A developmental psychology perspective on preschool science learning: Children's exploratory play, naïve theories, and causal learning

van Schijndel, T.J.P.

Publication date
2012

CHAPTER 7

Parent explanation and preschoolers' exploratory behavior and learning in a shadow exhibition

Van Schijndel, T. J. P., & Raijmakers, M. E. J. *Parent explanation and preschoolers' exploratory behavior and learning in a shadow exhibition.* Manuscript submitted for publication.

ABSTRACT

This study focuses on preschoolers' science learning in a shadow exhibition in science center NEMO, The Netherlands. It investigates, in an explorative manner, relations between parent explanation, children's' exploratory behavior, and learning. In addition, the effect of a theater show on parent and child variables is examined. Parent explanation is coded in a number of domain-general categories, such as causal explanations, evidence descriptions, and content-related directions (e.g. Crowley, Callanan, Jipson et al., 2001). Preschoolers' behavior and learning are quantified by using nonverbal measures. The Exploratory Behavior Scale (e.g. Van Schijndel, Franse & Raijmakers, 2010 / Chapter 3) is used to assess the extent to which children explored their physical environment. Children's learning is assessed in the knowledge domain of shadow size. Results show a positive relation between one type of parent explanation, evidence descriptions, and preschoolers' exploratory behavior. No positive relations between children's exploration and learning, or between parent explanation and children's learning were found. Last, theater attendance was found to affect children's learning on shadow size.

INTRODUCTION

The last decade preschoolers have become a more visible group in science museums. Museums have started offering activities for preschoolers and many museums nowadays have areas or exhibitions that have been designed for the preschooler age group. In spite of this trend, the preschooler group is still underrepresented in visitor research. Few studies have been performed that specifically address preschoolers' behavior and learning during museum visits, or parental guidance of preschoolers' visits. Studies investigating family science learning have often adopted a sociocultural perspective (e.g. Callanan & Valle, 2008; Rogoff, 1995), taking the group as unit of analysis and therefore not distinguishing between adults and children, or older and younger children (e.g. Allen, 2002; Szechter & Carey, 2009; Zimmerman, Reeve & Bell, 2009). This research has yielded important insights into the processes of meaning making taking place in museum settings, but does not give a detailed view of young children's informal science leaning. Preschoolers' behavior and learning in museums differs from that of older children. As their verbal capacities are still in development, preschoolers' talk may not reflect their reasoning or learning. This observation stands in contrast with the focus on conversations in many family learning studies (e.g. Ash, 2003; Allen, 2002; Zimmerman et al., 2009). Additionally, preschoolers' informal science learning experiences differ from those of older children in terms of parental guidance. Young children's experiences are generally guided very intensively by adults, and the division of roles is different in family groups with younger children than in groups with older children. Therefore, investigating this particular group's informal science learning, more so than any other groups, asks for distinguishing between the child and parent role in order to examine the ways by which parents guide the learning process (Schauble et al., 2002). The present study addresses these issues from a constructivist perspective (e.g. Gopnik & Meltzoff, 1997; Inhelder & Piaget, 1964; Wellman & Gelman, 1992). It focuses on preschoolers' science learning experiences in a shadow exhibition in science center NEMO, The Netherlands. Children's exploratory behavior and learning are assessed by quantitative measures that do not rely on their verbal capacities. Mainly, the study examines relation between children's behavior, learning, and parental guidance.

Parent explanation & preschoolers' exploratory behavior

Exploratory behavior is at the core of young children's science learning: preschool science programs emphasize the learning of skills that comprise exploration (e.g. French, 2004; Gelman & Brenneman, 2004), and science museums see meaningful, minds-on interactive behavior as indispensable to visitors' experience (Allen, 2002, 2004). Visitors' exploratory behavior in museum settings has been measured by using detailed, domain-specific measures (e.g. Crowley, Callanan, Jipson et al., 2001; Meisner et al., 2007), but more often by using global, domain-general measures (e.g. Boisvert & Slez, 1994, 1995; McManus, 1987). A limited set of studies have investigated the influence of adult presence, and adult interaction styles on preschoolers' exploratory behavior at exhibits (Crowley, Callanan, Jipson et al., 2001; Van Schijndel, Franse & Raijmakers, 2010 / Chapter 3). For example, Crowley, Callanan, Jipson et al. (2001) found that young children who explored the zoetrope exhibit with their parents did this longer and on a deeper level than children who explored the exhibit by themselves. However, as parent interaction styles consist of a wide range of verbal and nonverbal behaviors, more detailed study is required to understand what specific aspects of parental guidance benefit children's exploratory behavior in museum settings.

One way in which parents guide children's visits is by giving explanations. It has been shown that parents differ in the amount and type of explaining they do in museum settings, and these differences have been related to child characteristics, such as gender and prior knowledge, and parent characteristics, such as attitude towards science, and educational level (Crowley, Callanan, Tenenbaum, Allen, 2001; Palmquist & Crowley, 2007; Siegel, Esterly, Callanan, Wright & Navarro, 2007; Szechter & Carey, 2009). Few studies have connected parent explanation to children's exploratory behavior in museum settings. Fender and Crowley (2007) investigated the relation between one type of explanation, causal explanations, and young children's exploratory behavior. Causal explanations were defined as establishing causal relations or making connections between the exhibit and prior knowledge. In line with their hypothesis that this type of explanation does not provide children with procedural assistance, they did not find differences in exploratory behavior between children whose parents did and children whose parents did not give this type of explanation. Besides causal explanations, several other domain-general types of explanation have been distinguished in visitor research, prominent types being: open and closed questions, evidence descriptions, and content-related directions (Crowley, Callanan, Jipson et al., 2001; Crowley, Callanan, Tenenbaum et al., 2001; Fender & Crowley, 2007; Szechter & Carey, 2009; Zimmerman et al., 2009). To our knowledge, no studies have addressed relations between these types of explanation and preschoolers' exploratory behavior in museum settings. As investigating these relations could contribute to uncovering the mechanisms through which adults can optimally guide children's exploration, the first research question of the present study concerns these relations.

Preschoolers' exploratory behavior, parent explanation, & preschoolers' learning

A not uncommon assumption in visitor research, which is related to the sociocultural perspective (e.g. Callanan & Valle, 2008; Rogoff, 1995), is that behaviors, such as children's exploratory behavior and parents' explanation, indicate the occurrence of learning (Schauble et al., 2002; Serrell, 1998). Schauble et al. (2002) argue that visitor research on learning should go beyond investigating domain-general behaviors, and focus more on domain-specific behaviors, and understanding. The authors consider examining children's understanding and learning in specific knowledge domains a first step in improving adult guidance of children's informal science learning (Schauble et al., 2002). In line with this recommendation, the present study investigates preschoolers' informal learning in the domain of shadow size. Specifically, the second aim of this study is to examine the relations between preschoolers' learning, and children's exploratory behavior and parent explanation as assessed by domain-general measures.

Little research in museum settings has addressed the relation between young children's exploratory behavior and learning, but a number of studies on children's causal learning in more controlled settings have (Bonawitz, Van Schijndel, Friel & Schulz, 2012; Gweon & Schulz, 2008; Schulz, Gopnik & Glymour, 2007; Van Schijndel, Visser, Van Bers & Raijmakers, 2012 / Chapter 6). In these studies preschoolers' exploratory behavior was quantified by determining whether children, during free play, generated specific instances of evidence that could support learning. For example, Schulz, et al. (2007) studied preschoolers' learning of the causal structure of different gear toys. They found that half of the children working alone, but the large majority of children working in pairs generated evidence supporting learning. Depending on the complexity of the causal structure to be learned, 39 to 90% of the children that generated the evidence learned the correct structure. In a second study, Gweon and Schulz (2008) found that less than half of the preschoolers who were shown ambiguous evidence of a causal relation generated disambiguating evidence during exploration. 92% of the children who generated the evidence learned the correct causal relation, compared to 21% of the children who did not generate the evidence. These results suggest that preschoolers' patterns of exploration are related to their learning in these controlled settings. This study will investigate whether this relation also holds in a museum setting.

Besides by their own exploration, children's learning could also be affected by parent explanation (Gelman, 2009). Fender & Crowley (2007) investigated how one type of parent explanation, causal explanation, changes young children's learning in a museum setting. They found causal explanation to affect children's conceptual understanding: children whose parents gave causal explanations were more likely to encode experience with a zoetrope exhibit as being about animation than children whose parents did not give causal explanations (Fender & Crowley, 2007). However, no relation between parents' causal explanations and children's mechanistic or procedural understanding was found. This study will further examine the relation between parent explanation and young children's learning in a museum setting. Besides causal explanations, the study will also look at other types of domain-general explanation: open and closed questions, causal explanations, evidence descriptions, and content-related directions.

Present study

This study was performed in the Young explorers in NEMO exhibition (see Figure 1A): an exhibition specifically developed for the preschool age group. The exhibition consists of a theater show and an interactive exhibition space illustrating a number of physical principles related to shadows (see Method). In the study, child-parent teams participated in a pre-exhibition-, an exhibition-, and a post-exhibition phase.

In the pre-exhibition phase, the child's knowledge was assessed in the domain of shadow size (pre-task). This domain was chosen because the relation between the size of an object (size dimension), the distance of an object to the light source (distance dimension), and the size of the shadow, was the physical principle that was most prominent in the exhibition.[1] Further, several studies have investigated preschoolers' naïve theories in this domain (e.g. Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981; Van Schijndel et al., 2012 / Chapter 6), and these studies have come up with methodologies for assessing children's naïve theories in a reliable, nonverbal manner (see Method). These studies have uncovered several theories, or rules, that are common in the preschool age group: Rule 1, Rule 2-reversed and Rule 2 (Siegler, 1981, Van Schijndel et al., 2012 / Chapter 6). Children using Rule 1 understand that larger objects have larger shadows, but do not take into account the distance dimension in determining shadow size. Children using Rule 2-reversed understand that larger objects have larger shadows, and in addition consider the distance dimension if the object sizes are equal. However, they think that objects closer to the light source have smaller shadows than objects further away from the light source. Children using Rule 2 take into account both dimensions in the right direction. They understand that larger objects have larger shadows, and that objects closer to the light source have larger shadows. In this study, besides a group of children giving incoherent responses, we expected to find groups of children applying each one of these rules.

In the exhibition phase, child-parent teams visited the Young explorers in NEMO exhibition. As the use of a theater show as part of an exhibition was relatively new for the science center, this study had the sub-goal of investigating the effects of theater attendance on children and parents. We expected the theater show to affect parent explanation, and possibly children's behavior and learning. This expectation was based on the finding that parents' perceived lack of knowledge on science subjects affects their involvement in children's exploration (Schauble et al., 2002), and that one of the aims of the theater show was to remove this barrier by refreshing parents' knowledge on the shadow principles. To investigate this effect, half of the child-parent teams were assigned to the theater condition, and half the teams were assigned to the no-theater condition. Independent of their condition, all child-parent teams (subsequently) visited the exhibition space. During this visit, children's exploratory behavior was measured by means of the Exploratory Behavior Scale (Van Schijndel, Franse et al., 2010 / Chapter 3; Van Schijndel, Singer, Van der Maas & Raijmakers, 2010 / Chapter 2). This scale has the advantage of being domain-general and applicable in different settings, while at the same time being a relatively detailed measure that can be used to assess the quality of preschoolers' behavior (see Method). In addition, parent explanation was recorded. Due to time constraints one exhibit was selected for transcribing and coding of parent explanation: The Shadow Painting (see Figure 1B). The selection was based on the fact that the child-parent teams had interacted longest with this exhibit (see Results).

In the post-exhibition phase, the child's knowledge on shadow size was measured for the second time (post-task). Learning was defined by the use of a more advanced rule, or theory after visiting the exhibition compared to before.

METHOD

Participants

The final sample consisted of 89 teams. 97% of the children were accompanied by a parent so the teams are referred to as child-parent teams. Children were 31 4-year-olds (*M*=53.65 months, *SD*=4.19, 22 boys and 9 girls), 36 5-year-olds (*M*=65.56 months, *SD*=3.56, 18 boys and 18 girls) and 22 6-year-olds (*M*=75.73 months, *SD*=3.96, 11 boys and 11 girls). Adults had a mean age of 39.35 years (range=30-71, *SD*=5.46, 28 males and 61 females) and educational levels were relatively high: 79% had minimally a bachelor's degree (41% bachelor's degree, 38% master's or postdoctoral degree), 20% had a vocational degree or high school diploma (18% intermediate vocational degree or higher level high school diploma, 2% lower level vocational degree or lower level high school diploma), and from one adult the educational level was missing. Although most child-parent teams were from White, middle-class backgrounds, a range of ethnicities reflecting the diversity of the population was represented. Besides the 89 child-parent teams in the final sample, six other teams were recruited, but not included in the analyses: three teams were excluded because an error was made in administering

A. Young explorers in NEMO: theater show (left picture) and exhibition space (middle and right pictures)

B. Young explorers in NEMO: Shadow Painting exhibit

At the Shadow Painting exhibit child-parent teams are encouraged to create their own painting or to copy one of the paintings on the exhibit label. The teams have a collection of figures at their disposal, differing in shape (house, tree, rabbit, etc.), size, color, and transparency. The figures can be put in the exhibit at different distances from the light source. When a figure is put in the exhibit, the shadow appears on the two-sided screen. The exhibit is designed for child-parent teams to investigate two physical principles related to shadows. The first principle is that an object can have shadows of different sizes dependent on its distance to the light source. For example, the teams are encouraged to investigate this principle by a painting on the exhibit label containing two equally big rabbits, while the actual rabbit figures that they have at their disposal are of different sizes. The second principle is that a colored object can have a black or a colored "shadow" dependent on its transparency. For example, the teams are encouraged to investigate this principle by a painting on the exhibit label that contains a black house and a green tree, while the teams have both green transparent and green opaque tree figures and red transparent and red opaque house figures at their disposal.

FIGURE 1. Young explorers in NEMO exhibition. Photography: DigiDaan.

the shadow task to the child, and three teams were excluded because no complete audio-recordings of parent explanation were available.

Child-parent teams were randomly assigned to one of two theater attendance conditions stratified on the basis of children's age and children's and parents' gender. The resulting theater group (N=43 teams, children: *M*=64.00 months, *SD*=9.35, 22 boys and 21 girls, parents: *M*=38.84 years, *SD*=6.25, 13 males and 30 females) and no-theater group (N=46 teams, children: *M*=63.85 months, *SD*=9.50, 29 boys and 17 girls, parents: *M*=39.83 years, *SD*=4.61, 15 males and 31 females) did not differ in children's or parents' age, or distribution of children's or parents' gender.

Materials

Shadow task. To assess preschoolers' learning the shadow task (Inhelder & Piaget, 1958; Siegler, 1978, 1981) was used in a pre-test post-test design. The apparatus for the shadow task, the shadow machine, consists of two light sources, a screen placed on 50 cm from the light sources and puppets that can be placed in between the light sources and screen (see Figure 2). When a button is pressed the lights are activated and shadows of the puppets are portrayed on the screen. There are puppets of two sizes: two small ones measuring 5 x 2.25 cm and two large ones measuring 10 x 3 cm. The puppets could be placed at three distances from the light sources: 10, 20 and 30 cm. For each item the test leader puts two puppets in place and says: "I put this puppet here and this puppet here. When I make the shadows, which one will be the biggest? This one (pointing to the left side of the screen), this one (pointing to the right side of the screen) or will they be the same?" Different item types can be constructed, such as size items in which the size of the puppets is varied, but the distance from the puppets to the light sources is kept constant, and distance items in which the distance from the puppets to the light sources is varied, but the size of the puppets is kept constant (Siegler, 1981). In the task relative shadow size depends on both the size of the object and the distance from the object to the light source.[1]

For the pre-task the test leader introduced the task by demonstrating the shadow machine's working: she put two equally sized puppets at equal distances from the light sources, made the shadows and labeled them as "the same". She then administered the child 12 items, six size items and six distance items, in a fixed semi-random order. For the post-task the child was administered another six size items and six distance items in a fixed semi-random order. As a maximum of six size items could be constructed with the task, the size items were repetitions of items that had been administered during the pre-task. The distance items had not been used before. Importantly, during item administration children did not see shadows and therefore did not get any feedback. Responses were scored trichotomously: correct, incorrect, or incorrect "the same". The analysis of children's response patterns on the pre- and post-task is explained in the Statistical approach section.

FIGURE 2. The shadow task. During test administration for the study described in this paper, no other children were present. Photography: Hanne Nijhuis.

Exploratory Behavior Scale. To assess preschoolers' exploratory behavior the Exploratory Behavior Scale (EBS) was used (for an extended description of the scale see Van Schijndel, Franse et al., 2010 / Chapter 3; Van Schijndel, Singer et al., 2010 / Chapter 2). The EBS is a quantitative measure of young children's interactivity. More specifically, the EBS is developed from the psychological literature on exploration and play (e.g. Dunn, Kontos & Potter, 1996; Forman & Kuschner, 2005; Lindahl & Pramling Samuelsson, 2002; Rubenstein & Howes, 1979; Smilansky, 1968; Weisler & McCall, 1976), and measures the extent to which preschoolers explore their physical environment. Compared to more global measures of visitor behavior, such as holding times or interaction times (e.g. Boisvert & Slez, 1994, 1995; McManus, 1987), the EBS adds information about the quality of the hands-on behavior. Compared to more detailed measures of visitor behavior (e.g. Crowley, Callanan, Jipson et al., 2001; Meisner et al., 2007) the EBS has the advantage of being applicable in different museum settings. In addition, the EBS allows for quantification of unanticipated behavior. The scale consists of three levels of increasingly extensive exploration: (1) passive contact, (2) active manipulation, and (3) exploratory behavior. At the third and highest level of exploratory behavior, the child demonstrates a compound of behaviors that can be compared to scientific reasoning in action: sustained attention, manipulation, and repetition with variation. Table 1 gives brief descriptions of the three EBS levels plus examples of children's behavior at each of these levels at the Shadow Painting exhibit.

In this study, a trained test leader followed the child-parent team at a distance while they visited the exhibition space. She noted for each 30-second time interval the exhibit that the team interacted with, plus the highest EBS level that the child demonstrated within the interval. The Inter-observer reliability was determined by scoring the exploratory behavior of 18 children (20%) double. The reliability was shown to be sufficient: percentage agreement=83 and kappa=.69.

Explanation categories. To measure parent explanation, parents' utterances at the Shadow Painting exhibit were transcribed and coded in line with previous work on this topic (Crowley, Callanan, Jipson et al., 2001; Crowley, Callanan, Tenenbaum, et al., 2001; Fender & Crowley, 2007; Szechter & Carey, 2009; Zimmerman et al., 2009). Each utterance was assigned to one of seven mutually exclusive explanation categories: open question, closed question, explanation, evidence description, content-related direction, navigation-related direction, and affective talk. Table 2 gives brief descriptions of the explanation categories plus examples of parents' utterances in each of the categories at the Shadow Painting exhibit. Unclear utterances that could not be transcribed properly and unfinished utterances that could not be assigned to one of the seven categories were assigned to a rest category: other talk. The Inter-observer reliability was determined by scoring the explanation of 19 parents (21%) double. The reliability was shown to be sufficient: percentage agreement=82 and kappa=.77.

TABLE 1. Levels of the Exploratory Behavior Scale (EBS) and examples of children's behavior at each of these levels at the Shadow Painting exhibit (see Figure 1B).

Exploratory Behavior Scale (EBS):

1. Passive contact: A child walks, stands, sits or leans on something and may hold or transport an object. However, the child does not manipulate the object in an active and attentive manner.

- *A girl stands at the exhibit, she holds an object and watches other children play.*
- *A boy walks around the exhibit with his father, they discuss different parts of the exhibit.*

2. Active manipulation: A child manipulates an object in an active and attentive manner. This implies that the child pays attention to his or her action(s) and the outcome(s) of the action(s).

- *A girl puts a one or multiple figures in the exhibit and watches the shadow(s).*
- *A boy plays with a figure, for example he lets the rabbit-figure walk on the exhibit.*

3. Exploratory behavior: A child manipulates an object in an active and attentive manner (as Active manipulation). In addition, the child applies repetition and variation to his or her actions. "Repetition" implies that the child repeats an action (several times). "Variation" implies that the child performs different actions with one object or performs the same action with different objects. Actions that clearly differ in degree are also considered different actions.

- *A girl puts a figure in the exhibit, she watches the shadow, moves the figure closer to the light source and watches the shadow again.*
- *A boy puts a non-transparent figure in the exhibit, he watches the shadow, replaces the figure with a transparent one and watches the shadow again.*
- *A girl puts a figure in the exhibit, she watches the shadow, walks around the exhibit, and watches the shadow from the other side of the screen.*

Note. In the descriptions of all levels of the EBS an object is defined as any part of a child's physical environment.

TABLE 2. Explanation categories and examples of parents' utterances for each of these categories at the Shadow Painting exhibit (see Figure 1B).

Explanation categories:

1. Open question: Question which cannot be answered with "yes/ no", often starting with "What/ Why/ How".

- *What do you need to make this one [paining]?*
- *Why isn't that one [shadow] green?*
- *How can we make the house bigger?*

2. Closed question: Question which can be answered with "yes/ no", or question with a limited number of answering options.

- *Do you have more of those [figures]?*
- *Which shadow is bigger?*
- *Which one [shadow] is light and which one [shadow] is dark?*

3. Causal explanation: Talk establishing causal relations, or talk that makes a connection between the exhibit and children‟s prior knowledge or experience.

- *If you put it [figure] closer to the light, it [shadow] gets really big.*
- *If you can look through it [figure], you'll see a color.*
- *Did you ever see a rabbit that has the same size as a tree?*

4. Evidence description: Talk about exhibit features and observations.

- *This is the one [figure] with the colored glass.*
- *That one [shadow] is smaller than the car [shadow].*
- *They [shadows] are the same size now.*

5. Content-related direction: Talk about exhibit use.

- *Go ahead and look for the figures.*
- *Yes, put it [figure] over here.*
- *Then put it [figure] a bit more to the back.*

6. Navigation-related direction: Talk about exhibition-navigation.

- *We can go to something else.*
- *That girl is also playing.*
- *We can do this later if these people are done.*

7. Affective talk: Talk expressing emotions.

- *What a beautiful painting!*
- *That is silly.*
- *That is funny.*

Young explorers in NEMO exhibition

January 2010 science center NEMO (Amsterdam, The Netherlands) opened Young explorers in NEMO: an exhibition specifically developed for the preschool age group. The exhibition is the result of an ongoing collaboration between NEMO's Science Learning Center and the section Developmental Psychology of the University of Amsterdam. The exhibition is located in a separate area of the science center, and consists of a one-hour session in which visitors first attend a theater show (15 minutes) and then visit an exhibition space (maximally 45 minutes). Both the theater show and exhibition space are developed around the theme of shadows. The theater show is a combination of shadow play, mime play and a brief discussion with an explainer, and the exhibition space consists of five sets of interactive exhibits (see Figure 1A for an impression of the theater show and exhibition space and 1B for the Shadow Painting exhibit). Before developing the exhibition, a literature study was performed resulting in a report with guidelines for developing science activities for preschoolers (Franse, Van Schijndel & Raijmakers, 2010). Based on the report, three main points of departure for the development of the exhibition were determined: to offer explicit science content, to encourage meaningful exploration, and to stimulate parents to guide children's learning process.

First, the exhibition aims at offering preschoolers science content. Specifically, it illustrates a number of physical principles related to shadows. The principle most relevant to this study is that an object can have shadows of different sizes dependent on its distance to the light source. Other illustrated principles are that a 3D-object can have different shadows dependent on its orientation, that an object can have different shadows dependent on the surface on which the shadow is projected, and that a colored object can have a black or a colored "shadow" dependent on its transparency. The theater show briefly touches these principles, and the exhibition space covers each of these principles by one or more sets of exhibits.

Second, the exhibition focuses on stimulating visitors to engage in active exploration. Not just hands-on behavior, but meaningful, minds-on interactive behavior is encouraged. The emphasis is laid on children's practice of process skills: to question, predict, test, observe, and draw conclusions. To this end, the exhibition space contains interactive exhibits, some of which, for example, are explicitly designed for prediction to precede testing.

Third, the exhibition focuses on parental guidance of preschoolers' exploration. Child and parent can only enter the exhibition together, and they are addressed as a team by the explainer and by the exhibit labels. The theater show aims at refreshing parents' knowledge in order to optimize parental guidance of children's exploration (see Introduction). Last, the exhibition space contains several exhibits that are explicitly designed for child and parent to engage with together.

Procedure

The study was performed in six consecutive weekends in the spring of 2010. That year science center NEMO offered eight Young explorers in NEMO sessions per weekend: two on Fridays and three on Saturdays and Sundays. Each session had a capacity of nine child-parent teams, and during the period of the study two of the nine spots were reserved for the study's participants. Participants were recruited by flyers distributed on schools, by a mailing to parents who had previously participated with their children in infant research, and by the Young explorers in NEMO website. When parents signed up on the website, they were contacted to schedule a date and time for their participation. Participating child-parent teams received free entrance to the science center on the day of their participation.

Participation took one-and-a-half to two hours, and consisted of a pre-exhibition, exhibition, and post-exhibition phase. A team of trained test leaders guided child-parent teams through participation. Upon entry in the science center, the team was welcomed in an office space. The parent was talked through the features of the study, received a voice recorder, and was asked to sign a consent form and fill out a short background questionnaire. The child was administered the pre-task. The child-parent team then visited the exhibition, together with regular visitors who did not participate in the study. The teams in the theater condition attended the theater show, the teams in the no-theater condition did not. All teams (subsequently) visited the exhibition space. Before entering the space, the test leader activated the parent's voice recorder in synchrony with her stopwatch. Next, children's exploratory play was assessed and parent explanation was recorded (see Materials). The team's visit ended when parents indicated that they were done, or when 45 minutes had passed and the exhibition space was closed for visitors. Last, the child-parent team was asked to take a seat in a secluded area of the (closed) exhibition space. In this phase the child was administered the post-task.

Statistical approach for assessing learning

Siegler (1976, 1981) developed the Rule Assessment Methodology (RAM) to detect the different naïve theories children demonstrate on the shadow task. Siegler first defined possible naïve theories, or rules, on shadow size (see Introduction). He then constructed different item types (see Materials), and defined expected responses for these item types for children having different rules. For example, children using Rule 1 are expected to answer size items correctly, but to say "the same" on distance items. Children using Rule 2-reversed are expected to answer size items correctly, but to give the incorrect answer on distance items. Children using Rule 2 are expected to answer both size- and distance items correctly. By matching observed to expected response patterns on a series of items, Siegler assigned children to the different rules. In this study we used Siegler's Rule Assessment Methodology, but we replaced pattern matching by an advanced statistical technique: Latent Class Analysis

(LCA; for an introduction see e.g. McCutcheon, 1987; Rindskopf, 1987). LCA provides a statistically more reliable method to detect different types of response patterns than pattern matching (see Van der Maas & Straatemeier, 2008 for a more extended discussion). An important advantage of LCA is that the technique makes it possible to detect unanticipated response patterns, or rules. This advantage was shown in research on children's naïve theories on balance and shadow size: by using LCA additional rules to those proposed by Siegler (1981) were found (Boom, Hoijtink & Kunnen, 2001; Jansen & Van der Maas, 1997; Van Schijndel et al., 2012 / Chapter 6).

For the pre- and post-task separately, exploratory LCA was used to determine which latent class model described the data, preschoolers' trichotomous response patterns to the series of items, in the best and most parsimonious manner. Latent class models consist of a number of latent classes, which we in this study aim to interpret as naïve theories, or rules, on shadow size. Models with 1, 2, 3, 4, and 5 classes were fit to the data by calculating Log Likelihood estimates of the model parameters with the package depmixS4 (Visser & Speekenbrink, 2010) for the R statistical programming environment (R Development Core Team, 2011). Model parameters were estimated, including unconditional probabilities, which represent class sizes, and conditional probabilities, which represent probabilities of responses to items given membership of a specific class. In LCA the optimal number of latent classes cannot be estimated or tested, hence model selection was based on the Bayesian Information Criterion (BIC; Schwarz, 1978): the model with the lowest BIC was considered to be the most parsimonious, best fitting model. For the selected models, equality constraints were put on the conditional probabilities of the six size items in all classes and the same was done for the conditional probabilities of the six distance items in all classes. For both the pre-task model (Log likelihood ratio (80)=97.15, p=.09) and the post-task model (Log likelihood ratio (80)=82.59, p=.40) there was no significant difference in goodness-of-fit between the constrained and the unconstrained model, and therefore the more parsimonious, constrained models were used for interpretation. Interpretation was based on previous work on children's naïve theories on shadow size (e.g. Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981; Van Schijndel et al., 2012 / Chapter 6).

RESULTS

General

In this study a wide range of child and parent behaviors was measured at several exhibits. As the research questions concerned relations between parent explanation and children's exploratory behavior and learning, analyses were solely performed on behavior at the total exhibition and on behavior at the Shadow Painting (SP) exhibit (see Figure 1B). Behavior at the SP exhibit was analyzed separately, because this exhibit was selected for transcribing and coding of parent explanation.

Holding times

Child-parent teams spent an average 31.50 minutes (62.89 30-second intervals, range 33-90, *SD*=16.00) at the total exhibition. The average holding time for the SP exhibit was 13.14 minutes (26.27 30-second intervals, range 5-59, *SD*=12.24). No relations between holding times (total exhibition and SP exhibit) and children's or parents' age or gender were found. No effect of theater attendance on holding time (total exhibition and SP exhibit) was found.

Preschoolers' exploratory behavior

On average children demonstrated a mean EBS level of 2.32 (range 1.69-2.59, *SD*=.15) in the total exhibition. For the SP exhibit this was 2.40 (range 1.55-2.89, *SD*=.23). Children's exploratory behavior at the total exhibition (r=.51, p<.001) and at the SP exhibit (r=.40, p<.001) correlated significantly with their age in months: older children played at higher EBS levels than younger children. No relation between exploratory behavior (mean EBS levels total exhibition and SP exhibit) and children's gender was found. No effect of theater attendance on exploratory behavior (mean EBS levels total exhibition and SP exhibit) was found.

Parent explanation

Parents made an average of 143.88 utterances (*SD*=76.03) at the SP exhibit: 31% of these utterances consisted of content-related directions, 26% of evidence descriptions, 14% of closed questions, 8% of open questions, 4% of affective talk, 3% of navigation-related directions, 2% of explanations, and 12% of the utterances could not be assigned to one of the above-mentioned categories (see Table 3A). The parent explanation variables that were included in the analyses were based on the mean number of utterances per 30-second time interval at the SP exhibit (see Table 3B). As in this study children's exploratory behavior was expressed in mean EBS levels over intervals, using explanation variables based on means over intervals allowed for examining the relation between children's exploratory behavior and parent explanation in a valid way.

The mean number of navigation-related directions per interval correlated significantly with children's age in months (r=-.30, p<.01): parents gave less navigation-related directions to older children than to younger children. The mean number of closed questions per interval (r=.25, p<.05) and the mean number of evidence descriptions per interval (r=.22, p<.05) correlated significantly with parents' age in years: older parents asked more closed questions and described more evidence than younger parents. No relations between explanation (mean number of utterances per interval for each of the seven categories) and children's or parents' gender were found. No effects of theater attendance on explanation (mean number of utterances per interval for each of the seven categories) were found.

TABLE 3. Parent explanation: Mean number of utterances (A) and mean number of utterances per interval (B) at the Shadow Painting exhibit.

	A. Number of utterances			B. Number of utterances per interval		
Explanation category	Mean (Percentage)	Range	SD	Mean	Range	SD
Open question	11.48 (8)	0-38	9.00	.45	0-1.59	.30
Closed question	21.15 (14)	0-56	13.21	.82	0-2.32	.43
Explanation	2.61 (2)	0-11	2.79	.11	0-.55	.12
Evidence description	37.13 (26)	4-127	22.08	1.42	.20-2.61	.56
Content-related direction	45.34 (31)	7-172	30.92	1.74	.43-4.59	.84
Navigation-related direction	3.97 (3)	0-36	5.37	.17	0-1.33	.25
Affective talk	5.15 (3)	0-25	4.94	.21	0-1.08	.19
Other talk	17.06 (4)	1-54	11.61	.67	.09-1.88	.39
Total	143.88 (100)	28-352	76.03	5.58	2.27-10.96	1.90

Preschoolers' learning

Both the analyses on the pre- and post-task rendered models with four classes, indicating four different naïve theories on shadow size, or incoherent response patterns (see Table 4 for the goodness-of-fit measures of the different models). As shown in Figure 3, children in the first class had high probabilities of giving correct responses on size items and answering "the same" on distance items. This class was characterized as applying Rule 1. As children in the Rule 1 class, children in the second class had high probabilities of giving correct responses on size items and incorrect responses on distance items. However, this group tended to answer distance items by claiming that a puppet closer to the light source would give a smaller shadow than a puppet further away from the light source. This class was characterized as applying Rule 2-reversed. Children in the third class had high probabilities of giving correct responses on both the size items and the distance items. This class was characterized as applying Rule 2+.[2] Children in the last class showed incoherent responses to the size and/ or distance items. These responses were hard to interpret as a rule and therefore this class was denoted as guessing.

The most likely class membership was calculated for each child individually based on the posterior probabilities given the selected 4-class-models (e.g. McCutcheon, 1987). No relation between rule-use and children's age was found on the pre-task. Rule-use on the post-task was age-related ($\chi(6)=21.38$, $p<.01$): the percentages of children using Rule 1 and Rule 2-reversed decreased, and the percentage of children using Rule 2+ increased with age. No relations between rule-use and children's gender were found on both the pre- and post-task.

TABLE 4. Preschoolers' learning: Goodness-of-fit measures for Latent Class Models of response patterns to pre- and post-task.

	Pre-task			Post-task		
Number of classes	L	df	BIC	L	df	BIC
1	-873.61	24	1854.96	-898.17	24	1904.07
2	-757.63	49	1735.21	-735.08	49	1609.11
3	-672.79	74	1677.75	-608.55	74	1549.25
4	-597.59	99	1639.55	-520.53	99	1485.43
4e	-646.17	19	1377.61	-561.83	19	1208.94
5	-559.92	124	1676.42	-484.82	124	1526.23

Note. L=Log likelihood, df=degrees of freedom (calculated by the number of freely estimated parameters minus the number of parameters estimated at the boundary), BIC=Bayesian Information Criterion. Row 4e shows the goodness-off-fit measures of the selected 4-class models with equality constraints (see Method).

To examine children's learning, we inspected the crosstabs of children's rule-use on the pre- and post-task (see Table 5). Of the 64 children that did not apply the most advanced rule (Rule 2+) on the pre-task, 21 children (33%) applied a more advanced rule on the post-task than on the pre-task, 40 children (62%) showed consistency in rule-use, and 3 children (5%) applied a less advanced rule on the post-task than on the pre-task. Analyses concerning children's learning were performed on the total group of children that did not apply the most advanced rule on the pre-task (N=64). Within this group a learning group (N=21, children applying a more advanced rule) and no-learning group (N=43, children not applying a more advanced rule) were distinguished. No relations between learning (learning group vs. no-learning group) and children's age or gender were found. An effect of theater attendance on learning was found: a larger proportion of children in the theater group (47%) compared to the no-theater group (21%) learned, meaning they applied a more advanced rule on the post-task than on the pre-task ($\chi(1)$=4.92, p<.05)**.**

TABLE 5. Preschoolers' learning: Crosstabs of rule use on the pre- versus the post-task.

		Posttest				
		Guess	Rule 1	Rule 2-reversed	Rule 2+	Total
Pretest	Guess	9 (60)	2 (13)	3 (20)	1 (7)	15 (100)
	Rule 1	0 (0)	14 (70)	2 (10)	4 (20)	20 (100)
	Rule 2-reversed	3 (10)	0 (0)	17 (59)	9 (31)	29 (100)
	Rule 2+	3 (12)	0 (0)	5 (20)	17 (68)	25 (100)
	Total	15 (17)	16 (18)	27 (30)	31 (35)	89 (100)

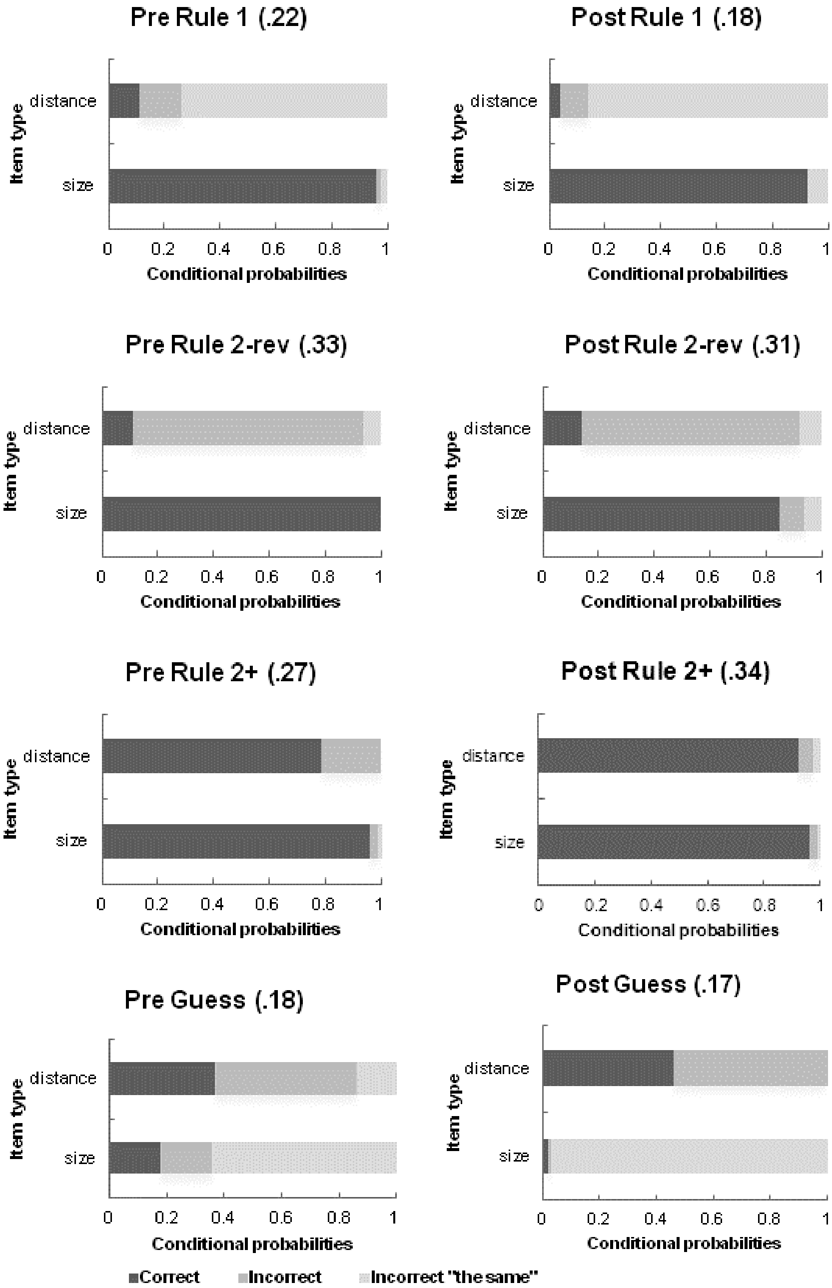

FIGURE 3. Preschoolers' learning: model parameters (conditional probabilities in figures and unconditional probabilities between brackets), for the selected pre- and post-task models.

Parent explanation & preschoolers' exploratory behavior

To investigate whether parent explanation significantly predicted children's exploratory behavior, a multiple regression analysis was performed with children's mean EBS level at the SP exhibit as the dependent variable and five parent explanation variables (mean number of open questions, closed questions, explanations, evidence descriptions, and content-related directions per interval) as predictors.[3] Theater attendance (theater group, no-theater group) and children's age in months were also included as predictors to investigate whether parent explanation predicted exploratory behavior controlling for theater attendance and children's age. Using the enter method,[4] two predictors were found to make a significant contribution to the predictive power of the model: children's age in months, and the mean number of evidence descriptions per interval (see Table 6 for the full model). The analysis was repeated with only these two predictors and it was demonstrated that together they explained 21% of the variance. With other variables held constant, children's exploratory behavior was positively related to both predictors, increasing by .01 for every month of age and by .09 for every evidence description (see Table 6 for the full model).

TABLE 6. Multiple regression models predicting preschoolers' exploratory behavior (mean EBS level at the Shadow Painting exhibit).

	B (SE)	*ß*
Model 7 predictors:		
Constant	1.66 (.17)	
Theater attendance (T)	.02 (.04)	.04
Age in months (C)	.01 (.00)	.41 ***
Mean number of open questions per interval (P)	.03 (.10)	.03
Mean number of closed questions per interval (P)	-.03 (.07)	-.06
Mean number of explanations per interval (P)	.30 (.19)	.16
Mean number of evidence descriptions per interval (P)	.10 (.05)	.25 *
Mean number of directions per interval (P)	-.03 (.03)	-.11
Model 2 predictors:		
Constant	1.67 (.16)	
Age in months (C)	.01 (.00)	.39 ***
Mean number of evidence descriptions per interval (P)	.09 (.04)	.23 *

Note. *B*=un-standardized beta coefficient, *SE*=standard error, *ß*=standardized beta coefficient, T=team, C=child, P=parent, Model 7 predictors: R^2=.24, R^2adj=.18, $F(7,81)=3.71$**, Model 2 predictors: R^2=.21, R^2adj=.19, $F(2,86)=11.44$***, *$p<.05$, **$p<.01$, **$p<.001$

Preschoolers' exploratory behavior, parent explanation & preschoolers' learning

To investigate whether children's exploratory behavior and parent explanation significantly predicted preschoolers' learning, a logistic regression analysis was performed with children's learning (learning group, no-learning group) as the dependent variable and children's mean EBS level at the SP exhibit and five parent explanation variables (mean number of open questions, closed questions, explanations, evidence descriptions, and content-related directions per interval) as predictors.[3] Theater attendance (theater group, no-theater group) and children's age in months were also included as predictors to investigate whether exploratory behavior and explanation predicted learning controlling for theater attendance and children's age. Using the enter method, three predictors were found to make significant contributions to the predictive power of the model: theater attendance, children's age in months, and children's mean EBS level at the SP exhibit (see Table 7 for the full model). The analysis was repeated with only these three predictors and it was demonstrated that together they explained 24% of the variance. Children's learning was positively related to theater attendance: the odds of a child learning was 5.15 times higher for teams who attended the theater show than for teams who did not attend the theater show. With other variables held constant, children's learning was also positively related to their age: the odds of a child learning changed by 1.09 for every month of age. Last, learning was negatively related to children's exploratory behavior: the odds of a child learning changed by .06 for every mean EBS level (see Table 7 for the full model).

TABLE 7. Multiple regression models predicting preschoolers' learning (learning group using a more advanced rule on the post- compared to pre-task, and no-learning group).

		95% CI for Exp b		
	B (SE)	Lower	Exp b	Upper
Model 8 predictors:				
Constant	.36 (3.24)			
Theater attendance (T)	1.39 (.67) *	1.08	4.02	15.00
Age in months (C)	.11 (.05) *	1.10	1.11	1.22
Mean EBS level (C)	-4.03 (1.75) *	.00	.02	.55
Mean number of open questions per interval (P)	-2.89 (1.64)	.00	.06	1.38
Mean number of closed questions per interval (P)	-.33 (1.16)	.07	.72	6.94
Mean number of explanations per interval (P)	-1.57 (3.46)	.00	.21	182.79
Mean number of evidence descriptions per interval (P)	.83 (.83)	.45	2.29	11.63
Mean number of directions per interval (P)	.80 (.50)	.85	2.23	5.90
Model 3 predictors:				
Constant	-.51 (2.93)			
Theater attendance (T)	1.64 (.04) *	1.49	5.15	17.80
Age in months (C)	.09 (.04) *	1.01	1.09	1.18
Mean EBS level (C)	-2.88 (1.41) *	.00	.06	.90

Note. *B*=un-standardized beta coefficient, *SE*=standard error, Exp *b*=exponentiated beta coefficient/ odds ratio, T=team, C=child, P=parent, Model 8 predictors: R^2= .36 (Nagelkerke), Model$\chi(8)$=19.36*, Model 3 predictors: R^2=.24 (Nagelkerke), Model $\chi(3)$=12.26**, *p<.05, **p<.01.

DISCUSSION

The present study fills a gap in existing visitor research by focusing on the preschool age group. Specifically, the study investigated, in an explorative manner, relations between parent explanation, children's exploratory behavior, and learning in a shadow exhibition in science center NEMO, The Netherlands. Parent explanation was coded in a number of domain-general categories, such as causal explanations, evidence descriptions, and content-related directions (Crowley, Callanan, Jipson et al., 2001; Crowley, Callanan, Tenenbaum, et al., 2001; Fender & Crowley, 2007; Szechter & Carey, 2009; Zimmerman et al., 2009). Preschoolers' exploratory behavior and learning were quantified by using nonverbal measures. The Exploratory Behavior Scale (EBS; Van Schijndel, Franse et al., 2010 / Chapter 3; Van Schijndel, Singer et al., 2010 / Chapter 2) was used to assess the level to which children explored their physical environment. Children's learning was assessed in the knowledge domain of shadow size.

The first research question concerned the relation between parent explanation and preschoolers' exploratory behavior. Fender and Crowley (2007) did not find a relation between parent explanation and young children's exploration. However, they focused on one type of explanation: causal explanations. In this study the relations between multiple types of parent explanation and preschoolers' exploration were investigated. We found a relation between one specific type of parent explanation, evidence descriptions, and preschoolers' exploration: children whose parents described more evidence demonstrated higher mean levels of exploratory behavior than children whose parents described less evidence. Parents' evidence descriptions might guide preschoolers' exploration by directing or maintaining children's attention to relevant task aspects or evidence resulting from their manipulations. Research on executive functions shows that the ability to attend to relevant evidence is still in development in childhood: older children are better at planning and executing effective information search strategies than younger children (e.g. Davidson, 1996; Miller & Weiss, 1981; Welsh, Pennington & Groisser, 1991). In addition, young children have difficulty shifting between tasks and have a relatively limited working memory capacity (e.g. Huizinga, Dolan & Van der Molen, 2006). Therefore, by describing evidence, parents might provide structure to children's exploratory process. Exploratory behavior is considered a key ingredient of children's visit to science museums (Allen, 2002, 2004), hence this result is highly relevant to the practice of informal science learning. However, on the basis of this result no causal conclusions can be drawn. To understand what mechanisms are underlying this relation, it is important for future research to replicate this result with an experimental paradigm.

The second research question concerned preschoolers' learning on shadow size. Three groups of children with different naïve theories, and a group of children with incoherent responses were distinguished on the basis of both the pre- and the post-task data. The detected theories were similar to those found in previous studies (Chen 2009; Ebersbach

& Resing, 2007; Siegler, 1981; Van Schijndel et al., 2012 / Chapter 6). It was found that a third of the preschoolers that did not use the most advanced theory on the pre-task, learned during their visit to the exhibition. That is, they had a more advanced theory after visiting the exhibition compared to before. In the next paragraphs we will first discuss the results concerning the relation between children's learning and exploration, followed by the results concerning the relation between children's learning and parent explanation.

In line with studies in more controlled settings (Bonawitz et al., 2012; Gweon & Schulz, 2008; Schulz et al., 2007; Van Schijndel et al., 2012 / Chapter 6), a relation was found between preschoolers' exploratory behavior and learning. However, in contrast to the findings of the controlled studies, in the present study this relation was negative: children who demonstrated higher mean EBS levels were less likely to learn than children who demonstrated lower mean EBS levels. Even though it is difficult to draw conclusions on the basis of unexpected results, we do spend some words on reflecting on this result, because besides theory-driven explanations, several methodological explanations exist for the found contrast. For example, in the controlled studies domain-specific measures for exploration were used, while in this study a domain-general measure for exploration was used. Instead of coding whether children did or did not generate instances of evidence that could support learning in the knowledge domain at hand, we used the EBS to determine the general level to which children explored their physical environment. Possibly, children's high EBS levels reflected them exploring a different principle than the relation between object size, object distance and shadow size. For example, they might have investigated the relation between object transparency and shadow color, or a principle that the Shadow Painting exhibit was not designed to illustrate. However, an observation that runs counter to this explanation is that random checks of the parent explanation transcripts suggested that all child-parent teams had generated multiple instances of evidence supporting learning on shadow size. The finding of a weaker relation between generating evidence and learning in this study compared to the studies in controlled settings (Bonawitz et al., 2012; Gweon & Schulz, 2008; Schulz et al., 2007; Van Schijndel et al., 2012 / Chapter 6), can be explained by the fact that in this study children's exploration took place in an exhibition space with many distractions. Moreover, for children to perform well on the learning task some transfer of knowledge was needed, which is known to be difficult. Another explanation for the contrasting findings on the relation between exploration and learning is that this study used mean levels of exploratory behavior over time intervals, while the studies in controlled settings did not (Bonawitz et al., 2012; Gweon & Schulz, 2008; Schulz et al., 2007; Van Schijndel et al., 2012 / Chapter 6). Possibly, the lower mean EBS levels in this study reflected children thinking or talking about the generated evidence. Reflection may increase learning from observations, explaining the negative correlation between exploratory behavior and learning.

Importantly, these findings do not diminish the value of the EBS as a measure for preschoolers' exploration in natural settings. In the case of the present study, children were encouraged by the design of the exhibition to explore a relatively wide range of knowledge: multiple shadow principles. The EBS produced a general level of behavior, including behaviors that were anticipated, and behaviors that were unanticipated by the exhibition developers. At the same time, children's knowledge acquisition was measured in a relatively narrow domain: on one of the shadow principles. In cases like this, the EBS might not be the best measure to uncover relations between behavior and learning. However, when a study aims at comparing children's exploratory behavior under different conditions, the EBS can be considered highly suitable. For example, the EBS can be used to investigate whether differences between exhibits or different types of adult guidance affect children's exploratory behavior (Van Schijndel, Franse et al., 2010 / Chapter 3; Van Schijndel, Singer et al., 2010 / Chapter 2).

Next, we investigated the relation between different types of parent explanation and preschooler's learning. Fender and Cowley (2007) found a relation between parents' causal explanations and children's conceptual learning, but not their mechanistic and procedural learning. As the task that was used in this study for assessing children's learning can best be characterized as being on a mechanistic or procedural level, our results can be considered in line with Fender and Crowley's (2007): no relations between parent explanation and children's learning were found. One explanation for the lack of this relation is that parent explanation was measured on a domain-general level. To check whether parents' domain-specific explanation was related to children's learning, we went back to the transcribed parent talk. We coded whether parents' utterances did or did not refer to one of the two factors influencing shadow size: the size of the object and the distance of the object to the light source. For example, utterances were coded as referring to the size dimension as parents used words such as "big", "bigger", "small", or "smaller". Utterances were coded as referring to the distance dimension when parents used words such as "close", "closer", "far", or "further". However, no relations were found between the number of utterances in which parents referred to the size and/ or distance dimension, and children's learning. These results speak to the complicated question of the relative contributions of children's self-directed exploration and their interactions with other people to their learning. The relative power of these two sources of input on children's learning under different task constraints is an important question for future research (Gelman, 2009).

The last research question concerned the effects of the theater show. In contrast to our expectations, no effects of theater attendance were found on parent explanation. Possibly parents have overlooked the principles in the show, or they might already have been familiar with the principles. However, there are multiple explanations for this outcome and only future research can shed light on this issue. Concerning the child variables, no effects of theater attendance were found on preschoolers' exploratory behavior. We did find an effect on preschoolers' learning: children in teams that had attended the theater show were more likely to learn than children in teams that had not attended the show. As discussed before, this effect was not mediated by parent explanation. Possibly, the effect was caused by the theater show having a calming effect on children. Alternatively, the effect might have been caused by the longer amount of time that the theater group had been engaged in shadow activities. As the finding of a positive effect of theater attendance on children's learning is of relevance for the field of informal science education, further research into the robustness and mechanisms of the effect is needed.

ACKNOWLEDGEMENTS

The research of Tessa van Schijndel is sponsored by an NWO-Aspasia grant and the Dutch Curious Minds program, which is supported by the Dutch Ministry of Education, Culture and Science and the Platform Bèta Techniek. The research of Maartje Raijmakers is sponsored by a NWO-VIDI grant. We would like to thank children and parents for their participation in the study. We thank Rooske Franse and Meie van Laar for help with the logistics of the project. We thank Elizabeth Borlefs, Jiska Osterhaus, Rudi Mur, and Juri Peters for help with the data collection and coding. We thank Brenda Jansen, Han van der Maas, Ingmar Visser, and Wouter Weeda for statistical advice.

NOTES

1. In all exhibits the distance between the light source and screen was fixed, so this variable could not be taken along in child-parent team's investigations on shadow size. Similarly, in the task that was used to assess children's knowledge on shadow size, the distance between the light sources and screen was kept constant.
2. As on the basis of the sole use of size- and distance items in this study children applying Rule 2 could not be distinguished from children applying Rule 3 or 4 (see Siegler, 1981), the plus sign (Rule 2+) was used to indicate the possible use of a more advanced rule.
3. In the regression analyses on children's exploratory behavior and learning, five types of parent explanation were included: open questions, closed questions, explanations, evidence descriptions, and content-related directions. To limit the number of variables in the analyses, two explanation types which were used very infrequently by parents, affective talk (4% of the utterances), and navigation-related direction (3% of the utterances) were not included. Besides its infrequent use, another reason not to include navigation-related direction was that these explanations did not concern children's exploration or leaning at the exhibits, but solely the team's navigation through the exhibition.
4. As stepwise techniques are influenced by random variation in the data and seldom give replicable results if the model is retested within the same sample (Field, 2005), we used the enter method for the regression analyses in this study.