

# Exploring the Role of Theory of Mind and Executive Functions in Preschool Children's Hypothesis Testing and Revision

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**Abstract:** A major goal of preschool science instruction is to foster children's scientific reasoning skills. This study explores the influence of children's theory of mind and executive function capacities on their ability to engage in hypothesis testing and revision. Results indicate that preschoolers are capable of engaging in basic hypothesis testing and revision on a physical science task, and theory of mind capacities may be related to children's performance. Implications for early science instruction are discussed.

## Issues Addressed and Potential Significance

There has been an increased focus on incorporating science instruction in U.S. preschool classrooms. A major goal of early science instruction is to aid preschoolers' development of scientific reasoning skills. Research indicates that young children's ability to test and revise hypotheses may depend on their executive function (EF) capacities (i.e., Gropen, Clark-Ciarelli, Hoisington & Ehrlich, 2011). Further, theory of mind (ToM) abilities may also play a role in scientific thinking (Kuhn & Pearsall, 2000). It is around the age of 4 years that children are able to think about beliefs as distinct from reality, and 3-year-olds are unlikely to reconcile inconsistencies between a preliminary belief and a later observation that falsifies it, while older children show less difficulty doing so (Gopnik & Astington, 1988). Thus, it is possible that EF and ToM capacities underlie young children's abilities to confirm and revise hypotheses. This study examines the relationships among preschool children's EF and ToM capacities and their ability to engage in hypothesis revision, a key scientific practice. Further, as research indicates that preschoolers can revise their originally mistaken scientific beliefs when given opportunities to reflect (i.e., Kloos & Van Orden, 2005), this study also explores whether the use of an instructional tool to scaffold children's hypothesis testing and revision (by facilitating children's reflection on their scientific investigations) leads to improved performance on scientific reasoning tasks in physical science. We hypothesized that use of the instructional tool would foster more accurate hypothesis revision by supporting children's reflection on the differences between their predictions and observed outcomes, and further, that this tool would be most beneficial for children with lower EF and ToM capacities. This work is significant in that it provides a foundation for creating developmentally-appropriate, early science educational experiences.

## Methods

Participants were 36 children (17 female) from a central, NJ public preschool (mean age= 53.6 months; range= 43-65). Children were predominantly middle-class and Caucasian. In a corner of their classroom, children were interviewed individually and were asked questions about the movement of objects on an inclined plane of adjustable height. Children were first pretested using a Dimensional Change Card Sort (DCCS) task and three standard theory of mind tasks. The DCCS task examines children's ability to sort objects based on two different dimensions (color and shape). The theory of mind tasks involve presenting a deceptive item to children (a crayon box that contained Band-Aids) and posing questions about the item. Pretest scores were used to create equivalent groups for the experimental and control conditions, controlling for age and gender across groups.

Materials included an inclined plane, six objects made from TinkerToys, a chart for recording predictions and observations, cards for marking predictions and observations on chart, and blue masking tape. Before the experimental task, children in the experimental condition engaged in a brief training session aimed at familiarizing children with using the prediction and observation charts. Immediately after the training session, children in the experimental condition began the test phase. Phase I involved predicting whether various objects would roll or slide down the inclined plane. For each object, the child made a prediction, recorded the prediction using the chart, tested the object on the inclined plane, verbally stated the observed outcome, and recorded the outcome on the chart. The child was then asked to use the chart to determine whether or not the original hypothesis needed to be revised. The child engaged in this hypothesis testing and possible revision two times consecutively for each of the six objects, presented in random order. Phase II involved the same procedure as Phase I, except children were asked to predict whether each object would pass over a piece of blue tape affixed to the floor approximately 18 inches from the bottom of the inclined plane. Children in the control group engaged in the same manipulations for Phase I and Phase II above, except they did not utilize the chart or image cards to record their predictions or observations. Rather, they were asked to verbally state predictions, observed outcomes, and whether the original prediction needed to be revised.

## Preliminary Findings

Children scored reliably above chance on both the ToM and DCCS tasks. The DCCS mean score was 13.33/14 (1-sample t-test [2-tailed]:  $t=31.793$ ,  $p<.001$ ), and the ToM mean score was 1.86/3 (1-sample t-test [2-tailed]:  $t=2.255$ ,  $p=.03$ ). Under the strict criterion of 3/3 points, 12 children passed the ToM task and 24 did not pass. Scores were near ceiling on the DCCS task. Phase I and Phase II scores were significantly correlated ( $r=.524$ ,  $p=.001$ ). For the remainder of analyses, Phase I and Phase II scores were combined to form a Total Score for each participant out of a possible of 120 points. The combined Total Score was correlated with the ToM scores ( $r=.518$ ,  $p=.002$ ) and with DCCS scores ( $r=.355$ ,  $p=.039$ ).

Children scored reliably above chance on the experimental task, with a mean Total Score of 112.56/120 (1-sample t-test [2-tailed]:  $t=40.258$ ,  $p<.001$ ). Children in the experimental condition performed as well as children in the control condition. The mean Total Score for children in the experimental group was 114/120, and the mean for the control condition was 111.12/120. Performing a median split by age illustrated that children in the older age group (mean= 60 months; range=54-65) scored reliably higher than children in the younger age group (mean= 47.35 months; range= 43-53), regardless of experimental condition. The mean Total Score for the older children was 116/120 and the mean the younger children was 109.12/120. A one-way analysis of variance indicated that this difference was significant ( $F= 8.534$ ,  $p=.006$ ).

High performance and ceiling effects on the DCCS and the experimental tasks made it difficult to determine whether pretest scores were associated with performance on the experimental tasks. A multiple regression analysis was used to test whether experimental condition, age group, ToM score and DCCS score significantly predicted children's Total Score. The results of the regression indicated that the model significantly predicted Total Score and explained 37.7% of the variance ( $F(4,29)= 4.389$ ,  $p=.007$ ,  $R^2 = .337$ ). ToM score significantly predicted Total Score ( $b =.356$ ,  $p=.041$ ). No other predictors in the model were significant.

The mean Total Score for the 12 children who passed the ToM pretest was 118.5/120; the mean Total Score for the 22 children who did not pass the ToM was 109.32/120. A one-way analysis of variance found that this difference in group means was significant:  $F=16.654$ ,  $p<.001$ . Thus, children who passed the ToM tasks scored reliably higher on the hypothesis testing and revision tasks than children who did not pass the ToM tasks. Among the 12 children who passed the ToM pretest, 7 were in the experimental condition and 5 were in the control condition. The mean Total Score for the 7 children in the experimental condition who passed the ToM pretest was 119.29/120. The mean total score for the 5 children in the control condition who passed the ToM pretest was 117.4/120. Among the 22 children who did not pass the ToM pretest, 10 were in the experimental condition, with a mean Total Score of 110.3, and 12 were in the control condition, with a mean Total Score of 108.5. Thus, although there was a trend for children who utilized the prediction and observation reflection charts to perform better than those who did not use the charts when examining groups based on passing/failing the ToM tasks, small n's result in unreliable differences between these groups.

## Conclusions and Implications

This study illustrates that preschool children are capable of engaging in the key scientific practices of basic hypothesis testing and revision on a physical science task, and these abilities increase with age. Further, although the role of EF capacity on children's hypothesis testing and revision abilities remains unresolved, findings provide evidence that ToM capacities may be related to these scientific skills. More work is needed to determine the role of prediction and observation reflection charts in supporting children's hypothesis revision capacities. Relevant implications for preschool education include that children can benefit from instruction designed to help them develop ToM and EF capabilities, and to apply these capacities to learning in scientific domains. Further, children can benefit from educational experiences that involve hypothesis testing and revision as children explore with objects and materials, as well as those which encourage reflection on scientific observations and investigations. Future work is planned to further explore these questions with a larger sample including younger children as well as participants of diverse cultural and socio-economic backgrounds.

## References

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