

Learning and Children's Theory of Gravity

Michelle Beth Bass, Danielle Beale, Lisa M. Richards, and Kathleen Schisa,
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Advised by Richard Aslin, Ph.D.

Department of Brain and Cognitive Sciences, University of Rochester

Introduction

By 24 months of age children can comprehend that during occlusion, objects exist and can be moved to hidden locations.³ The development of such spatial reasoning in young children has been explored by a number of tasks that involve novel invisible displacements. These tasks obscure an object (e.g., a ball) in a container, and the object is subsequently moved to a number of possible hiding places.

More recent research has shown that infants as young as 4 months of age have some understanding of object permanence, gravity displacement, solidity of objects, and continuity of objects in motion. This has been established by demonstrating that the infants expect an unsupported object to fall in a straight trajectory unless obstructed by a solid obstacle.⁴ However, it has also been shown that 2- and 3-year-old children cannot use knowledge about the way obstacles constrain motion to predict an object's trajectory.¹

Hood examined the spatial skills of 2 to 4 and 1/2 year olds by constructing complex invisible displacement tasks where a ball was dropped into an opaque tube that led to one of three possible hiding places.¹ However, the tubes were never arranged in a vertical orientation; therefore, the ball was never found directly below the tube's entryway. The tubes redirected the path of the ball so that the ball's final location was not the result of a straight-down trajectory due to gravity. Hood found that task performance was significantly related to tube complexity; older children solved arrangements with more tubes than younger children. He also found that the children's search errors were consistently aimed at the location directly below the location where the ball was inserted into the tube, and this pattern of response was called the "gravity error."

Subsequent studies by Hood tested children's naïve concept of gravity and confirmed that young children are inclined to believe that falling objects travel in a straight line.² However, children did not show an anti-gravity error when shown a videotape that played the event backwards (the ball appeared to move up the tube rather than down the tube). Taken together, these findings suggest that young children believe the naïve theory of gravity regarding falling objects, and this theory overrides the cues provided by the tubes that would violate the gravity bias. With age and experience, children seem to experience a progressive awareness of the way tubes restrict the

movement of a falling object.^{1,2}

The goal of the present study was twofold. The first was to investigate whether children who were allowed to watch an adult make both correct and incorrect responses on an invisible displacement task would perform better compared to children who did not receive this observational training. The children in the non-observational group simply continued to perform the search task without assistance. We predicted that performance would increase in both groups of children but that the observational group would show a greater increase in performance during the test phase. The second purpose of the study was to determine whether or not the majority of children's first-search errors were in fact gravity errors. We predicted that the majority of first-search errors would be aimed towards locations directly below the ball's entryway into the tube and could therefore be classified as gravity errors.

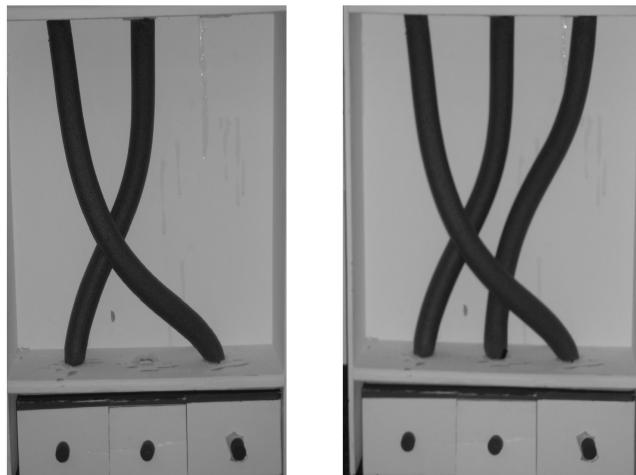


Figure 1: Apparatus configurations showing difficulty level 2 (left) and level 3 (right).

To investigate these hypotheses, we tested children between 3 and 5 years of age using Levels II and III of Hood's tube configurations (see Figure 1) and recorded the children's responses, including their specific search patterns.¹ Hood's

findings show that children 24 months of age and older are able to pass level II of the opaque tube experiment, in which there are only two alternative tube locations, but are unable to pass level III, in which there are three tube locations.¹ All children in the present experiment first had to pass level II to ensure they had the capacity to correctly retrieve the object. All subsequent testing involved level III, which has been shown to be very difficult for 2- to 4-year olds. After an initial set of test trials at level III, we randomly assigned the children to either the watch-learning group or the self-learning (control) group. Children in the watch group observed an experimenter correctly find the ball after being dropped down each of the three tubes, while children in the self group simply continued to perform an additional set of trials at level III without experimenter interference. After the learning trials, the configuration of the three tubes was changed to ensure that the children were not simply memorizing the path of the tubes. The children were then asked to perform a post-learning test phase with this new tube configuration. The measure of interest was the improvements in correct first search locations in the post-learning test trials compared to the pre-learning test trials.

Method: Participants

Thirteen children ranging in age from 36 to 59 months participated in the experiment. However, the results of four children were not included in the study; three children failed to pass Level II, and a fourth child scored perfectly on the Level III pre-test and therefore could not demonstrate a learning curve. Of the remaining nine children, there were five males with a mean age of 47.8 months ($SD=9.07$) and four females with a mean age of 52.9 months ($SD=4.77$). The participants represented a range of races and socioeconomic classes. The children were recruited at a local daycare center through written consent forms, which were distributed to parents whose children attended the daycare. There was no payment in exchange for participation in the experiment; however, children were given stickers as a reward for their participation regardless of the accuracy of their responses. The children were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct."⁵

Apparatus

The apparatus, which was made out of wood and painted white, was very similar to the one used by Hood.¹ The width of the apparatus was 53.5 cm and the height was 69 cm. The height of the distance that the tubes actually traveled was 50.5 cm. The top of the frame had three holes; each hole led to the hiding box directly below. Each hiding box was 16 x 11 x 11 cm and had a circular hole in the top (Figure 1). The hiding boxes were also painted white and were insulated with padding to prevent the sound of the ball from influencing the children's responses. Each entryway was connected to a nonaligned hiding box by the length of one of the tubes. The three tubes were constructed from grey, flexible, foam tubing and were connected to a given hole by Velcro and yellow duct tape. The diameter of the tubes was approximately 2.5 cm, and the horizontal separation between the tubes was 10.5 cm. The foam material of the tubes also prevented any sound of the ball's movement from influencing the children's responses.

The plastic, colored balls (blue, red, pink, green, and orange) were 1.8 cm in diameter. The color of the ball used during the experiment was chosen according to each child's individual preference.

Design and Procedure

Each child was tested in an isolated area of his or her assigned classroom with two experimenters present. One of the experimenters performed the experiment while the other recorded the children's responses. The apparatus, child, and experimenters were seated on the floor. Prior to testing, children were allowed to play with a sample piece of tubing and one of the balls in order to become familiar with the materials and to demonstrate that the tubes were hollow. The child was never shown a vertical arrangement of the tubes. Throughout testing, experimenters were careful to use consistent, objective language with the participants to avoid any biasing of the data.

The first portion of the formal experiment tested the children on Level II of Hood's tube configurations.¹ On this trial and all subsequent trials, excluding training, either the child or the experimenter dropped the ball into one of the tubes. Once the ball had been dropped, it was out of sight until it was retrieved. After the ball had been dropped, the children searched until they found the ball in one of the hiding boxes. The pattern of each child's search behavior was recorded by an experimenter. Each child completed five trials on Level II. If they found the ball correctly (on their first try) on four or more of the five trials, they proceeded to the next level. If a child failed to find the ball correctly on four or more trials, they did not proceed to level III, and their responses were not included in the results. This is based on the established notion that children who are unable to pass Level II (the "easier" level) would subsequently be unable to pass the more complex Level III.¹

The second portion of the experiment involved Level III of Hood's tube configurations (see Figure 1).¹ There were three separate phases at Level III; a "pre-test", "training", and "test" phase. Each phase included five trials, resulting in a total of 15 trials.

Each child's search pattern was recorded by an experimenter. For the training phase, children were randomly assigned to either the "watch" or "self" group. Four children were included in the "watch" group, and five children were included in the "self" group. Children in the "watch" group completed the training phase by watching the experimenter both drop and find the ball. The accuracy with which the experimenter found the ball varied; on some occasions the ball was found on the first attempt, while on other occasions it was not. The purpose of this was to demonstrate both correct and incorrect responses to the child. If incorrect responses had not been shown, the child might have assumed that a ball could be found in any location, and the training phase would therefore be ineffective. On the other hand, children in the "self" group were instructed to both drop and find the ball themselves. Therefore, this group of children did not receive direct training from the experimenter.

For the test phase, the experimenter reconfigured the tubes to produce a mirror image of the previous configuration. This was done to make sure that the child had to reassess the change of the tubes' arrangement. The children's search patterns were recorded by a second experimenter for each of the trials.

Scoring

The observing experimenter scored each participant's responses. For each trial, the location (left, middle, or right) of the opening through which the ball was dropped and the search locations (correct, incorrect gravity, or incorrect irrelevant) were recorded. The scoring process involved comparing the individual participant's pretest trial score and test trial score. A score was given as the number of correct searches on the first attempt out of each set of five trials. Each child was then given an overall learning score that was obtained by subtracting the pre-test score from the test score. Each individual's score from the "watch" and "self" groups were then averaged together for subsequent analyses.

Results

Overall, there was no statistically significant change from the pre-test score to the test score within participants for either the "self" group ($t(4)=0.31$, $p=0.772$), the "watch" group ($t(3)=1.67$, $p=0.194$), or the groups combined ($t(8)=1.02$, $p=0.336$). A small drop in mean score was seen in both groups, with the "self" group score dropping by 1.25 ($SD=1.5$) and the "watch" group dropping by 0.4 points ($SD=2.88$). An unpaired t-test comparing these score changes shows no significant result ($t(7)=0.53$, $p=0.612$) (see Figure 2). There is also no significant correlation between age and performance with or without inclusion of the four participants eliminated from the study.

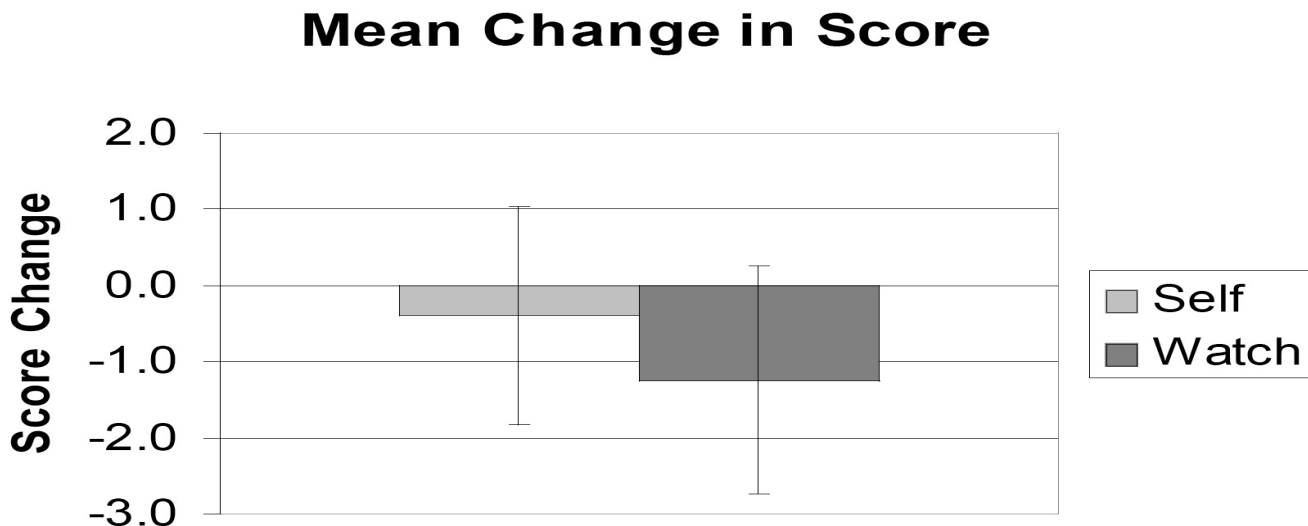
Discussion

The results of the present study indicate that 3- to 5-year-old children do not readily learn the effect of the tubes on the ball's trajectory within 20 trials. Since there was no significant difference between the pre-test and test scores, this indicates that no change occurred in the participants' ability to successfully search for the ball. However, the participants consistently searched correctly at a rate higher than chance, which shows that they do have some rudimentary understanding of the mechanism by which the tubes constrain the movement of the ball.

Since the performance of the children in the "watch" group did not differ significantly from that of the "self" group, there is no support for the hypothesis that observing the experimenter perform the task, including both correct and incorrect responses, caused an improvement in learning.

The frequency with which the search errors were made in the gravity location indicates that children are perseverating on the gravity rule. This could be due to a failure to inhibit the rule that dropped objects fall toward the ground with a straight trajectory. Once children have this knowledge, it may interfere with the acquisition of conflicting information. Children sometimes show difficulty switching rules or inhibiting information in a variety of tasks, and this may play a major role in their perseveration on the gravity error.⁶

Figure 2: Mean change in scores for the Self and Watch groups as measured by subtracting the number of correct searches on the 5 pre-test trails from the number of correct searches from the 5 test trails. Error bars represent standard deviation.



Participants searched correctly on the first attempt 50% of the time in the gravity location on 43% of trials and in the irrelevant location on 7% of trials. Of the errors made, the 86% made in the gravity location is well above the 50% chance between gravity and irrelevant location search errors. Each group showed a slight drop in the mean percentage of gravity errors from the pre-test to the test. In the "self" group, 100% of the errors made in the pre-test, and 91.67% of the errors made in the test were gravity errors. In the "watch" group, 88.89% of the pre-test errors, and 71.43% of the test errors were in the gravity location. Neither of these drops in error rates was statistically significant.

However, the fact that the participants show slight, though insignificant, declines in their overall errors and in the percentage of gravity errors may indicate that they are changing their search strategy as they gain experience. If children perceive that their initial hypothesis is wrong, they may attempt to formulate a new hypothesis or strategy. If they come to believe that the ball will not appear where they expect it to, they might change their search pattern, leading to an increase in the search errors made in the irrelevant location.

The decrease in error scores and gravity errors may also be due to the participants' mistrust of the experimenters or the apparatus. Children may have been nervous as a result of the



interaction with an unfamiliar adult and task. Also, children of this age may be suspicious of games played with adults. Some adults tend to employ deception when playing with children to confuse or surprise them; so, any children exposed to this phenomenon outside of the experiment may have believed that the experimenters were tricking them.¹ This belief could have been intensified in any children who made errors in the pre-test, since they might have formed the belief that their search strategy was incorrect without understanding why and so attributed that to deception on the part of the experimenter.

It is also possible that children were distracted, bored, or lost interest in the study over the training and testing session. This would account for low scores overall, but loss of interest would strongly affect the final test scores and the change from pre-test. The fact that other children were engaged in activities throughout the classroom may have been very distracting to the study participants, especially if they were not motivated to attend to the task.

It is not likely that participants' persistent low scores were due solely to the difficulty of the task. The difficulty level was designed to be challenging, but not impossible for this age group. Prior research has shown that children are able to pass this level of task difficulty (Level III) at approximately 44 months of age.¹ Since the mean age of participants in this study was 53 months, this indicates that factors other than task difficulty confounded the children's performance.

Engaging the children in the task with familiar, trusted adults as experimenters and performing the study in a less distracting environment would help to clarify the results of this study. We are currently expanding our sample size to further investigate the correlation between age and performance, and at what age children are typically able to learn the role the tubes play in the constraint of object movement. It is clear, however, that children approaching 5 years of age may still persist in making errors that are consistent with the gravity rule that objects fall in a straight trajectory. Knowing how children form this rule and how they learn variations or subsets of this rule would allow for a more complete understanding of human cognitive development.

References

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