Using Thought-Provoking Children’s Questions to Drive Artificial Intelligence Research

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Abstract

We propose to use thought-provoking children’s questions (TPCQs), namely Highlights BrainPlay questions, as a new method to drive artificial intelligence research and to evaluate the capabilities of general-purpose AI systems. These questions are designed to stimulate thought and learning in children, and they can be used to do the same thing in AI systems, while demonstrating the system’s reasoning capabilities to the evaluator. We introduce the TPCQ task, which takes as input a TPCQ question and produces as output (1) answers to the question and (2) learned generalizations. We discuss how BrainPlay questions stimulate learning. We analyze 244 BrainPlay questions, and we report statistics on question type, question class, answer cardinality, answer class, types of knowledge needed, and types of reasoning needed. We find that BrainPlay questions span many aspects of intelligence. Because the answers to BrainPlay questions and the generalizations learned from them are often highly open-ended, we suggest using human judges for evaluation.

Introduction

As artificial intelligence tasks like fact-based question answering [Ferrucci et al., 2013] and face recognition [Taigman et al., 2014] become mostly solved, there is a need for harder tasks. Consider the following questions from the children’s magazine Highlights:

Why doesn’t every key open every lock?
Which is older, a tree or a leaf on the tree?
Why aren’t pants pockets as big as backpacks?
Flags wave, people wave, and the ocean has waves. How are these waves alike?
What part of a fish is farthest from the head?
Is an ice-cream cone wider at the bottom or at the top?
Could you sing a song in a dark room? Could you put together a puzzle?
Why can’t you move faster than your shadow?
What might happen if you put a bee in your pocket?
If you could not remember today’s date, what are five ways you could find out?

Although these questions are short and designed to be answered by young children, they are very hard for computers. It is unlikely that the reader has heard these questions before, and yet correct answers can be produced by most children within seconds, as well as explanations of the reasoning behind these answers. The embarrassing fact is that answering and learning from these questions is way beyond the capabilities of existing AI systems. They are wide open.

We propose answering and learning from thought-provoking children’s questions (TPCQs), which are available in the BrainPlay column of Highlights, as a useful metric for driving research and evaluating general-purpose AI systems. TPCQs test a system’s ability to make novel connections, which is necessary for intelligence.

While this method does require that the system have a powerful language facility, this is a crucial capability for a large class of useful AI systems. Without the system having the capacity to understand and generate language, it is extremely difficult for researchers to communicate abstract goals and tasks to the system, to draw its attention to salient topics, to receive answers to questions, and for the system to explain its behavior.

Task Definition 1 (TPCQ) Given a thought-provoking children’s question $Q$, produce

- one or more answers to the question $A_1, A_2, \ldots$
- one or more learned generalizations $L_1, L_2, \ldots$

Example:

$Q$: Name three animals that hatch from eggs.

$A_1$: birds
$A_2$: chickens
$A_3$: ducks
$A_4$: snakes

$L_1$: Animals with feathers hatch from eggs.

Learning doesn’t only happen through real experiences and doesn’t always require the addition of new knowledge. A hallmark of human-level intelligence is the ability to combine existing knowledge through imagined situations, to answer questions which you have never before been asked. You may have pieces of knowledge whose connections are not apparent until someone pushes you to notice them. This is what BrainPlay questions are designed to do.*

*BrainPlay questions are published each month in Highlights, which is available from https://www.highlights.com/
Highlights BrainPlay

*Highlights* magazine was started in 1946 by Garry Cleveland Myers and Caroline Clark Myers. The magazine includes a BrainPlay column, which was called Headwork before November 2004. In this paper, we use the term BrainPlay for both Headwork and BrainPlay questions.

The *Highlights* editors develop BrainPlay questions with great care. The questions are designed to “stimulate” children from five to twelve to think and reason by working over in their heads what is already there, arriving at new ideas not learned from books (Myers, 1968).

For example, consider the BrainPlay question “In a room with a staircase leading to the second floor, how can you figure out the height of the first-floor ceiling?” This question suggests a novel technique: to measure the height of a ceiling when there is a staircase leading up to the next floor, multiply the rise of the steps by the number of steps.

BrainPlay first appeared in the second issue of *Highlights* in September 1946 (Wood, 1986). Each month, BrainPlay presents around 20 questions arranged by age level (Myers and Myers, 1964). Correct answers to the questions aren’t provided.

### Analysis of BrainPlay Questions

To get an idea of what we’re up against, we performed an analysis of BrainPlay questions in the *Highlights* issues from January 2000 to December 2000. We started by segmenting each top-level question into one or more subquestions. For example, the top-level question

> Would you rather wear a hood or a hat? Why?

is segmented into a first question and a second question.

Table 1 shows the composition of subquestions. Table 2 gives statistics on the length of subquestions. The first question tends to be the longest. The second and following questions typically ask for explanations for the answer to the first question, ask variations on the first question (often involving coreference), or follow up in some other way. For the remainder of the analysis, we considered only first questions.

We annotated each first question with exactly one question type, question class, answer cardinality, and answer class, and we annotated each first question with one or more types of knowledge needed and types of reasoning needed. We developed an initial set of annotation tags like Open-Ended and What-If and revised them as needed during the annotation process.

#### Table 1: Subquestion Composition

| Subquestion | % Questions | # Questions |
|-------------|-------------|-------------|
| 1st         | 65.07%      | 244/375     |
| 2nd         | 22.13%      | 83/375      |
| 3rd         | 6.40%       | 24/375      |
| 4th         | 3.47%       | 13/375      |
| 5th         | 1.60%       | 6/375       |
| 6th         | 0.80%       | 3/375       |
| 7th         | 0.27%       | 1/375       |
| 8th         | 0.27%       | 1/375       |

#### Table 2: Subquestion Length (number of words, SD = standard deviation)

| Type          | % Questions | # Questions |
|---------------|-------------|-------------|
| Open-Ended    | 87.30%      | 213/244     |
| Multiple Choice | 11.59%     | 28/244     |
| Yes-No        | 1.23%       | 3/244       |

#### Table 3: Question Type

**Question Type**

Statistics on the question type are shown in Table 3.

| Type          | % Questions | # Questions |
|---------------|-------------|-------------|
| Open-Ended    | 87.30%      | 213/244     |
| Multiple Choice | 11.48%     | 28/244     |
| Yes-No        | 1.23%       | 3/244       |

**Question Class**

Statistics on the question class are shown in Table 4.

- **Facts** Asks about facts (may require reasoning).
  - Name three animals that hatch from eggs.
  - How does a turtle protect itself?
- **Caring** Stimulates thought about caring and kindness.
  - What could you do today to help someone else?
  - If your family has company, what can you do to be a good host?
- **Comparative** Involves a comparative.
  - Is it easier to swallow a pill or a spoonful of medicine?
  - Would it be easier to remember the date of a party or the date of a haircut appointment?
- **Personal Experience** Asks about personal experiences.
  - Have you ever been so busy that you forgot to eat a meal?
  - What popular sayings did you first hear in a song or movie?
- **Personal Preference** Asks about personal preferences.
  - Describe your favorite place to go for a walk.
  - If you could meet any person in the world, who would it be?
A number of questions involve personal experiences, preferences, and facts. The answers to these questions are person-dependent. How shall we deal with these? The first reaction might be simply to throw them out. But consider that an intelligent, autonomous AI system will have its own personal experiences and preferences. These are essential aspects of a general-purpose AI system. Therefore it would be a mistake to throw these questions out. Because there is no gold standard answer key for them, answers can be judged for plausibility by human judges, as in the Turing test [Turing, 1950].

Some questions request an action to be performed. Again, we could throw these out, but then we would be throwing out some of the most revealing questions. Instead, the system can perform the actions in a three-dimensional simulator (or in the world if the system has a body), and the results can be judged by humans.

Human judging is more time-consuming, but it is currently the best way of evaluating novel, previously unseen answers to novel, previously unseen questions.

A question like “Have you ever been so busy that you forgot to eat a meal?” makes sense for an AI system, because the question probes essential knowledge of goals, plans, and mental states. General-purpose AI systems must be able to recognize, remember, and apply concepts like “being busy” and “forgetting to perform a task.”

### Answer Cardinality
Statistics on how many answers are required by a question are shown in Table 5.

| Cardinality | % Questions | # Questions |
|-------------|-------------|-------------|
| 1           | 49.59%      | 121/244     |
| >1          | 45.90%      | 112/244     |
| 3           | 3.28%       | 8/244       |
| 2           | 0.82%       | 2/244       |
| 5           | 0.41%       | 1/244       |

Table 5: Answer Cardinality

his flight from Rhode Island to Oregon. Why was this?
Jackson and his family were watching TV when suddenly they lost reception. What might have caused this?

**Description** Asks for a description.
Describe some rocks you’ve seen.
Describe how a wheel works.

**Count** Asks for a count.
How many pets do you know by name?

**Sort** Asks for items to be sorted by some attribute.
List these in order of size: moon, bird, star, airplane.

### Theory of Mind
Evaluates theory of mind [Doherty, 2009].
Ryan looked at the sliced apple and said, “This must have been sliced a while ago.” How might he have known?

When Otis arrived at the pool, he quickly figured out which person was the new swim coach. How might he have guessed?

### Purpose
Asks about the purpose or function of something.
What tools do you need for drawing?
Name three uses for bells.

### Difference
Asks for the differences between two things.
How is taking a music lesson different from playing music on your own?
What’s the difference between a riddle and a joke?

### Reason
Asks about the reason for something.
Why do babies cry more often than adults?
Why do we frame paintings and photos before hanging them up?

### Meaning
Asks for the meaning of a word or phrase.
What is meant by the saying “Money doesn’t grow on trees”?
What does it mean to “go the extra mile”?

### Action
Asks for an action to be performed like singing or drawing.
Draw a heart in the air with your finger.
Make a hand signal that means “good job.”

### Personal Facts
Asks about personal facts.
Are you ticklish?
How many teeth do you have?

### Similarity
Asks for the similarities between two things.
How are socks and mittens alike?
How is honey like maple syrup?

### Superlative
Involves a superlative.
What is the best smell in spring?
Where do you laugh the most: at school, at home, or with friends?

### Debugging
Requires debugging of a problem or situation.
When Erik looked at his plane tickets, it seemed as if his flight from Oregon to Rhode Island would take six hours longer than...
3 Three answers.
   Name three ways to have fun on a rainy day.
   Name three objects that are shaped like a triangle.

5 Five answers.
   List the top five things that you like to do with your friends.

Answer Class
Statistics on the answer class are shown in Table 6. A gold standard answer key can be developed for questions of class Exactly One and Several. Thus the answers to 103 (42.21%) of the 244 BrainPlay questions we analyzed can be evaluated automatically.

What about the remaining questions? Human judging will be needed for the answers to questions of class Many, Personal, Open, Debatable, and Nontextual Answer. More points should be awarded for correct answers to harder questions.

Many The question has many short, correct answers.
   When might it be useful to know some jokes?
   Where can you find spiders?

Exactly One The question has a single possible correct answer.
   During which season do you usually wear sunglasses?
   What does it mean to be "on cloud nine"?

Several The question has a few short, correct answers.
   Name three animals that hatch from eggs.
   Try to make your body into the shape of each letter in your name.

Personal The question can only be answered relative to personal experience.
   Try to name all of the people you have talked with today.
   What do elbows and knees have in common?

Open The question has many possibly long answers.
   What might happen if televisions everywhere stopped working?
   If you had a pet that could talk, what would the two of you talk about?

Debatable It is difficult to judge the correctness of the answer.
   Is it easier to swallow a pill or a spoonful of medicine?
   Is it harder to ride a bike or to run fast?

Nontextual Answer The question cannot be answered using text.
   Instead, it requires an action to be performed.
   Try to clap your hands behind your back.
   Sing part of a song you know.

Types of Knowledge Needed
Statistics on the types of knowledge needed to answer questions are shown in Table 7. The percentages sum to more than 100 because each question is annotated with one or more types of knowledge.
Mental States

Mental states.

- Why do people make New Year’s resolutions?
- If a friend lied to you, how could he or she regain your trust?

Animals

Animals.

- Why might a bear with a cub be more dangerous than a bear by itself?
- Name an animal that can walk as soon as it is born.

Lexicon

English lexicon or dictionary.

- What does it mean to be “on cloud nine”?
- What does it mean to “go the extra mile”?

Emotions

Human emotions.

- Describe how it feels to watch someone opening a gift that you gave.
- How can you tell when someone is nervous about something?

Shapes

Shapes of objects.

- Name three objects that are shaped like a triangle.
- Draw polka dots.

Sounds

Sounds.

- What noise would a dragon make?
- What kinds of shoes are noisy?

Location

Locations and places.

- Describe your favorite place to go for a walk.
- Name three jobs that involve working outdoors.

Plants

Plants.

- During which season might you rake leaves?
- What makes a salad a salad?

Food

Food and cooking.

- Think of a fruit and a vegetable that begin with the letter p. Name three foods that are purple.

Weather

Weather.

- Name three ways to have fun on a rainy day.
- Where is the safest place to be during a thunderstorm?

Letters

The alphabet and letters.

- Try to make your body into the shape of each letter in your name.
- Which letters of the alphabet can you draw using only curved lines?

Taste

Taste.

- Name three foods that might cause you to make a face when you eat them.

Smell

Smell.

- What is the best smell in spring?

Table 8: Reasoning Needed

| Reasoning Type          | % Questions | # Questions |
|-------------------------|-------------|-------------|
| Database Retrieval      | 37.70%      | 92/244      |
| Simulation              | 24.59%      | 60/244      |
| Planning                | 22.54%      | 55/244      |
| Comparison              | 18.85%      | 46/244      |
| Episodic Memory         | 9.84%       | 24/244      |
| Visualization           | 8.61%       | 21/244      |
| 3D Simulation           | 7.79%       | 19/244      |
| Invention               | 3.28%       | 8/244       |
| Arithmetic              | 1.23%       | 3/244       |

Correlation with Question Position

The correlation of various annotations with position in the BrainPlay column is given in Table 9. Only correlations with magnitude above 0.1 are shown. The Highlights editors present the BrainPlay questions in increasing order of difficulty [Myers and Myers, 1964], so these correlations give a rough idea of difficulty. High positive correlations correspond to high difficulty, whereas high negative correlations correspond to low difficulty.

BrainPlay’s Coverage of Intelligence

We can use the major sections of the fifth edition of The Cognitive Neurosciences [Gazzaniga and Mangun, 2014] as a guide to the many areas of human intelligence. A rough correspondence between these sections and BrainPlay is shown in Table 10 (“VI Memory” includes prediction and imagination.) We see that BrainPlay questions span many aspects of intelligence.

By design and intent, many of the thought-provoking children’s questions are designed to push the system into gener-
Table 9: Correlation with Question Position

| Tag                  | Correlation |
|----------------------|-------------|
| Caring               | 0.3059      |
| Planning             | 0.2599      |
| Plans/Goals          | 0.2293      |
| Interpersonal Relations | 0.1838   |
| Scripts              | 0.1396      |
| Simulation           | 0.1269      |
| Arithmetic           | 0.1263      |
| 5                    | 0.1017      |
| Properties/Attributes| -0.1005     |
| Personal Experience  | -0.1081     |
| Location             | -0.1083     |
| Plants               | -0.1308     |
| Letters              | -0.1330     |
| Database Retrieval   | -0.1413     |
| Nontextual Answer    | -0.1741     |
| Human Body           | -0.1923     |
| Action               | -0.2242     |

Table 10: Correspondence of Gazzaniga and Mangun (2014) sections and BrainPlay

| Gazzaniga/Mangun Part                          | BrainPlay                          |
|------------------------------------------------|------------------------------------|
| I Developmental and Evolutionary Cognitive Neuroscience | learning from questions           |
| II Plasticity and Learning                     | Shapes, Sounds, Smell Visualization |
| III Visual Attention                           | Action, Planning                   |
| IV Sensation and Perception                    | Episodic Memory, Facts Scripts, What-If Simulation |
| V Motor Systems and Action                     | Meaning, Lexicon                   |
| VI Memory                                      | Description                        |
| VII Language and Abstract Thought              | Emotions, Caring                   |
| VIII Social Neuroscience and Emotion           | Interpersonal Relations Theory of Mind |
| IX Consciousness                               |                                     |
| X Advances in Methodology                      |                                     |
| XI Neuroscience and Society                    |                                     |

Conclusion

Highlights BrainPlay questions can be answered by young children. If today’s artificial intelligence systems can’t even answer these questions, how can we really say that they are intelligent? We believe that building systems that can answer and learn from BrainPlay questions will increase progress in artificial intelligence.
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