Development of Concept of Transitivity in Pre-Operational Stage Children

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Abstract

Piaget's Theory gives a general overview on the cognitive development of a child from infancy to adulthood. There have been many arguments for and against the proposed timescale of cognitive learning versus the age of the child. We plan, via this work, to explore the learning capabilities of a child in pre-operational stage. The abstract concept of transitivity, which is not understood well by children of the age of 3-5 years of age, was induced in a group of children using physical analogy of a train system. It was then shown that the physical analogies (contrary to abstract ones) provide better insight and help children understand transitivity related concepts.

1 Introduction

Piaget Theory [3] has been a highly influential work on the development of children's minds. As the child matures psychologically, he/she becomes competent to undertake certain tasks, which would have been difficult to understand before. The original research implies that the development of children's thinking is not smooth. There are certain regions in the timeline of a child, during which a transition to newly found capabilities occur. Although, this has been taken to imply that before those transition periods the child will be incapable of understanding things in a given way, some researchers argue that there is more to child's development than a mapping of timescales to capabilities.

Experiments have been performed to understand the role of analogy in learning process. An interesting work done by Goswami in [1] has proved analogy as a tangible candidate for helping children in the pre-operational stage to understand transitivity. Here the story of Goldilocks and the Three Bears was used to explain the abstract concept of transitivity and then analogous problems were introduced with clear reference to the story. The results did not point to a clear success of analogy. Motivated by this approach, abstract concepts of transitivity were reduced to physical concepts in [2] and then used in similar analogous problems.

Rest of the work is organized as follows. Section 2 gives an introduction to the basics of Piaget's Theory and relevant points tackled in this project. Physical Analogy is discussed in Section 3 which is followed by the experiments proposed in Sections 3.2 and 3.3. Based on the experiment, some results are obtained in Section 4 which motivate the future work in Section 5.

2 Piaget's Theory

Deductive reasoning, which is a desired trait as a human, has transitive inference as a core pre-requisite. Transitivity is an abstract concept applicable in innumerable practical scenarios. If **A** is greater than **B**, based on some quantitative of qualitative measure, and **B** is greater than **C**, transitivity will imply that **A** is greater than **C**. Piaget's Theory [3,4] states that transitive inference based on size measure develops towards the end of Pre-Operational Stage (3-8 year old children) as shown in Figure 1. Weight and Volume requires even more time to sink in (9 to 11 years).



Figure 1: Various Stages in Piaget's Theory

Although, arranging objects in serial order based on one dimension such as length or weight is mastered at the age of 6, transitivity requires a step further which involves relating objects based on relative sizes and not absolute ones. Also, the concept of reversibility aids in inferring transitivity. For example, if \mathbf{A} is bigger than \mathbf{B} then, \mathbf{B} is smaller than \mathbf{A} . This concept comes in handy, when our mind is handling the middle sized object in the problem of transitivity.

It has been proposed in [5], that induction, analogy and deduction are performed via the same mechanism, hence providing a motivation to use analogy for deductive reasoning. Also in [6], Halford comments on the need of building up analogical understanding to promote deductive reasoning. This hypothesis has been used as the basis of the proposed experiment to induce transitive learning in children belonging to the pre-operational stage.

3 Analogy for learning

Analogy has been used before as an abstract concept by Goswami [1]. The results prompted other researchers to explore this area. In [7], Family analogy similar to Goswami has been put to use, whereas in [2, 7] an new concept of physical analogy has been used. The relations between the given objects are explicitly explained using a train system of the stronger object pulling the weaker one. The experiment is so designed that the train is visible and explained before the actual experiment to the subject in question.

Based on the discussion hypotheses is proposed which is validated against experimental results.

Hypothesis 1 : A physical analogy, such as a physical train relationship, can help children in pre-operational stage improve their performance in arenas of transitive inference.

Hypothesis 2 : A physical analogy, such as a physical train relationship, can help children in pre-operational stage improve their performance in arenas of transitive inference, even in the case of hidden objects.

3.1 Setup

There are 2 sets of peacocks with each set containing relatively different sized peacocks. One of the set belongs to the experimenter and the other to the subject which is clarified in the beginning. We also keep a set of arrows which are used to connect the 3 objects in form of a train as a part of the physical analogy experiment. The strength of the peacocks is proportional to the size and hence is used as a qualitative measure for transitivity inference. Also the peacocks aare placed in random order in form of a triangle with no spatial relation between the 2 sets of objects. Initially 2 trails are performed to get the child comfortable with the new environment and then 5 trials of the actual experiment are performed.

Experiment 1 and 2 are illustrated as a flowchart in Figure 2 and as a series of instructions in Sections 3.2 and 3.3.

3.2 Experiment 1:

Procedure (Performed in Hindi Language)

Control Group (Base-Line): These are my peacocks and those are your peacocks. We will now play a game of hiding paper. Turn around as I hide a paper



Figure 2: Series of Questions describing Experiment 1 and 2

beneath one of your objects. Now, from these 2 peacocks of my set (biggest and medium sized peacocks), this one is stronger than the other one (while pointing at the bigger peacock). From these 2 peacocks of my set (smallest and medium sized peacock) this one is stronger than the other one (while pointing at the bigger peacock).

From these 2 peacocks of your group which one is the bigger one? From these 2 peacocks of your group which one is the bigger one? Now, I will hide this paper under this peacock (explicitly showing the hiding act). Where do you think is the paper hidden in your set?

Visible Objects with arrows to depict Train analogy: These are my peacocks and those are your peacocks. We will now play a game of hiding paper. Turn around as I hide a paper beneath one of your objects. Now, from these 2 peacocks of my set (biggest and medium sized peacocks), this one is stronger than the other one (while pointing at the bigger peacock). From these

2 peacocks of my set (smallest and medium sized peacock) this one is stronger than the other one (while pointing at the bigger peacock). Look, I have now placed the arrows such that the stronger peacock is pulling the weaker one like a train. Please do the same with your set.

From these 2 peacocks of your group which one is the bigger one? From these 2 peacocks of your group which one is the bigger one? Now, I will hide this paper under this peacock (explicitly showing the hiding act). Where do you think is the paper hidden in your set?

3.3 Experiment 2:

Procedure (Performed in Hindi Language)

Control Group (Base-Line): These are my peacocks and those are your hidden peacocks. Now, from these 2 peacocks of my set (biggest and medium sized peacocks), this one is stronger than the other one (while pointing at the bigger peacock). From these 2 peacocks of my set (smallest and medium sized peacock) this one is stronger than the other one (while pointing at the bigger peacock).

From these 2 peacocks (which are hidden) of your group which one is the stronger one? From these 2 peacocks (which are hidden) of your group which one is the stronger one? Which one of the hidden peacocks is the strongest?

Hidden Objects with arrows to depict Train analogy: These are my peacocks and those are your hidden peacocks. Now, from these 2 peacocks of my set (biggest and medium sized peacocks), this one is stronger than the other one (while pointing at the bigger peacock). From these 2 peacocks of my set (smallest and medium sized peacock) this one is stronger than the other one (while pointing at the bigger peacock). Look, I have now placed the arrows such that the stronger peacock is pulling the weaker one like a train. Please do the same with your set.

From these 2 peacocks (which are hidden) of your group which one is the stronger one? From these 2 peacocks (which are hidden) of your group which one is the stronger one? Which one of the hidden peacocks is the strongest?

4 Results and Discussion

A group of 20 children from a local school, between the age of 4 to 5 years were used as subjects for this study. 10 students were used as the control group for Experiment 1 and 10 students were induced to the train-analogy experiment. After a trial of 2 rounds, 5 recorded experiments were conducted. The number of correct answers were noted down for each experiment. Some captures from the experiment are illustrated in Figure 3. For the complete video please click here

Histograms indicating the average number of correct answers for each experiment are illustrated in Figure 4. The mean for the 'control-group' case in



Experiment 1 (Control Group)

Experiment 2 (Control Group)



Experiment 1 (Train Analogy) Experiment 2 (Hidden Object + Train Analogy

Figure 3: Image Captures illustrating Experiment 1 and 2 in action

Experiment 1 is 2.1 which is significantly lower than the 'visual-objects' case which is 3.1. Clearly analogy relating the objects with a train-like structure is providing a better learning medium than plain abstract concepts.

Similar to Experiment-1, 'draw-bar + train' case performs better with a mean of 3.3 as compared to 2.2 mean for the 'control-group' case.

When compared to the experiments performed in [2], the absolute values of correct answers has increased for all experiments. But the relative improvement for the train-analogy is the same and is clearly evident. This increase in the absolute average correct values may be attributed to the change in demographics of the experiment. Also the average age of the children in our experiment was 4 years and 5 months as compared to 4 years and 1 month for the children in [2].

In Figure 5, it is clear that the percentage of wrong answers decreases after the introduction of Train-Analogy, hence further strengthening the claim on the hypothesis.

Apart from the strongly positive quantitative results, a few points are worth



Figure 4: Histograms illustrating the average correct answers for Experiment 1 and 2 $\,$



Figure 5: Pie-Charts illustrating percentage correct answers for Experiment 1 and 2 $\,$

mentioning. As the objects were randomly arranged in a triangle, some of the children got confused and pointed out answers based on same relative position in space. Also, two of the peacocks, one from each of the sets, were of the same absolute size but differed in size-rank in its own set. This caused a cer-

tain amount of confusion while choosing the hidden paper position. The train analogy seemed to dominate and hence removed the confusion of absolute size similarity and relative position in space.

5 Future Work and Conclusions

Physical analogy has proved to be effective in the understanding of the concept of transitive inference. Hence, as a follow-up analogical reasoning for deduction could be performed with 4 or more objects. Other ways of transferring concept of transitivity to real life scenarios would be helpful.

This work provides a concrete evidence on the role of physical analogy on learning concepts. Hence this can be used as a foundation while designing the style of teaching for students of age 3-5 years. Also, this provides a heuristic basis for a model of learning in humans which would act as an anchor in the field of Artificial Intelligence.

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