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Parent Explanation and Preschoolers' Exploratory Behavior and Learning in a Shadow Exhibition

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ABSTRACT: The present study fills a gap in existing visitor research by focusing on the preschool age group. The study explores relationships between parent explanation, children's exploratory behavior, and their domain-specific learning in a shadow exhibition. In addition, the effect of a preceding theater show on child and parent behaviors is examined. In the study, parent–child pairs were observed while playing in a science center exhibition illustrating physical principles of shadows. Parent explanation was scored on a number of domain-general categories, such as causal explanations, evidence descriptions, and content-related directions. Preschoolers' exploratory behavior and learning were quantified by using nonverbal measures. The Exploratory Behavior Scale was used to assess children's exploration of the physical environment. Children's learning was assessed in the knowledge domain of shadow size. Results showed a positive relationship between one type of parent explanation, evidence descriptions, and preschoolers' exploratory behavior. No positive relationships between children's exploration and their domain-specific learning or between parent explanation and children's domain-specific learning were found. Last, theater attendance was found to affect children's learning on shadow size. © 2015 Wiley Periodicals, Inc. *Sci Ed* **100:**153–178, 2016

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INTRODUCTION

Over the last decade, preschoolers have become a more visible group in science museums. Many museums have started offering activities for preschoolers or have areas or exhibitions aimed at the preschool age group. In spite of this trend, the preschooler group is still underrepresented in visitor research. Studies investigating family science learning have often adopted a sociocultural perspective, taking the family 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). However, preschoolers' behavior and learning differ from that of older children. Preschoolers' verbal capacities are still in development, and therefore their speech may not accurately reflect their reasoning or learning. This observation suggests a potential limitation of the focus on conversations in many family learning studies (e.g., Allen, 2002; Ash, 2003; Zimmerman, Reeve, & Bell, 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 more intensively by adults than those of older children. Even though the line of visitor research adopting a sociocultural perspective has yielded important insights into the processes of meaning making taking place in museum settings, the differences between preschoolers and older individuals necessitate alternative approaches to fully understand the preschool age group's learning experiences in these settings.

Therefore, in contrast to many family-learning studies taking a Vygotskian sociocultural perspective (e.g., Rogoff, 1995), the present study takes a Piagetian constructivist perspective (e.g., Inhelder & Piaget, 1964; Wellman & Gelman, 1992) in investigating preschoolers' learning experiences in a shadow exhibition (for an extensive discussion of the differences between these perspectives see Callanan & Valle, 2008). The choice of a constructivist perspective allows for a better distinction between the child and parent role in order to examine the ways by which parents guide the learning process (Schauble et al., 2002).

Specifically, the present study focuses on preschoolers' domain-general exploratory behavior and their domain-specific learning.[1] Exploratory behavior is at the core of young children's science learning. Accordingly, 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). A frequent assumption in visitor research adopting a sociocultural perspective (e.g., Callanan & Valle, 2008; Rogoff, 1995) is that behaviors, such as children's exploratory behavior and conversations, indicate the occurrence of learning (Schauble et al., 2002; Serrell, 1998). Schauble et al. (2002), however, argue that visitor research on learning should go beyond investigating domain-general behaviors and focus on domain-specific behaviors and understanding as well. 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 relationships between preschoolers' domain-general exploratory behavior, their domain-specific learning, and parental guidance of these processes.

[1] With the term "domain-specific learning" we imply the acquisition of knowledge in a specific knowledge domain, such as floating and sinking or light and shadows. In contrast, domain-general skills, such as different levels of exploratory behavior measured in the present study, can be applied over knowledge domains.

Relating Parent Explanation to Preschoolers' Exploration

Only a few studies have investigated the influence of adult guidance on preschoolers' exploratory behavior at exhibits. Crowley, Callanan, Jipson et al. (2001) investigated the effect of adult presence on young children's exploration of a zoetrope exhibit. They found that children who explored the exhibit with their parents did this longer and on a deeper level than children who explored the exhibit by themselves. Van Schijndel, Franse, and Raijmakers (2010) investigated the effect of different coaching styles, the scaffolding, explaining, and minimal style, on preschoolers' exploratory behavior at different exhibits. When scaffolding, the trained experimenter tried to take the child's investigations to the next level by asking open questions, acting like she did not understand and directing the child's attention to specific parts of the exhibit. When explaining, the experimenter named causal connections, physical principles, and connected the experience to the child's existing knowledge. In addition, she demonstrated the workings of the exhibit. When performing the minimal style, nothing was explained or demonstrated and no scaffolding took place. Van Schijndel et al. found that it was dependent on the specific exhibit which coaching style led to more high-level exploratory behavior. However, as each of these adult coaching styles consisted of a wide range of verbal and nonverbal behaviors, more detailed study is required to understand which 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. These differences have been related to child characteristics: parents have been shown to explain more to boys than to girls (Crowley, Callanan, Tenenbaum, & Allen, 2001) and to novice children than to expert children (Palmquist & Crowley, 2007). These differences have also been related to adult characteristics: parents with higher educational levels have been shown to be more directive (Siegel, Esterly, Callanan, Wright, & Navarro, 2007) and to make more connections to children's prior experience (Szechter & Carey, 2009) than parents with lower educational levels.

Few studies, however, have connected parent explanation to children's exploratory behavior in museum settings. Fender and Crowley (2007) investigated the relationship between the occurrence of 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, there are several other types of explanations that have been studied on a frequent basis 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 relationships between these domain-general explanation types and preschoolers' exploratory behavior in museum settings. Investigating these relationships could contribute to uncovering the mechanisms through which adults can optimally guide children's exploration. As the domain-general nature of the explanation types can be considered an advantage in generalizing possible detected mechanisms to other settings, the results of such a study would be relevant for the practice of informal science education. Therefore, the first research question of the present study is: "What are the relationships between different types of parent explanation and preschoolers' exploratory behavior in a museum setting?"

Relating Preschoolers' Exploration to Preschoolers' Domain-Specific Learning

Little research in museum settings has addressed the relationship between young children's exploratory behavior and their domain-specific learning, but a number of studies in more controlled settings have (e.g., Bonawitz, Van Schijndel, Friel, & Schulz, 2012; Schulz, Gopnik, & Glymour, 2007; Van Schijndel, Visser, Van Bers, & Raijmakers, 2015).[2] We will briefly describe two studies that have been performed in controlled settings that are particularly relevant to the present study. In these studies, preschoolers' exploratory behavior was quantified by determining whether during free play children generated specific instances of evidence that could support learning. That is, whether they manipulated the materials in such a way that the resulting evidence allowed them to draw correct conclusions on the causal structure of the knowledge domain at hand.

In a first study, Schulz et al. (2007) investigated preschoolers' exploratory behavior and learning in the knowledge domain of gears. Children were given a toy with two gears and were told that there was a hidden motor that was either connected to one of the gears (causal chain) or to both of them (common cause), and were asked to figure out how the toy worked. As simply switching on the motor would make both gears spin, this manipulation did not inform on the causal structure of the toy. Exploratory behavior generating evidence supporting learning therefore implied first switching the motor on and off with only one gear in place and then repeating this action with only the other gear in place. Half of the children working alone and the large majority of children working in pairs generated this type of evidence. The results demonstrated that children learned from the evidence they generated: they were more likely to choose the correct structure from three options (common cause, causal chain gear A to B, causal chain gear B to A) when the generated evidence was in line with that structure.

In a second study, Van Schijndel et al. (2015) investigated preschoolers' exploratory behavior and learning in the knowledge domain of shadow size. As this knowledge domain was also used in the present study (see the Present Study section), we will elaborate a bit on the findings on children's knowledge in this domain here, as these are also relevant for the present study. In their study, Van Schijndel et al. first assessed children's (naïve) theories, or rules, of shadow size. They found, in line with previous literature (Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981), a group of children using a size rule (Rule 1) and a group of children using a size and distance rule (Rule 2). Children using the size rule understand that larger objects have larger shadows, but do not take into account the distance of an object to the light source in determining shadow size. Children using a size and distance rule understand that larger objects have larger shadows, and that objects closer to the light source have larger shadows. In contrast to previous literature (Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981), Van Schijndel et al. also found a group of children using a size and distance-reversed rule (Rule 2-reversed). Children using the size and distance-reversed rule understand that larger objects have larger shadows, but think that objects closer to the light source have smaller shadows than objects further away from the light source. Ebersbach and Resing's (2007) results on participants' implicit and explicit beliefs on shadow size had already suggested the existence of the size and distance-reversed rule in the preschool age group. Concerning participants' implicit beliefs, they found, depending on age, that participants estimated 63–93% of shadows of objects in the closest position to the light source as being longer than shadows of objects in the furthest position. Concerning

[2] With the term "controlled setting" we imply a test setting for an individual child in a lab-, school- or other context, in which as many as possible variables are controlled, such as the items to be solved, the explanation the child receives, the presence of other people, the background noise, etc.

participants' explicit beliefs, they found that approximately half the 5-year-olds and the majority of older participants gave a correct answer to the question whether a shadow would become longer, shorter or would stay the same when an object approaches the light. However, Ebserbach and Resing did not systematically assess individual children's naïve theories, or rules.

After rule assessment, a second step in Van Schijndel et al.'s (2015) study was to select children having one particular rule: the size rule. This group was then asked to play with a shadow machine (Inhelder & Piaget, 1958; Siegler, 1978, 1981), consisting of two light sources, a screen, and puppets of different sizes that could be placed at several distances in between the light sources and screen. Children's exploratory behavior was investigated by assessing whether they generated evidence supporting learning on the distance dimension during free play. Generating this type of evidence implied performing a distance experiment, that is, to place two puppets of equal size at different distances from the light sources. Then a second rule assessment followed and learning was defined as the use of a more advanced theory or rule (size and distance-reversed rule or size and distance rule) after play compared to before. Results showed that children's learning was related to the evidence they generated during free play: more than one quarter of the children who made a distance experiment learned, whereas none of the children who did not make a distance experiment did.

Together, these results tentatively suggest that preschoolers' exploratory behavior is related to their learning in controlled settings. However, it is as yet unknown whether this relationship also holds in a museum setting. The second research question is thus: "What is the relationship between preschooler's exploratory behavior and their domain-specific learning in a museum setting?"

Relating Parent Explanation to Preschoolers' Domain-Specific Learning

Besides by their own exploration, children's learning could also be affected by parent explanation (Gelman, 2009). Fender and 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 relationship between parents' causal explanations and children's mechanistic or procedural understanding was found. This study will further examine the relationship 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. The third research question therefore is: "What is the relationship between different types of parent explanation and preschoolers' domain-specific learning in a museum setting?"

Present Study

The aim of the present study is to investigate relationships between (1) parent explanation and preschoolers' exploration, (2) preschoolers' exploration and preschoolers' domain-specific learning, and (3) parent explanation and preschoolers' domain-specific learning. The study was performed in Science Center NEMO's Young explorers in NEMO exhibition: an exhibition specifically developed for the preschool age group (see Figure 1). The exhibition consisted of a theater show (15 minutes), followed by the visit

Figure 1. Young explorers in NEMO: impression theater show (top row, left picture), exhibition space (top row, middle and right pictures), and Shadow Painting exhibit (bottom row).
Description Shadow Painting exhibit: At the 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.
Note. Photography: DigiDaan and Rein van Zaanen.

to an interactive exhibition space illustrating a number of physical principles related to shadows (maximally 45 minutes; see the Method section for more information).

In the study, 89 child–parent teams participated in a pre-exhibition, exhibition, and post-exhibition phase. In the preexhibition phase, the child's knowledge, that is, (naïve) theory or rule, was assessed in the domain of shadow size. This domain was chosen because the relationship between the size of an object, the distance of an object to the light source, and the size of the shadow, was the physical principle that was most prominent in the exhibition.[3] The prominence of the shadow-size principle, however, did not guarantee that child–parent teams focused their investigations on this principle (see the Discussion section).

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 exploratory 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 the effect of theater attendance on child and parent behaviors, child–parent teams were randomly assigned to either the theater condition or the no-theater condition. Independent of their condition, all child–parent teams (subsequently) visited the

[3]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.

exhibition space. During this visit, children's exploratory behavior was measured by means of the Exploratory Behavior Scale (EBS) (Van Schijndel, Franse et al., 2010; Van Schijndel, Singer, Van der Maas, & Raijmakers, 2010). This scale does not rely on children's verbal capacities. It 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 the Method section). In addition, parent explanation was recorded. Due to time constraints, one exhibit was selected for transcribing and coding of parent explanation: the Shadow Painting (SP) (see Figure 1). The selection was based on the fact that the child–parent teams had interacted longest with this exhibit (see the Results section).

In the post-exhibition phase, the child's knowledge, that is, (naïve) theory or rule, on shadow size was assessed for the second time. Learning was defined by the use of a more advanced rule after visiting the exhibition compared to before (see the Statistical Approach for Assessing Learning and Results sections).

METHOD

Participants

Ninety-five child–parent teams participated in the study. Six teams were excluded from the analyses: three teams were excluded because an error was made in administering the shadow task to the child, and three teams were excluded because no complete audio recordings of parent explanation were available. The final sample consisted of 89 teams. Ninety-seven percent 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). In The Netherlands, preschool is integrated in primary school. Children start preschool when they are 4 years of age and stay, depending on their date of birth, 1.5–2.5 years before going to the first grade. Therefore, the preschool age range includes 4-, 5-, and 6-year-olds. 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: 80% had minimally a bachelor's degree (42% bachelor's degree, 38% master's or postgraduate 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). Adults reported relatively frequent reading of science-related newspaper articles (40% weekly, 35% monthly, 9% yearly, 15% never, 1% no answer), visiting science museums (8% monthly, 25% half yearly, 45% yearly, 20% never, 2% no answer), and listening to or watching science shows on the radio or television (33% weekly, 49% monthly, 6% yearly, 10% never, 2% no answer). Although most child–parent teams were from White, middle-class backgrounds, a range of ethnicities reflecting the diversity of the population was represented. More detailed information about the ethnicities of the participants was not 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.

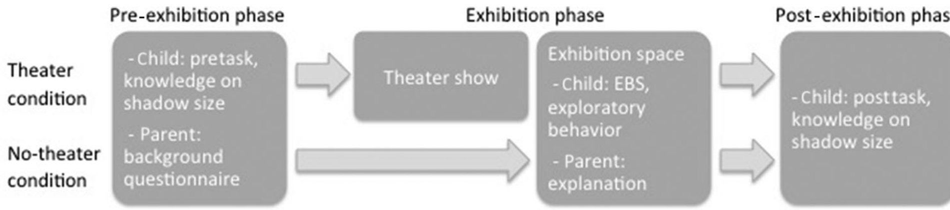

Figure 2. Flowchart of the study's design.

Procedure

The study was performed in six consecutive weekends in the spring of 2010 in Science Center NEMO's Young explorers in NEMO exhibition. That year the science museum offered eight Young explorers in NEMO sessions (see the Young Explorers in NEMO Exhibition section) 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 in infant research with their younger children, and by the Young explorers in NEMO Web site. When parents signed up on the Web site, 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 90 minutes for teams in the no-theater condition and 105 minutes for teams in the theater condition, and consisted for all teams of a pre-exhibition, exhibition (theater show, exhibition space), and postexhibition phase (see Figure 2 for a flowchart of the study's design). A team of experimenters consisting of trained research assistants guided child–parent teams through participation. They planned each team's participation individually, so teams did not have to wait for each other. Upon entry in the science center, the pre-exhibition phase (30 minutes) started. The team was welcomed in an office space and 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-version of the shadow task (see the Materials section). During the exhibition phase (45 minutes no-theater and 60 minutes theater condition), the child–parent team visited the exhibition, together with regular visitors who did not participate in the study. The teams in the theater condition first attended the theater show (15 minutes), the teams in the no-theater condition did not. All teams (subsequently) visited the exhibition space (maximally 45 minutes; see the Young Explorers in NEMO Exhibition section), in which they were free to explore whichever exhibits they wanted in every possible sequence. Before entering the exhibition space, the experimenter activated the parent's voice recorder in synchrony with her stopwatch. During the visit to the exhibition space children's exploratory play was assessed and parent explanation was recorded (see the Materials section). 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. During the postexhibition phase (15 minutes), 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-version of the shadow task (see the Materials section).

Young Explorers in NEMO Exhibition

In January 2010 Science Center NEMO (Amsterdam, The Netherlands) opened Young explorers in NEMO: an exhibition specifically developed for the preschool age group. The exhibition was the result of an ongoing collaboration between NEMO's Science Learning Center and the section Developmental Psychology of the University of Amsterdam. The exhibition was located in a separate area of the science center, and consisted of a session in which visitors first attended a theater show (15 minutes) and then visited an exhibition space (maximally 45 minutes). Both the theater show and exhibition space were developed around the theme of shadows. The theater show was a combination of shadow play, mime play and a brief discussion with an explainer, and the exhibition space consisted of five sets of interactive exhibits (see Figure 1 for an impression of the theater show and exhibition space). 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 goals for the exhibition were determined. First, the exhibition focused on offering explicit science content. Specifically, it illustrated a number of physical principles related to shadows. The principle most relevant to this study was that an object can have shadows of different sizes dependent on its distance to the light source. Other illustrated principles were 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 touched these principles, and the exhibition space covered each of these principles by one or more sets of exhibits.

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

Third, the exhibition focused on parental guidance of preschoolers' exploration. In contrast to other exhibitions in NEMO, child and parent could only sign up for the exhibition together. The theater show aimed at refreshing parents' knowledge in order to optimize parental guidance of children's exploration (see the Introduction section). In addition, child and parent were addressed as a team by the explainer and the exhibit labels. Last, the exhibition space contained several exhibits that were explicitly designed for child and parent to engage with together, that is, these exhibits consisted of games for two people. For example, at one exhibit one person held three-dimensional objects behind a screen, and the other person guessed what these were based on their two-dimensional shadows.

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 setup for the shadow task, the shadow machine, consists of two light sources, a screen placed 50 centimeters from the light sources and puppets that can be placed in between the light sources and screen (see Figure 3). 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 × 2.25 centimeters and two large ones measuring 10 × 3 centimeters. The puppets could be placed at three distances from the light sources: 10, 20, and 30 centimeters. For each item the experimenter 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

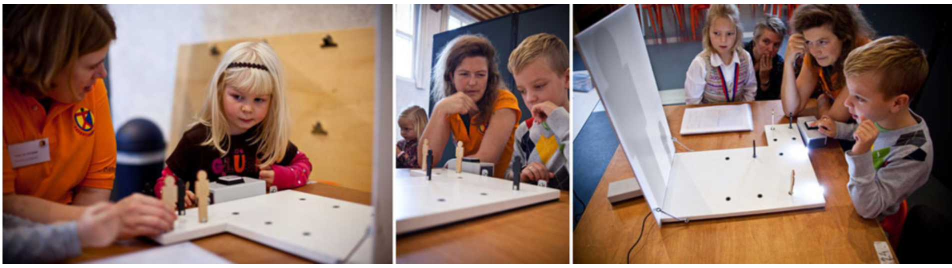

Figure 3. The shadow task.
Note. During task administration for the study described in this paper, no other children were present. Photography: Hanne Nijhuis.

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.[2]

For the pre-task (15 minutes) the experimenter introduced the task by demonstrating how the shadow machine worked: 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.[4] For the post-task (15 minutes) 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 pretask. The distance items had not been used before. Importantly, during item administration children did not manipulate the puppets, nor saw any shadows and therefore did not get any feedback. Responses were scored trichotomously: correct (“left biggest” or “right biggest” depending on the specific item), incorrect “different” (“left biggest” or “right biggest” depending on the specific item), or incorrect “the same size” (“the same size” was never a correct response with the used apparatus and hence always incorrect). Making the distinction between two types of incorrect responses (incorrect “different” and incorrect “the same size”) was necessary to be able to differentiate between children using different theories, or rules. For further information on the analysis of children’s response patterns on the pre- and posttask, please see the Statistical Approach for Assessing Learning section.

Exploratory Behavior Scale. To assess preschoolers’ exploratory behavior the EBS was used (for an extended description of the scale see Van Schijndel, Franse et al., 2010; Van Schijndel, Singer et al., 2010). The EBS is a quantitative measure of young children’s interactivity. The scale was developed based on 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 & Mc Call,

[4]A semi-random order was defined as a random order with two restrictions. With the used shadow-task apparatus three different size items could be constructed (both puppets either on the first, second or third distance from the light sources). Each of these items consisted of two mirrored versions: one with the large puppet on the left and the other with the large puppet on the right. The first restriction was that no two mirrored versions of a size item could follow each other. The second restriction was that no more than three similar correct answers (“left biggest” or “right biggest”) could follow each other.

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 1)

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.

1976), and measures the extent to which preschoolers explore their physical environment. Compared to more global measures of visitor behavior, such as holding times (the average time visitors spend at an exhibit; 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 experimenter 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, as well as the highest EBS level that the child demonstrated within the interval. The interobserver reliability was determined by scoring the exploratory behavior of 18 children (20%) double, that is, two experimenters scored children's behavior simultaneously. The reliability was shown to be sufficient: percentage agreement = 83% and kappa = .69.

Explanation Categories. To measure parent explanation, parents' utterances at the SP 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 interobserver 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.

Statistical Approach for Assessing Learning

Several studies have investigated preschoolers' naïve theories in the domain of shadow size (e.g., Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981; Van Schijndel et al., 2015), and these studies had developed methodologies for assessing children's naïve theories in a reliable, nonverbal manner. 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 the Introduction section). He then constructed different item types (see the Materials section), and defined expected responses for these item types for children having different rules. For example, children using the size rule are expected to answer size items correctly, but to say "the same" on distance items. Children using the size and distance-reversed rule are expected to answer size items correctly, but to give the incorrect answer on distance items. Children using the size and distance rule 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 RAM, 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., 2015).

For the pre- and posttask separately, exploratory LCA was used to determine which latent class model described the data, that is, preschoolers' trichotomous patterns of responses (correct, incorrect "different" and incorrect "the same") to the series of items, in the best and most parsimonious manner. Latent class models consist of a number of latent classes, which in this study represented naïve theories, or rules, on shadow size. Models with 1, 2, 3, 4, and 5 classes were fitted to the data by calculating log likelihood estimates of the model parameters with the package depmixS4 (Visser & Speekenbrink, 2010) for

TABLE 2
Explanation Categories and Examples of Parents' Utterances for Each of These Categories at the Shadow Painting Exhibit (See Figure 1)

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.*

the R statistical programming environment (R Development Core Team, 2009). 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 pretask model (log likelihood ratio (80) = 97.15, $p = .09$) and the posttask 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., 2015).

RESULTS

Descriptive Overview of Child and Parent Behavior

In this study a wide range of child and parent behaviors was measured at several exhibits. The Shadow Painting (SP) exhibit was selected for transcribing and coding of parent explanation, because child–parent teams interacted longest with this exhibit. As the research questions concerned relationships between parent explanation and children's exploratory behavior and learning, descriptive results are therefore reported separately for both the total exhibition and the specific SP exhibit.

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, $SD = 12.24$). Correlations showed that teams' holding times (total exhibition and SP exhibit) were not related to children's or parents' age. t-tests showed that teams' holding times (total exhibition and SP exhibit) did not differ according to children's or parents' gender.

Preschoolers' Exploratory Behavior. On average children demonstrated a mean EBS level of 2.32 (range 1.69–2.59, $SD = 0.15$) in the total exhibition. For the SP exhibit this was 2.40 (range 1.55–2.89, $SD = 0.23$). Correlations showed that children's exploratory behavior at the total exhibition ($r = .37$, $p < .01$) and at the SP exhibit ($r = .40$, $p < .01$) was related to their age in months: older children played at higher EBS levels than younger children. t-tests showed that children's exploratory behavior (mean EBS levels total exhibition and SP exhibit) did not differ according to their gender.

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 3 for the mean number of utterances from each of the explanation categories that was made at the SP exhibit). 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 3 for the mean number of utterances from each of the explanation categories that was made per time interval at the SP exhibit). 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 relationship between children's exploratory behavior and parent explanation.

Correlations showed that the amount of navigation-related directions was related to children's age in months ($r = -.30$, $p < .01$): parents demonstrated a lower mean

TABLE 3
Parent Explanation: Mean Number of Utterances from Each of the Explanation Categories (A) and Mean Number of Utterances From Each of the Explanation Categories Per Time Interval (B) at the Shadow Painting Exhibit

	A. Number of Utterances			B. Number of Utterances per Time Interval		
Explanation Category	Mean (Percentage)	Range	*SD*	Mean	Range	*SD*
Open question	11.48 (8)	0–38	9.00	0.45	0–1.59	0.30
Closed question	21.15 (14)	0–56	13.21	0.82	0–2.32	0.43
Explanation	2.61 (2)	0–11	2.79	0.11	0–.55	0.12
Evidence description	37.13 (26)	4–127	22.08	1.42	0.20–2.61	0.56
Content-related direction	45.34 (31)	7–172	30.92	1.74	0.43–4.59	0.84
Navigation-related direction	3.97 (3)	0–36	5.37	0.17	0–1.33	0.25
Affective talk	5.15 (3)	0–25	4.94	0.21	0–1.08	0.19
Other talk	17.06 (4)	1–54	11.61	0.67	0.09–1.88	0.39
Total	143.88 (100)	28–352	76.03	5.58	2.27–10.96	1.90

number of navigation-related directions per interval when exploring with older children than with younger children. The amount of closed questions ($r = .25, p < .05$) and evidence descriptions ($r = .22, p < .05$) were related to parents' age in years: older parents demonstrated a higher mean number of closed questions and evidence descriptions per interval than younger parents. *t*-tests showed that the amount of causal explanations differed according to parents' gender ($t(84.26) = -2.07, p < .05$): women demonstrated a higher mean number of causal explanations per interval than men. No relationships between explanation (mean number of utterances per interval for each of the seven categories) and children's gender were found. In addition, no relationships between explanation and parents' educational levels were found, but these results have to be interpreted with care, as there was limited variance in educational levels in the study's sample, and it was not possible to create low- and high educational groups of comparable sizes (20% of the parents was assigned to the low educational group, while 80% of the parents was assigned to the high educational group).

Preschoolers' Domain-Specific Learning. As explained in the Methods section, we modeled the pre- and posttask data with a series of latent class models with an increasing number of classes (Table 4 shows the goodness-of-fit measures of the different latent class models). Model selection for both the pre- and posttask resulted in optimal models having four classes, indicating four groups of children showing different response patterns on the series of items. Different response patterns signal the use of different strategies on a task, either reflecting children having different (naive) theories, or rules, on shadow size and answering the items accordingly, or children guessing. Children in the first group had high probabilities of giving correct responses on size items and answering "the same" on distance items. This group was characterized as applying the size rule. As children in the size rule group, children in the second group 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 group was characterized as applying the size and distance-reversed rule. Children in the third group

TABLE 4
Preschoolers' Learning: Goodness-of-Fit Measures for the Fitted Latent Class Models of Response Patterns to Pre- and Post-task

Number of Classes	Pre-task			Post-task		
	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-of-fit measures of the selected 4-class model, which is a specific case of the exploratory 4-class model with equality constraints on the parameters (see the Method section).

had high probabilities of giving correct responses on both the size items and the distance items. This group was characterized as applying the size and distance+ rule. As on the basis of the sole use of size- and distance items in this study children applying the size and distance rule could not be distinguished from children applying a more advanced rule in which they combined the size and distance dimensions (see, e.g., Siegler's (1981) Rule 3 or Rule 4), the plus sign (size and distance+ rule) was used to indicate the possible use of a more advanced rule. Children in the last group showed incoherent responses to the size and/or distance items. These responses were hard to interpret as a rule and therefore this group was denoted as guessing. Figure 4 shows the group sizes for the four groups on the pre- and posttask, and the probabilities of responses to size- and distance items given membership of a specific group.

The most likely group membership was calculated for each child individually based on the posterior probabilities given the selected 4-group-models (e.g., McCutcheon, 1987). ANOVA's showed that the rule groups on the pretask did not differ in age, but the rule groups on the posttask did ($F(3,85) = 8.22$, $p < .001$): post hoc tests with Bonferroni corrections showed that children in the size and distance+ group had a higher mean age in months than children in the size group ($t(45) = -4.95$, $p < .001$). Chi-square tests showed that there were no relationships between children's rule-use on pre- or posttask and their gender.

To examine children's learning, we inspected the crosstabs of children's rule-use on the pre- and posttask (see Table 5). Of the 64 children that did not apply the most advanced rule (size and distance+ rule) on the pretask, 21 children (33%) applied a more advanced rule on the posttask than on the pretask, 40 children (62%) showed consistency in rule-use, and 3 children (5%) applied a less advanced rule on the posttask than on the pretask. Analyses concerning children's learning were performed on the total group of children that did not apply the most advanced rule on the pretask ($N = 64$). 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. A t-test showed that the learning groups did not differ in age. A chi-square test showed that there was no relationship between children's learning and their gender.

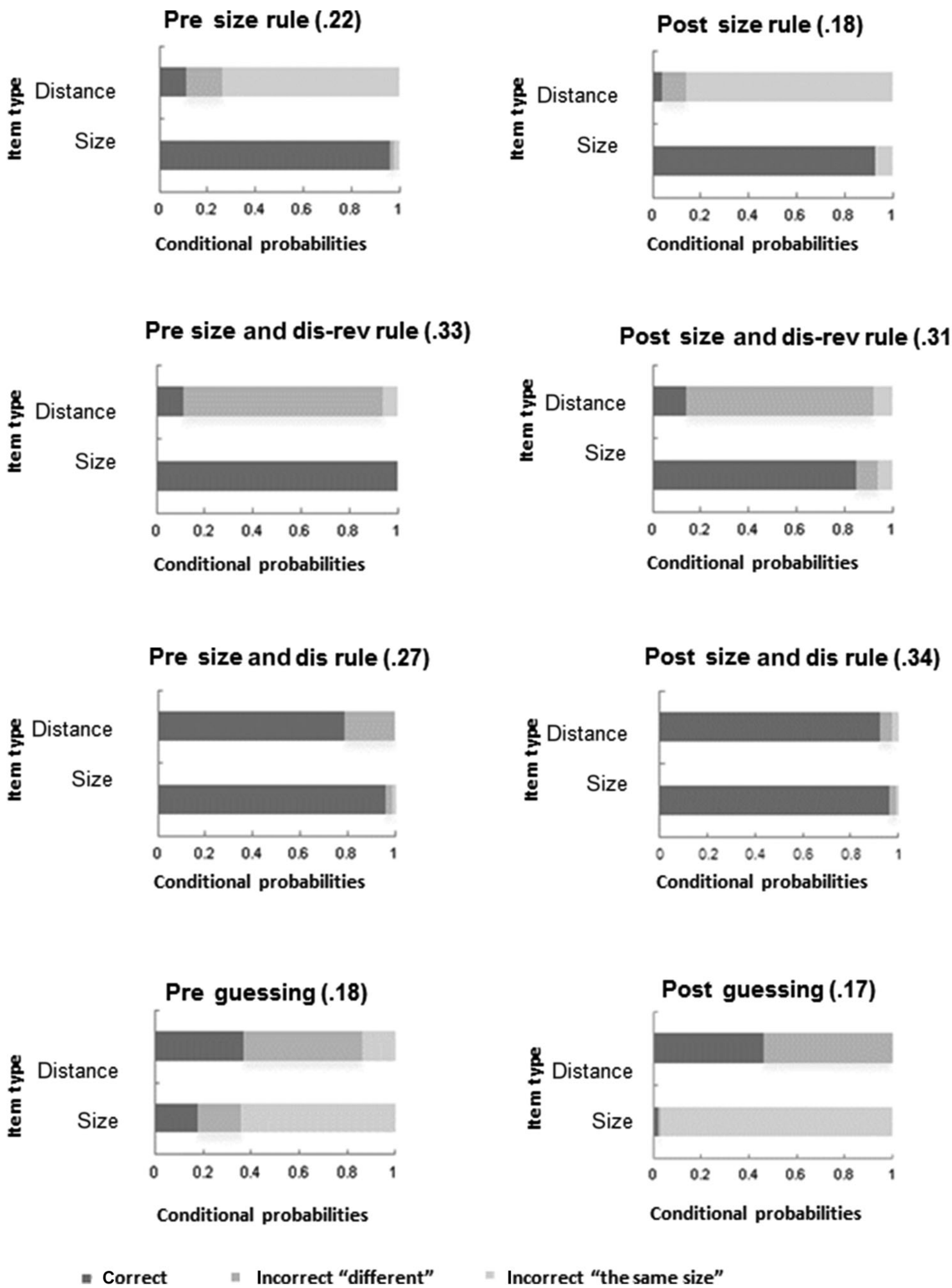

Figure 4. Preschoolers' learning: model parameters for the selected pre- and posttask models: group sizes (unconditional probabilities; between brackets), and probabilities of responses to size- and distance items given membership of a specific group (conditional probabilities).

TABLE 5
Preschoolers' Learning: Crosstabs of Rule Use on the Pre- Versus the Post-task

		Post-test				
		Guess	Size rule	Size and distance-rev rule	Size and distance+ rule	Total
Pre-test	Guess	9 (60)	2 (13)	3 (20)	1 (7)	15 (100)
	Size rule	0 (0)	14 (70)	2 (10)	4 (20)	20 (100)
	Size and distance-rev rule	3 (10)	0 (0)	17 (59)	9 (31)	29 (100)
	Size and distance rule	3 (12)	0 (0)	5 (20)	17 (68)	25 (100)
	Total	15 (17)	16 (18)	27 (30)	31 (35)	89 (100)

Theater Attendance. MANOVA's showed that there were no effects of theater attendance on the teams' holding times, children's exploratory behavior, or parent explanation. However, a chi-square test showed a relationship between theater attendance and learning: 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 posttask than on the pretask ($X^2(1) = 4.92$, $p < .05$).

Research Question 1: Relating Parent Explanation to Preschoolers' Exploration

To investigate whether parent explanation significantly predicted preschoolers' 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.[5] 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,[6] 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

[5] 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.

[6] 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.

TABLE 6
Multiple Regression Models Predicting Preschoolers' Exploratory Behavior (Mean EBS Level at the Shadow Painting Exhibit)

	B (*SE*)	β
Model 7 predictors:		
Constant	1.66 (0.17)	
Theater attendance (T)	0.02 (0.04)	.04
Age in months (C)	0.01 (0.00)	.41***
Mean number of open questions per interval (P)	0.03 (0.10)	.03
Mean number of closed questions per interval (P)	−0.03 (0.07)	−.06
Mean number of causal explanations per interval (P)	0.30 (0.19)	.16
Mean number of evidence descriptions per interval (P)	0.10 (0.05)	.25*
Mean number of content-related directions per interval (P)	−0.03 (0.03)	−.11
Model 2 predictors:		
Constant	1.67 (0.16)	
Age in months (C)	0.01 (0.00)	.39***
Mean number of evidence descriptions per interval (P)	0.09 (0.04)	.23*

Note. B, un-standardized beta coefficient; *SE*, standard error; β, standardized beta coefficient; T, team; C, child; P, parent; Model 7 predictors: $R^2 = 0.24$, $R^2 adj = 0.18$, $F(7,81) = 3.71^{**}$; Model 2 predictors: $R^2 = 0.21$, $R^2 adj = 0.19$, $F(2,86) = 11.44^{***}$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

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).

Research Questions 2 and 3: Relating Preschoolers' Exploration and Parent Explanation to Preschoolers' Domain-Specific Learning

To investigate whether preschoolers' exploratory behavior and parent explanation significantly predicted preschoolers' domain-specific 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.[7] Last, learning was

[7] Despite the fact that there was no simple relationship between children's age and learning (in Section "Preschoolers' Domain-Specific Learning," it is reported that the learning and no-learning groups did not differ in age), a more complicated relationship existed: older children had a higher chance of learning, but only when exploratory behavior was included in the regression model, that is, the relationship between age and learning only existed within exploratory behavior groups.

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	0.36 (3.24)			
Theater attendance (T)	1.39 (.67)*	1.08	4.02	15.00
Age in months (C)	0.11 (0.05)*	1.10	1.11	1.22
Mean EBS level (C)	−4.03 (1.75)*	0.00	0.02	0.55
Mean number of open questions per interval (P)	−2.89 (1.64)	0.00	0.06	1.38
Mean number of closed questions per interval (P)	−0.33 (1.16)	0.07	0.72	6.94
Mean number of causal explanations per interval (P)	−1.57 (3.46)	0.00	0.21	182.79
Mean number of evidence descriptions per interval (P)	0.83 (0.83)	0.45	2.29	11.63
Mean number of content-related directions per interval (P)	0.80 (0.50)	0.85	2.23	5.90
Model 3 predictors:				
Constant	−0.51 (2.93)			
Theater attendance (T)	1.64 (0.04)*	1.49	5.15	17.80
Age in months (C)	0.09 (0.04)*	1.01	1.09	1.18
Mean EBS level (C)	−2.88 (1.41)*	0.00	0.06	0.90

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: $R^2 = 0.36$ (Nagelkerke); Model $\chi(8) = 19.36^*$; Model 3 predictors: $R^2 = 0.24$ (Nagelkerke), Model $\chi(3) = 12.26^{**}$, $^*p < .05$, $^{**}p < .01$.

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).

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, relationships between parent explanation, children's exploratory behavior, and their domain-specific learning in a shadow exhibition.

The first research question concerned the relationship between parent explanation and preschoolers' exploratory behavior. Fender and Crowley (2007) did not find a relationship between parent explanation and young children's exploration. However, they focused on one type of explanation: causal explanations. In this study, the relationships between multiple types of parent explanation and preschoolers' exploration were investigated. We found a relationship 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. One explanation for this finding is that parents' evidence descriptions guide preschoolers' exploration by directing or maintaining children's attention to relevant task aspects or evidence resulting from their manipulations. For example, a relevant task aspect at the Shadow Painting exhibit is the principle that an object can have shadows of different sizes dependent on its distance to the light source. Examples of evidence descriptions guiding children's attention to this task aspect are: "The tree is smaller than the house," and "Now the rabbit is getting very big." Parents' evidence descriptions could also be related to the principle that a colored object can have a black or a colored "shadow" dependent on its transparency: "Look, this one is red and this one is blue, but they have the same shadow," and "Yes, it is transparent." 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. From a constructivist perspective (e.g., Inhelder & Piaget, 1964; Wellman & Gelman, 1992) that considers the social context "input" to the child's learning process (Callanan & Valle, 2008), this is a plausible explanation for the finding of a positive relationship between parents' evidence descriptions and preschoolers' exploratory behavior. However, it is important to keep in mind that no causal conclusions can be drawn on the basis of this result. The correlational finding does not exclude the possibility of a third factor affecting both parent explanation and child exploration. Nor does the finding reveal the nature of the interaction between child and parent at the exhibit: possibly children's exploratory behavior has affected parents' evidence descriptions (Van Geert & Steenbeek, 2005). However, as our main interest is in effective ways for adults to guide preschoolers' exploration, we consider it important for future research to investigate what mechanisms are underlying this relation by replicating this result with an experimental paradigm (Haden, 2010).

The second research question concerned the relationship between preschoolers' exploratory behavior and their domain-specific learning. First, we investigated children's knowledge of shadow size and distinguished three groups of children with different naïve theories and a group of children with incoherent responses on the basis of both the pre- and the posttask data. The detected theories were similar to those found in previous studies (Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981; Van Schijndel et al., 2015), and for the posttask data they were age related. We subsequently investigated whether children learned during their visit to the exhibition, that is, whether they had a more advanced theory after visiting the exhibition compared to before. It was found that a third of the preschoolers who did not use the most advanced theory on the pretask (size and distance+ rule, taking into account both the size and the distance dimension) learned. Concerning the research question, in line with studies in more controlled settings (Bonawitz et al., 2012; Schulz et al., 2007; Van Schijndel et al., 2015), a relationship was found between preschoolers' exploratory behavior and learning. This relationship only existed when age was included in the regression model, that is, it only existed within age groups. However, in contrast to the findings of the controlled studies, in the present study this relationship was negative: children who demonstrated higher mean levels of exploratory behavior were less likely to learn than children who demonstrated lower mean levels of exploratory behavior. This unexpected result may be due methodological differences. 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 Exploratory Behavior Scale to determine the general level to which children explored their physical environment. Possibly, children's high levels of exploratory behavior reflected them exploring a different principle than the relationship between object size, object distance, and shadow size. For example, they might have investigated the relationship 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 relationship between generating evidence and learning in this study compared to the studies in controlled settings (Bonawitz et al., 2012; Schulz et al., 2007; Van Schijndel et al., 2015), 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 relationship 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; Schulz et al., 2007; Van Schijndel et al., 2015). Possibly, the lower mean levels of exploratory behavior 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.

The third research question concerned the relationship between different types of parent explanation and preschooler's domain-specific learning. Fender and Crowley (2007) found a relationship 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 relationships between parent explanation and children's learning were found. One explanation for the lack of this relationship 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 relationships 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).

To summarize the results on children's domain-specific learning, neither a positive relationship between children's exploration and learning, nor between parent explanation and children's learning was found. One might relate these findings to the choice of a learning measure that was developed for research in controlled settings. On the one hand, the use of such a measure has clear advantages. Research in controlled settings has come up with reliable methodologies for assessing children's naïve theories on shadow size, and clear descriptions of the theories that are held by preschoolers (e.g., Chen, 2009; Ebersbach & Resing, 2007; Siegler, 1981; Van Schijndel et al., 2015), On the other hand, the choice for such a learning measure did imply we only assessed children's learning in the narrow domain of shadow size. The use of domain-general learning measures not only focusing on children's cognitive learning, but also on their affective and social learning (e.g., Feder, Shouse, Lewenstein & Bell, 2009), would have had the advantage of sketching a more complete picture of the preschool age group's informal learning in a museum setting.

An additional 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. This finding is in line with several studies showing that museum theatre enhances visitors' learning and experience (e.g., Baum & Hughes, 2010; Jackson & Leahy, 2005). Baum and Hughes (2010) summarized a series of theatre evaluations at the Museum of Science in Boston. They concluded that theatre caused enjoyment, knowledge gains, and the expression of abstract and complex ideas. Jackson and Leahy (2005) used a qualitative approach to investigate whether and how museum theatre affected 10- and 11-year-olds' experiences. Even though the type of theatre in Jackson and Leahy's study, single character historical storytelling, differed from the type of theatre we used, shadow- and mime play, some of their conclusions might be applicable to our findings. It was found that both theatre and object handling/role play stimulated children's active learning, Specifically, the theatre condition was described as capturing children's imagination and holding their attention. Children strongly responded to the narratives, and demonstrated more empathy. Our findings could be connected to the ideas of active learning, capturing children's imagination, and enhanced recall of (mime) narratives. As the finding of a positive effect of theater attendance on children's learning is relevant for the field of informal science education, further research into the robustness and mechanisms of the effect is needed.

As exploratory behavior is considered a key ingredient of children's visit to science museums (Allen, 2002, 2004), studies investigating effects of parent guidance on children's learning experiences are highly relevant to the practice of informal science learning. The present study's results suggest new directions for developing preschooler activities in science museums. The setup of the exhibition, being in an isolated room with predefined visitor slots, resulted in very large holding times and intensive play at the exhibits. Moreover, we found an interesting relation between parent explanation and children's exploration, suggesting that preschoolers benefit from external attentional control. Based on these results, we think that accounting for children's limited executive functions would be an interesting direction to further explore in designing exhibits for the young age group.

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