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 3

The Exploratory Behavior Scale: Assessing young visitors' hands-on behavior in science museums

Van Schijndel, T. J. P., Franse, R. K., & Raijmakers, M. E. J. (2010). The Exploratory Behavior Scale: Assessing young visitors' hands-on behavior in science museums. *Science Education, 94,* 794–809.

ABSTRACT

In this paper we introduce the Exploratory Behavior Scale (EBS), a quantitative measure of young children's interactivity. More specifically, the EBS is developed from the psychological literature on exploration and play and measures the extent to which preschoolers explore their physical environment. A practical application of the EBS in a science museum is given. The described study was directed at optimizing parent guidance in order to improve preschoolers' exploration of exhibits in science center NEMO. In experiment 1 we investigated which adult coaching-style resulted in the highest level of exploratory behavior at two exhibits. In experiment 2 we investigated if informing parents about an effective way of coaching influenced preschoolers' exploratory behavior at two exhibits. The results of the study demonstrate the added value of the EBS in visitor behavior research: compared to existing global measures of visitor interactivity, the EBS adds information about the quality of the hands-on behavior. Compared to existing detailed measures of visitor interactivity, the EBS has the advantage of being applicable in different museum settings and enabling comparisons between exhibits or exhibitions. In addition, the EBS allows for quantification of unanticipated behavior.

INTRODUCTION

Interactivity is seen as a vital characteristic of science museums (Allen, 2004). Visitors spend more time at interactive exhibits than at non-interactive exhibits (Richards & Menninger, 2003 in Allen, 2004; Sandifer, 2003) and interactivity is associated with better learning and recall of information (Borun & Dritsas, 1997 in Allen, 2004; Madden, 1985 in Ramey-Gassert, Walberg & Walberg, 1994; Schneider & Cheslock, 2003 in Allen, 2004). The effects of different aspects of interactivity on visitor behavior and learning have been studied (e.g. Afonso & Gilbert, 2007; Sandifer, 2003). For example, Sandifer (2003) found that open-endedness and technological novelty influence the amount of time visitors spend at exhibits. Interactivity is an important ingredient in adult visitors' science museum experience, but it is an indispensable part of young children's visit. Hands-on experiences are considered crucial for this group's science learning (French, 2004; Gelman & Brenneman, 2004; Neuman, 1971). The emphasis on interactivity with respect to young children, calls for a strong need to investigate this age group's on-exhibit behavior. The aim of this paper is to introduce the Exploratory Behavior Scale (EBS), a quantitative measure of preschoolers' hands-on behavior that allows for assessing the quality of children's exploration in different museum settings. Before introducing the EBS, we will present a brief overview of frequently used measures for visitor behavior in science museums.

Research with regard to visitor behavior in science museums is also described as research into visitors' learning-related behaviors (McManus, 1987), visitors' learning-associated behaviors (Boisvert & Slez, 1994) or visitors' learning agenda's (Dierking & Falk, 1994).

Global time-based measures of visitor behavior have been used in the majority of studies that concern visitor behavior at the exhibit level (e.g. Boisvert, 1994, 1995; Edu, Inc., 2004, in Brody, Bangert & Dillon, 2008; McManus, 1987; Randi Korn & Associates, Inc., 2002 in Brody et al., 2008; Sandifer 1997, 2003). Frequently used measures in these studies are the average time visitors spend at an exhibit (holding time) and the percentage of visitors that stop at a certain exhibit (attraction power). Other well-known measures concern the time visitors talk to each other at exhibits, the time they interact or play with exhibits and the time they spend reading at exhibits. These measures have been used to compare different science museums, exhibitions and exhibits (e.g. Boisvert, 1995; Sandifer, 2003) and the behavior of different visitor groups (e.g. Boisvert, 1994; McManus, 1987; Sandifer, 1997). In most of these studies, descriptive or correlational research methodologies have been used and data has been gathered by means of observations or tracking software (see Brody et al. (2008) for an overview of research methodologies and data acquisition methods in the field of informal science learning). It can be concluded that these time-based measures have the advantage of being non exhibit-specific, enabling quantitative comparisons between museum settings. These measures, however, provide little information about the quality of visitor behavior.

In other studies, more detailed measures of visitor behavior have been used. Instead of solely recording the time visitors' talk to each other at exhibits, the content of visitors' conversations has been analyzed. These analyses have been used to investigate the use of specific exhibits (e.g. Meisner et al., 2007; Tunnicliffe, 2000) and to investigate how parents guide their children's science learning (e.g. Ash, 2003; Fender & Crowley, 2007; Siegel, Esterly, Callanan, Wright & Navarro, 2007). More detailed measures for physical interactivity have also been applied. Instead of solely recording the time visitors interact with exhibits, the patterns of interaction individuals have with exhibits have been analyzed. This technique has been done in ethnographical studies (e.g. Meisner et al., 2007), but also in a more quantitative manner (e.g. Crowley et al., 2001; Fender & Crowley, 2007). Crowley et al. (2001) investigated the effect of parent and peer presence on four- to eight-year-olds exploration of the zoetrope exhibit at the Children's Discovery Museum in San Jose, California.[1] To make a detailed analysis of children's exploratory behavior, two main operators of the zoetrope exhibit were defined: spinning the cylinder or not spinning the cylinder (rotation state) and looking through the slots or looking over the top (observational vantage point). An evidence space of the exhibit consisting of four categories was defined by the factorial combination of rotation state and observational vantage point. By means of observations, it was determined if children viewed each category of evidence and if they viewed combinations of categories of evidence. In a follow-up study, Fender and Crowley (2007) used the same measure to investigate the effect of parent explanation on three- to eight-year-olds' exploration of the zoetrope exhibit at the Children's Museum of Pittsburgh. In most of the studies in which detailed measures of visitor behavior have been used, descriptive, correlational or ethnographical research methodologies have been applied and data has been gathered by means of observations (Brody et al., 2008). The detailed measures provide valuable information about the quality of visitors' behavior; visitors' exploration of exhibits, understanding of exhibits, inquiry skills, and patterns of social interaction. The majority of these measures, however, do not allow for comparison across museum settings because of their exhibit-specific nature (Crowley et al., 2001; Fender & Crowley, 2007; Tunnicliffe, 2000).

Based on this review, it can be concluded that a tradeoff has to be made between being able to measure visitor behavior in different museum settings and being able to describe visitor behavior on a more detailed level. With regard to measuring interactivity, holding times or interaction times allow quantitative comparisons between exhibits and exhibitions, but do not provide information on how and on which level visitors interact with exhibits. The measure Crowley et al. (2001) used for interactivity, on the other hand, gives insight in how visitors manipulate the zoetrope exhibit and what kind of evidence they encounter, but the use of this measure is restricted to this one exhibit and does not include behavior that was not anticipated. The tradeoff between global and detailed measures is more difficult when focusing on young visitors' behavior because the assumptions about the informative values of both types of measures are less straightforward for this age group. With regard to the global measures, it is often assumed that longer holding times correspond to more opportunities to learn or even to more learning taking place (Serrell, 1998; Smith, 1990 in Ramey-Gassert, Walberg & Walberg, 1994). However, especially for the preschool age group, this assumption is not necessarily the case. Children are known to be inefficient in the exploration of evidence (e.g. Schauble, 1996). Preschoolers tend to manipulate materials in the same manner for relatively long periods of time. Therefore, a more detailed analysis of children's hands-on behavior will yield more information about preschoolers' opportunities to learn than the time-based measures. With regard to the detailed measures of visitor behavior, measures relying on visitors' language use have less informative value for the young visitor group than for older visitor groups. Preschoolers' verbal utterances cannot be considered an accurate reflection of their level of reasoning as logic-in-action precedes verbal reasoning in young children's development (Gifford, 2004; Inhelder & Piaget, 1964; Singer, 2002). Large individual differences in language skills exist in the preschool age range and a measure of children's reasoning relying on verbal utterances could easily be confounded with children's language skills. Therefore, focusing on preschoolers' actions will yield more information about this age group's reasoning than focusing on their verbalizations.

In this paper we introduce the Exploratory Behavior Scale (EBS), a quantitative measure of preschoolers' hands-on behavior that allows for assessing the quality of children's exploration in different museum settings. The EBS is focused on measuring preschoolers' exploration of their physical environment, as from a psychological point of view exploration is a key concept in the description of young children's behavior. In the next part of this paper, we will describe the EBS and its psychometrical characteristics. Next, we will give an example of a study in which the EBS is used. Finally, we will discuss the added value of the EBS compared to existing measures of interactivity on the basis of the results of the described study.

THE EXPLORATORY BEHAVIOR SCALE

The Exploratory Behavior Scale (EBS) is developed from the psychological literature on exploration and play. Exploration is considered an important factor in children's cognitive and social development (e.g. Rusher, Cross & Ware, 1995; Weisler & Mc Call, 1976) and a universal activity in play from infancy into childhood (Sutton-Smith, 1975). The exploration process has been described as changing with age; exploration becomes increasingly sophisticated with age and certain phases of the exploration process are reduced or eliminated with maturation (e.g. Zaporozhets, 1970 in Forman & Kuschner, 2005; Weisler & McCall, 1976). For the preschool age group that we developed the EBS for, we are interested in the quality of their exploratory behavior, i.e. the quality of their interaction with the physical environment. For infants, the quality of exploratory behavior has been found to correlate with measures of cognitive ability (Jennings, Harmon, Morgan, Gaiter & Yarrow, 1979). Additionally, infant exploratory competence has been found to correlate with caregiver stimulation and responsiveness (Belsky, Goode, & Most, 1980; Fortner-Wood & Henderson, 1997). To define the EBS levels, process descriptions of exploration as well as existing measures of exploration and play were examined in order to distinguish aspects of behavior that could be included in the scale. Two behaviors were found to be prominent in exploration measures as well as in play measures: manipulation of the physical environment and sustained attention (Dunn, Kontos & Potter, 1996; Rubenstein & Howes, 1979; Smilansky, 1968; Weisler & McCall, 1976). The time spent manually or visually investigating new objects or environments is often taken as a measure of exploration (Weisler & McCall, 1976). Furthermore, in play scales manipulation of the physical environment can be performed in the presence of sustained attention (*active use of objects*) or in the absence of sustained attention (*passive use of objects)* (e.g. Dunn, Kontos & Potter, 1996).

However, manipulation and sustained attention only give a limited specification of *how* children explore the environment. Therefore, to distinguish high-level exploratory behavior, another aspect of behavior that is part of the exploration process was employed: repetition with variation (Forman & Kuschner, 2005; Lindahl & Pramling Samuelsson, 2002). For instance, Forman and Kuschner (2005) refer to this kind of behavior when mentioning 4- and 5-year-olds who transform objects, for example they rotate or remove the mirrors of a periscope, in order to discover the workings of an object. This compound of behaviors, manipulation, sustained attention and repetition with variation, comprises high-level exploratory behavior and could be compared to scientific-reasoning-in-action. An example of high-level exploratory behavior is a young visitor of a science museum who actively manipulates the exhibit "Rolling, Rolling, Rolling" (see Figure 1A) by rolling a cylinder down different tracks and who attentively observes the effect of the different surface materials of the tracks on the speed of the cylinder. With this high-level exploratory behavior, the child creates exemplars of exhibit-specific phenomena; in this case that a cylinder rolls faster over a smooth surface than over a rough surface. The sequence of behaviors that Crowley et al. (2001) refer to as combinations of categories of evidence at the zoetrope exhibit, would also be considered high-level exploratory behavior. For instance, a child could spin the cylinder and look over the top and then spin the cylinder again and look through the slots. It is important to note that high-level exploratory behavior is not necessarily related to the purposes of the exhibit. If a child applies variation by rolling cylinders up and down the ramp or by investigating how and if a square object can also roll down the ramp, this behavior would be seen as high-level exploration (see also Discussion).

The EBS was designed to have three levels of increasingly extensive exploration of the physical environment: 1) *passive contact*, 2) *active manipulation*, and 3) *exploratory behavior*.[2] Table 1 gives a short description of the EBS levels and examples of children's behavior. The complete EBS and accompanying coding procedures are described in a technical report (Van Schijndel, Singer & Raijmakers, 2007).

Psychometrical characteristics of the Exploratory Behavior Scale

For an observational instrument to be a useful measure of behavior, different observers need to be able to apply the instrument in the same manner and rate behavior in similar ways. To assess the consistency of scoring between multiple observers, inter-observer reliabilities and Kappas are calculated. For the Exploratory Behavior Scale (EBS), this has been done in different settings. Studies in science museum settings yielded percentage agreements of 81% (Dreef & Eriksson, 2007) and 92% (Van Beek, 2008). Matching Kappas were respectively 0.63 and 0.81. According to Sattler (2002), Kappa values of 0.40 to 0.69 indicate fair to good agreement. Studies in childcare and development settings, in which an extended version of the EBS was used, yielded average percentage agreements of 78% (Van Schijndel, Singer, Van der Maas & Raijmakers, 2010 / Chapter 2) and 82% (Tiemersma & Van den Berg van Saparoea, 2007).[2] Matching Kappas were 0.56 and 0.64. The test-retest reliability of the extended version of the EBS was established in a childcare and development setting: correlations between two administrations of $r=0.53$, $p<0.10$ and $r=0.74$, $p<0.01$ have been found (Tiemersma & Van den Berg van Saparoea, 2007). It is typically expected that on average, older children show a higher level of exploratory behavior than younger children (Zaporozhets, 1970 in Forman & Kuschner, 2005). Therefore, a significant positive relation between EBS level and age can be considered evidence for the validity of the EBS. In a childcare and development setting, a correlation of $r=0.43$, $p<0.05$ has been found between mean EBS level (extended version) and age (Van Schijndel et al., 2010 / Chapter 2).

A: The Exhibit “Rolling, rolling, rolling” in science center NEMO

The exhibit consists of a wooden ramp with three descending tracks: one covered with artificial grass, one covered with carpet and one without covering. Six cylinders are provided: three made out of PVC and three made out of wood. The PVC cylinders are heavier than the wooden ones. The exhibit is designed for children to investigate the effect of track covering (friction resistance) and cylinder weight (gravity) on the speed of the cylinder when it rolls down the ramp (note that the former has an effect and the latter has not).

B: The exhibit “Spinning Forces” in science center NEMO

The exhibit consists of a chair that can be spun around and two blocks with handles, adapted to children‟s size. The exhibit is designed to investigate how the position of the blocks influences the speed with which a person sitting on the chair spins around. One goes faster when holding the weights close to the body (rotation axis) than when holding the weights far away from the body. A screen next to the exhibit shows a video clip in which a young ice-skater demonstrates the principle to be investigated with blocks similar to those provided at the exhibit.

FIGURE 1. The exhibits “Rolling, Rolling, Rolling” (A) and “Spinning forces” (B) at science center NEMO, Amsterdam.

TABLE 1. The Exploratory Behavior Scale (EBS): levels of exploratory behavior and examples of children's behavior at each of these levels at the exhibit "Rolling, rolling, rolling" (see Figure 1).

Level 1 Passive contact: 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 on the side of the exhibit and watches other children play.*
- *A girl leans against the exhibit. She holds a cylinder, but does not manipulate it.*
- *A boy walks around the exhibit with his father. They discuss different parts of the exhibit.*

Level 2 Active manipulation: 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 boy rolls a cylinder down the ramp and follows the cylinder with his eyes.*
- *A boy attentively hits two cylinders against each other and laughs.*
- *A girl rolls two PVC cylinders down a track and then says: "They are fast!"*

Level 3 Exploratory behavior: 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 rolls a wooden cylinder down the track covered with carpet twice after which she rolls the same cylinder down the track covered with artificial grass.*
- *For instance, a boy rolls a PVC cylinder up and down the ramp several times and varies the force he exerts on the cylinder.*
- *A boy rolls a wooden cylinder down the wooden track twice after which he rolls a PVC cylinder down the same track.*

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

A PRACTICAL APPLICATION OF THE EXPLORATORY BEHAVIOR SCALE: THE EFFECT OF PARENTAL COACHING ON PRESCHOOLERS' HANDS-ON BEHAVIOR IN A SCIENCE CENTER

Exhibits in science center NEMO are designed for children from six years and older. However, many families with children in the preschool age group visit NEMO. For this age group, adult guidance is crucial to a successful visit. In several studies, the effects of parent presence on children's hands-on behavior have been demonstrated (Crowley et al., 2001; Fender & Crowley, 2007). Crowley et al. (2001), for instance, found that four- to eight-year-olds that engaged with an exhibit with their parents explored longer, broader, and on a deeper level than children exploring with peers or by themselves. The researchers concluded that the parent-guided group had more opportunity to learn than the other groups of children. Parents are known to take on qualitatively different roles in interacting with their children in science museums (Brown, 1995; Siegel et al., 2007). Therefore, an important question is what characteristics of parent guidance contribute to children's optimal exploration of exhibits. Fender and Crowley (2007) investigated the effect of one of those characteristics, parent explanation, on three- to eight-year-olds' hands-on behavior at an exhibit. Explanation was defined as talk that highlighted causal relations or talk that connected the exhibit to the child's prior knowledge. In line with their hypothesis that parent explanation does not provide children with procedural assistance, the researchers did not find differences in exploratory behavior between children whose parents did explain and children whose parents did not explain. In the present study, the question which aspects of parent guidance influence preschoolers' exploration of exhibits has been further investigated.

The aim of the study was to optimize parent guidance in order to improve preschoolers' exploration of exhibits in science center NEMO. Hence, in experiment 1 we investigated which coaching style resulted in the highest level of exploratory behavior at two exhibits. As observational studies are informative, but not conclusive, the parental roles were performed by trained test leaders and children were randomly assigned to a test leader and coaching style. On the basis of the results of experiment 1, an instructional video was made to inform parents about effective ways of coaching preschoolers in a science museum. Experiment 2 was performed with parents who visited NEMO with their preschoolers. Half of the adults were shown the instructional video and the effect of informing parents on their children's exploratory behavior was determined. In both experiments the exhibits "Rolling, Rolling, Rolling" (see Figure 1A) and "Spinning Forces" (see Figure 1B) were used. These exhibits were chosen because unlike most exhibits in science center NEMO, they were suitable for the age range of the children that participated in the study. "Rolling, Rolling, Rolling" and "Spinning Forces provided ample opportunities for hands-on behavior, exploratory behavior and adult guidance of the child's behavior. In addition, a pilot study demonstrated that preschoolers were attracted to the exhibits and physically capable of operating them.

Experiment 1: The effect of different coaching styles on preschoolers' exploratory behavior

Participants and procedure. Seventy-one four- to six-year-olds (38 girls, 33 boys, M=61 months, SD=7) participated in the experiment. They visited science center NEMO during closing hours with their preschool class. Each child was assigned to one of three test leaders and one of three coaching styles in a random manner, counterbalancing age and gender between the test leaders and coaching styles. The test leader accompanied the individual child to two exhibits, "Rolling, Rolling, Rolling" and "Spinning Forces", and the child was asked to play at the exhibits by oneself.[3] The test leader coached the child in one of the three styles she was trained in: the scaffolding, explaining, or minimal style. When using the scaffolding coaching style, the test leader tried to take the child's investigations to the next level by asking open questions, by acting like she did not understand what was going on and by directing the child's attention to specific parts of the exhibit. In addition, she challenged the child to verbalize his or her thoughts. For example, at the exhibit "Rolling, rolling, rolling" she could ask: "Does the one on this track go as fast as the one on that track? How is that possible?" When using the explaining coaching style, the test leader gave the child explanation about the exhibit; she named causal connections, explained physical principles underlying the exhibit and connected the experience to the existing knowledge of the child. In addition, she demonstrated the workings of the exhibit. For example, at the exhibit "Rolling, rolling, rolling", she could say: "The one on this track goes faster, because this track is smoother than the other track." The minimal coaching style served as the control condition in this experiment. Nothing was explained or demonstrated and no scaffolding took place. When necessary, the test leader encouraged the child to continue playing by making remarks such as "This is a nice game, isn't it?" Independent of the coaching style, the child was encouraged to keep playing at each exhibit for five minutes. Two observers were trained to score children's behavior by means of the EBS. The training consisted of observing and describing preschoolers' behavior at "Rolling, rolling, rolling" and "Spinning forces" and discussing which EBS levels should be assigned to specific behaviors. The observers assessed one child at the time. Per time interval the highest level of exploratory behavior that a child demonstrated within the interval was noted. For "Rolling, rolling, rolling" the used time-interval was 30 seconds and for "Spinning forces" this was 15 seconds.[4] In order to determine the inter-observer reliability, 20 percent of time intervals was double-scored. The inter-observer reliability proved to be good: a percentage agreement of 93%, K=0.79 was found.

Statistical approach. In order to compare children's exploratory behavior at the two exhibits a multivariate repeated measures analysis of variance was conducted with exhibit ("Rolling, rolling, rolling" and "Spinning forces") as within-subjects factor on the following three outcome measures: number of seconds a child showed EBS level 1 behavior, EBS level 2 behavior and EBS level 3 behavior.[5] To investigate the effects of the different coaching styles, for each exhibit separately a factorial multivariate analysis of variance was performed with coaching style (scaffolding, explaining and minimal style), gender (boy, girl) and test leader (test leader 1, test leader 2 and test leader 3) as between-subjects factors on the same three outcome measures. The between-subjects factor test leader was included in the analyses as a control factor to check if possible effects of coaching style were not explained by differences between test leaders. Post hoc tests with Borferroni corrections were used to further explore found effects.

Results. It was found that children's behavior at the two exhibits differed: the exhibit "Rolling, rolling, rolling" elicited more *active manipulation* (EBS level 2; $F(1,70)=5.10$, $p<0.05$), while the exhibit "Spinning forces" elicited more *passive contact* (EBS level 1; $F(1,70)=25.68$ $p<0.001$; see Figure 2).[6] Due to the differences between the exhibits, at each exhibit a different coaching style resulted in the longest period of high-level exploratory behavior. At "Rolling, rolling, rolling" children showed more *exploratory behavior* (EBS level 3) when they were coached with the minimal style, compared to the explaining style ($F(2,53)=7.66$, $p<0.01$; $t(23.32)=4.14$, $p<0.001$; see Figure 3A). Apparently children immediately start playing at the exhibit and reached high levels of exploratory behavior by themselves. The adult's explanation only seemed to interfere with their investigations. At "Spinning forces" children showed more *active manipulation* (EBS level 2) when they were coached with the scaffolding style compared to the explaining style ($F(2,53)=3.84$, $p<0.05$); $t(46)=3.73$, $p<0.01$) and more *exploratory behavior* (EBS level 3) when they were coached with the explaining style compared to the other two coaching styles ($F(2,53)=8.73$, $p<0.01$; scaffolding $t(24.96)=3.25$, $p<0.01$; minimal $t(24.10)=3.35$, $p<0.01$; see Figure 3B). Apparently children did not immediately start playing at the exhibit. They relied on the adult's explanation and demonstration to figure out what could be investigated at the exhibit and how to do that.

At "Rolling, rolling, rolling" no differences between boys and girls were found. At "Spinning forces" girls were found to show more *exploratory behavior* (EBS level 3) than boys when coached with the explaining style, but this was a marginal difference ($F(2,53)=3.61$, p<0.05).

At "Rolling, rolling, rolling" it was found that test leader 2 observed more *passive contact* (EBS level 1) than test leader 1 ($F(2,53)=3.96$, $p<0.05$; $t(34.47)=-2.65$, $p<0.05$). However, no interaction between test leader and coaching style was found. Hence, this effect was not expected to influence the results with regard to coaching style as each test leader had performed each coaching style equally often. At "Spinning forces" no differences between the test leaders were found.

Experiment 1 was performed in a relatively controlled situation; children were observed during closing hours of NEMO and parental rolls were played by trained test leaders. Experiment 2 was designed to investigate the possibility of optimizing parent guidance in a natural setting. Therefore, this experiment was performed during opening hours of NEMO and children were coached by their parents.

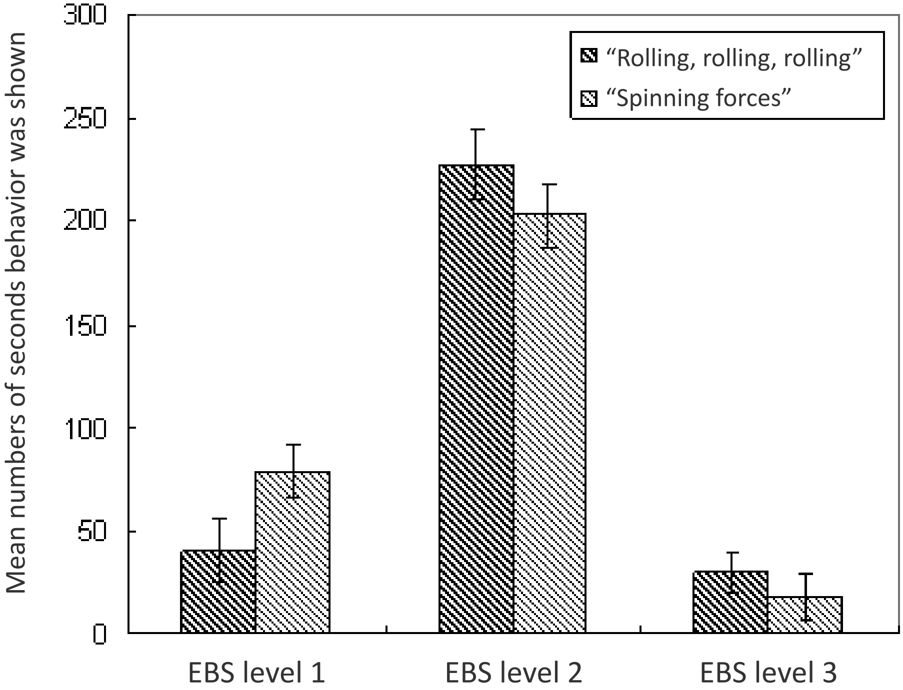

FIGURE 2. Experiment 1: Mean number of seconds that EBS level 1, level 2 and level 3 behavior was shown at the exhibit "Rolling, rolling, rolling" and "Spinning forces". Error bars represent 95% confidence intervals.

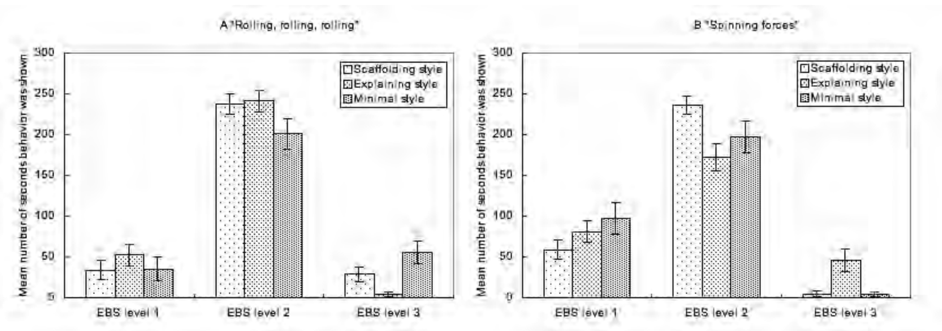

FIGURE 3. Experiment 1: Mean number of seconds that EBS level 1, level 2 and level 3 behavior was shown by the children coached with the scaffolding, explaining and minimal coaching style at the exhibits "Rolling, rolling, rolling" (A) and "Spinning forces" (B). Error bars represent 95% confidence intervals.

Experiment 2: The effect of informing parents about effective coaching on preschoolers' exploratory behavior

Participants and procedure. Seventy-five four- to six-year-olds (31 girls, 44 boys, M=67 months, SD=9) participated in this experiment together with a parent (49 female, 26 male). The sample was representative of the museum population, which is predominantly Caucasian and middle- to upper-class. Parental education was high: 5 parents had low, 19 had middle and 49 had a high educational level (educational levels were available for 73 parents). The parent-child pairs visited science center NEMO during opening hours. Parent-child pairs were assigned to the informed or uninformed condition in a random manner, counterbalancing age and gender of the child over the two conditions. Parents in the informed condition were shown the seven minute video: "How to stimulate your preschooler to exploratory behavior in NEMO". This video was made on the basis of the results of experiment 1. The film started with a short introduction about science center NEMO, after which an explanation of the exhibits "Rolling, rolling, rolling" and "Spinning Forces" followed. Next, parents were advised how to stimulate their preschooler to engage in exploratory behavior on the basis of three steps: *getting to know the material*, *investigating* and *drawing conclusions*. The advice in the video contained elements of all three coaching styles that had been used in experiment 1, the scaffolding, explaining and minimal style, and was demonstrated through carefully selected video-fragments of parent-child pairs playing at "Rolling, rolling, rolling" and "Spinning forces". Parents in both conditions (informed and uninformed) were asked to visit the exhibits "Rolling, rolling, rolling" and "Spinning Forces" with their child. Trained observers (who also participated in experiment 1) recognized participants by badges on their shirts and children's hands-on behavior was scored with the EBS. As in experiment 1, the observers assessed one child at the time. Per time interval the highest level of exploratory behavior that a child demonstrated within the interval was noted. For "Spinning forces" the used time-interval was 15 seconds and for "Rolling, rolling, rolling" this was 40 seconds.[4] The inter-observer reliability proved to be good: a percentage agreement of 91%, K=0.83 was found.

Statistical approach. In order to compare children's exploratory behavior at the two exhibits a multivariate repeated measures analysis of variance was conducted with exhibit ("Rolling, rolling, rolling" and "Spinning forces") as within-subjects factor on the following three outcome measures: number of seconds a child showed EBS level 1 behavior, EBS level 2 behavior and EBS level 3 behavior.[5] To investigate the effects of informing parents about an effective coaching-style, for each exhibit separately a multivariate analysis of variance was performed with condition (informed, uninformed) and gender (boy, girl) as between-subjects factors on the three same outcome measures.

Results. With regard to the differences between exhibits, the results of experiment 1 were replicated: the exhibit "Rolling, rolling, rolling" elicited more *active manipulation* (EBS level 2; $F(1,74)$=69.10, p<0.001), while the exhibit "Spinning forces" elicited more *passive* *contact* (EBS level 1; $F(1,74)=13.09$ $p<0.01$; see Figure 4).[6] At both exhibits an effect of informing parents about effective coaching was found. At "Rolling, rolling, rolling" children whose parents had seen the instruction video showed more *active manipulation* (EBS level 2; $F(1,71)=8.96$, $p<0.01$) and *exploratory behavior* (EBS level 3; $F(1,71)=5.02$, $p<0.05$) than children whose parents had not seen the video (see Figure 5A). At "Spinning forces" children whose parents had seen the instruction video showed more *active manipulation* (EBS level 2) than children whose parents had not seen the video ($F(1,71)=5.39$, $p<0.05$; see Figure 5B). These results show that informing parents about an effective coaching-style by means of a short instruction-video has a positive effect on children's exploratory behavior; at both exhibits children of informed parents showed more high-level exploratory behavior. No differences between boys and girls were found at both exhibits.

DISCUSSION

In this paper we introduced the Exploratory Behavior Scale (EBS), a quantitative measure of young children's hands-on behavior. The EBS consists of three levels of increasingly extensive exploration of the physical environment. The EBS has been developed for the preschool age group. Preschoolers are a relatively new visitor group in science museums. However, teaching science to preschoolers is in accordance with young children's intrinsic motivation to explore the world around them and preschoolers can, to a certain extent, reason scientifically (Eshach & Fried, 2005; French, 2004; Gelman & Brenneman, 2004; Greenes, Ginsburg & Balfanz, 2004). As science museums increasingly emphasize their educational role (Ramey-Gassert et al., 1994; St. John & Perry, 1993 in Dierking & Falk, 1994), there is a great demand for research concerning visitor behavior and learning. Few studies have been published that focus specifically on the preschool age group's science museum experiences. As the EBS enables quantification of preschoolers' exploratory behavior at exhibits, it can serve as a useful instrument for generating knowledge about young children's behavior at science museums. The study that was reported in this paper stressed the importance of parent guidance of preschoolers' exploration of exhibits. Another important result for science museums is that fact that parent guidance can be influenced in a positive way with little time-investment. Children that were guided by parents who had watched a seven minute instruction-video showed more high-level exploratory behavior that children whose parents had not watched the video. In this study we offered parents advice with regard to structuring the exploration process of their child by dividing it into three steps. At each step in the exploration process they were shown examples on how to stimulate their preschooler's exploratory behavior. For example, at the second step*, investigating*, they were encouraged ask open questions to direct the child's attention to another part of the exhibit and at the third step, *drawing conclusions*, they were encouraged to let their child summarize what he or she had discovered.

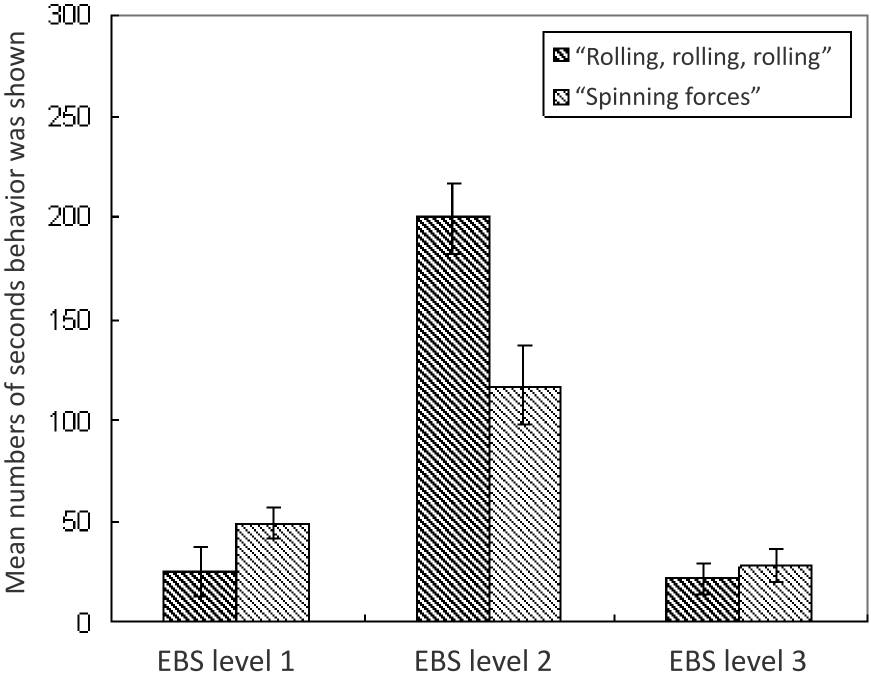

FIGURE 4. Experiment 2: Mean number of seconds that EBS level 1, level 2 and level 3 behavior was shown at the exhibits "Rolling, rolling, rolling" and "Spinning forces". Error bars represent 95% confidence intervals.

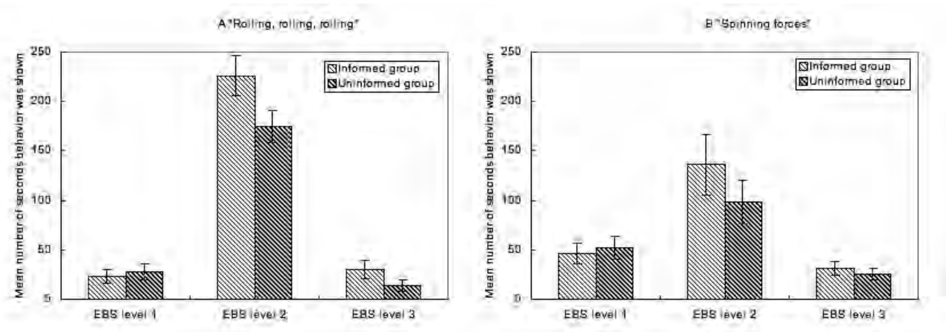

FIGURE 5*.* Experiment 2: Mean number of seconds that EBS level 1, level 2 and level 3 behavior was shown by the informed and uninformed group at the exhibits "Rolling, rolling, rolling" (A) and "Spinning forces" (B). Error bars represent 95% confidence intervals.

The Exploratory Behavior Scale has several advantages compared to other measures of interactivity that have been used to measure visitor behavior in science museums. Regarding its level of detail, the EBS stands between existing global measures of interactivity and more detailed measures. Existing global measures of interactivity, such as holding times or interaction times, do not distinguish between exploratory behaviors of different quality. The EBS on the other hand, gives information about the relative level on which the hands-on behavior takes place. For instance, in the study described in this paper, it was found that the two exhibits differed in the amount of *passive contact* and *active manipulation* they elicited while the effects of adult guidance were visible in the amount of *active manipulation* and *exploratory behavior* the children demonstrated. In comparison to existing detailed measures of interactivity, such as the measure applied by Crowley et al. (2001) and Fender and Crowley (2007), the EBS has the advantage of being applicable in different museum settings and therefore enabling comparisons between different exhibits or exhibitions. In addition, the EBS not only allows for anticipated behavior to be coded, but also unanticipated behavior can be quantified. For instance, the exhibit “Rolling, rolling, rolling” in NEMO is developed to investigate if the weight of a cylinder (gravity) and the covering of a track (friction resistance) have an effect on the speed of a cylinder when it rolls down the ramp. We expected children to vary their actions by using cylinders of different weights and tracks with different coverings. Children did show the expected behavior, but, in addition, they demonstrated unanticipated behavior that seemed related to their own research questions. For instance, several children not only rolled cylinders down the ramp, but also tried rolling cylinders up the ramp. They varied the force they exerted on the cylinders and used cylinders of different weights. By using the EBS, this unanticipated high-level exploratory behavior was taken into account in the description of the exhibit.

The EBS is an observational measure. The use of observations as a method for studying visitor behavior has apparent advantages. Observations are considered unobtrusive (Falk, 1982 in Sandifer, 1997; Serrel, 1998) and as young children are easily influenced by more obtrusive methods, such as think aloud-protocols, tests of surveys (Bronson, 1994; Ginsburg & Golbeck, 2004), observations can be considered a suitable method for assessing the young age group. A second advantage of observations is that they do not rely on visitors’ language use. This is especially important when studying preschoolers, as their verbal utterances cannot be considered an accurate reflection of their level of reasoning. However, the choice for using observations does also bring about certain methodological challenges. One of the challenges is balancing the amount of detail in the observation scale with the practicality of the scale. For a measure to be applicable in different settings, it is necessary to maintain a certain amount of freedom to interpret visitor behavior. However, this freedom must not affect inter-observer reliability. For the EBS, sufficient inter-observer reliabilities were obtained with observer trainings of reasonable lengths. Another challenge when using observational measures in science museums is dealing with the physical dissimilarities between exhibits. Observational measures making use of interval scoring require decisions on the length of the time intervals; intervals must be long enough to allow for the behavior of interest to take place within the interval, but short enough to allow for a reasonable amount of observations. When comparing exhibits, an important question is whether intervals of different lengths should be used. With regard to the use of the EBS, the amount of time that is necessary to execute EBS level 3 behavior depends on the specific exhibit. In the study that was described in this paper, for this reason time intervals of different lengths were used for the exhibits "Rolling, rolling, rolling" and "Spinning forces". The question whether to take into account physical dissimilarities between exhibits not only applies to measures making use of interval scoring, but to all quantitative observational measures. For instance, holding times and interaction times are also influenced by the physical characteristics of exhibits. It is important to be aware of this issue when comparing exhibits with quantitative observational measures.

The Exploratory Behavior Scale has many possible uses in the field of visitor research. As was shown in this paper, the EBS enables answering questions with regard to the level of exploratory behavior different exhibits elicit. In addition, it was shown that the EBS can be used to assess effects of different factors on preschoolers' interaction with exhibits. In this paper the effects of adult guidance were investigated, but other possible factors are the presence of other visitors or the manner in which information about exhibits is conveyed. Besides these topics, another important issue that could be investigated by using the EBS is the relationship between preschoolers' interactivity and learning.[7] Behavioral measures have often been associated with learning. For instance, holding times have been suggested to equal the amount of learning taking place (Serrell, 1998; Smith, 1990 in Ramey-Gassert, Walberg & Walberg, 1994). Few studies, however, have provided evidence for this claim (Sandifer, 1997) and, in spite of the emphasis on hand-on experiences in preschoolers' science learning (French, 2004; Gelman & Brenneman, 2004; Neuman, 1971), none of those studies has been directed at the preschool visitor group. As children are inefficient in their exploration of evidence (e.g. Schauble, 1996), the relationship between interactivity and learning is less straightforward for the preschool visitor group than for older visitor groups. Therefore, a behavioral measure that takes into account the quality of the interaction, such as the EBS, is more suitable for investigating the relationship between interactivity and learning than measures that do not take into account the quality of the interaction, such as holding times or interaction times. When a child plays on a high EBS level, he or she generates exemplars of exhibit-specific phenomena. If the child will learn about the underlying principles of the exhibit from these phenomena, is a question open for investigation. Playing on a high EBS level does imply practicing process skills, such as observation and systematic manipulation, which are considered crucial in preschool science learning (Ginsburg & Golbeck, 2004, Wasserman, 1988).

Quantification of behavior, as is done by means of the EBS, enables comparison between situations, but does lead to a loss of information. Ethnographical studies on visitors' hands-on behavior, such as Meisner et al.'s (2007) study, generate richer and more detailed descriptions of behavior than studies in which quantitative approaches are adopted. Therefore, we recommend the EBS be used in combination with other measures. This recommendation is in line with Brody et al.'s (2008) advice for the use of a variety in research methodologies and data acquisition methods in assessing informal science learning. In terms of the overview of methodologies and methods Brody et al. (2008) propose, the EBS is typically used when adopting descriptive, correlational or experimental research methodologies. These methodologies could complement ethnographical or case study methodologies. The data acquisition method of the EBS, observation, could also be paired with other data acquisition methods, such as interviews or surveys. This combining of methodologies and methods could result in a better view of children's interactivity in science museums.

ACKNOWLEDGEMENTS

This work was funded by the Dutch Organization for Scientific Research (NWO) and the Dutch Curious Minds program, which is supported by the Ministry of Education, Culture and Science and Platform Bèta Techniek. We would like to thank children and parents for their enthusiasm in participating in the studies. Special thanks to the children and parents who were featured in the instructional video. We thank students and student-assistants Lineke van Beek, Karin den Hartog, Linda Heuft, Mirjam Provoost, and Marian Trap for their help in collecting the data. We thank Joris Smaling, Ruben Bulsink en Jomme Keller for their assistance in making the instructional video. We would like to express appreciation to Nico Notebaart and René van de Belt for their audiovisual advice and technical support. We thank Dorothy Mandell and Bianca van Bers for comments on an earlier draft of the paper. Finally, we would like to thank Wouter Weeda for statistical advice.

NOTES

1. The zoetrope is an animation device that produces the illusion of motion through a stroboscopic effect involving persistence of vision and the Phi phenomenon (Crowley et al., 2001).
2. The EBS consists of three levels. The Exploratory Play Scale, that has been used in childcare and development settings, is an extended version of the EBS. The Exploratory Play Scale consists of four levels; construction and pretense play are incorporated into this scale (Van Schijndel, Singer, Van der Maas & Raijmakers, 2010).
3. The order in which the child and test leader visited the exhibits was not counterbalanced.
4. Time-intervals of different lengths have been used at the two exhibits. The length of the intervals was determined on the basis of the time it took to execute EBS level 3 behavior at the exhibits. As (non-systematic) pilot observations showed that children needed more time to demonstrate EBS level 3 behavior at “Rolling, rolling, rolling” than at “Spinning forces”, it was decided to use larger time intervals at the former exhibit than at the latter exhibit.
5. The dependent variables in the reported analyses of both experiments are based on the number of seconds instead of the number of intervals that behavior of a particular EBS level was shown at the exhibits. The number of seconds was obtained by multiplication of the number of intervals with the number of seconds within a time interval. The number of seconds informs the reader about the respective holding times at each level of exploratory behavior for the different groups at “Rolling, rolling, rolling” and “Spinning forces”. Note, however, that as a result of the interval scoring, one cannot assume that when in the paper mentioning is made of a (mean) number of seconds that behavior on a particular EBS level was shown, the child demonstrated this behavior each and every second.
6. The choice to use dependent measures based on seconds enabled comparison of the two exhibits with regard to the level of exploratory behavior that they elicit. However, differences in exploratory behavior between exhibits have to be interpreted with care; it has to be kept in mind that the dependent measures used at “Rolling, rolling, rolling” were based on longer time intervals than the dependent measures used at “Spinning forces”. Nevertheless, we do not expect the differences between the exhibits that were found in both experiments to be a result of the use of intervals of different lengths. Differences were found in the amount of EBS level 1 and EBS level 2 behavior the exhibits elicited. Because of the short period of time that is needed to execute EBS level 2 behavior, it is unlikely that the relatively short time interval that was used at “Spinning forces” caused less EBS level 2 behavior to be scored at the exhibit than when a longer time interval would have been used.
7. In this discussion we focus on cognitive learning outcomes (Brody et al., 2008) as a result of a visit to a science museum. Although we do acknowledge the importance of affective learning outcomes (Brody et al., 2008), such as the development of curiosity, interest, positive feelings and attitudes, discussing those would go beyond the scope of this paper.