions may be much easier to remember, such as 8.

With a much larger sample size, we hope to be able to reduce the noise level in the data. Since different children choose different questions as high or low curiosity, based on their own prior knowledge and experience, we hope that the effects of these idiosyncratic factors such as familiarity with specific words or numbers will wash out. It also remains to be seen if the age difference we have found will hold up with a larger sample size, and whether other less verbal methods may produce the same results.

Conclusions

In the past researchers and philosophers have struggled to define curiosity in any sufficient manner. With Loewenstein's (1994) information gap theory we can describe it not just as a desire to learn but as a psychological concept with positive results for learning and memory. This study has shown that the benefits of curiosity are not just for adults.

This study has shown that 8-year-old children do seem to have higher memory retention of facts that elicit more curiosity, whereas, 7-year-olds apparently do not. This is important not only for our own curiosity as developmental cognitive scientists but also for others involved in child development such as teachers and parents.

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