

Real World Word Learning: Exploring Children's Developing Semantic Representations of a Science Term

Abstract

Assessments of lexical acquisition are often limited to pre-school children on forced choice comprehension measures. This study assessed the understandings 30 school-age children (mean age = 6;7) acquired about the science term, *eclipse* following a naturalistic exposure to a solar eclipse. The knowledge children acquired about eclipses and a control term, *comet* was assessed at three points in time (baseline-test, two-week post-test and five-month post-test) using a range of assessment tasks (multiple-choice comprehension, picture-naming, drawing and a model of a solar system task). Children's knowledge was compared to 15 adult controls during the baseline-test and two-week post-test. Children acquired extensive knowledge about eclipses, but not comets; at the two-week post-test and five-month post-test, the majority of children named and drew eclipses and 'made' an eclipse using models of the sun, moon and earth. Also, children's eclipse knowledge more closely approximated adult-level understandings at the two-week post-test than at the baseline-test. Implications for the study of lexical acquisition in later development are discussed.

### Introduction

School-age children acquire hundreds of new words each year (Anglin, 1993). Many new words are acquired incidentally, from uses in verbal and written contexts, rather than through explicit vocabulary instruction (Nagy & Herman, 1987; Penno, Wilkinson, & Moore, 2002). Although children are adept word learners (Bloom & Markson, 1998), children's incidental word learning from oral language and written language is not necessarily inevitable (Swanborn & de Glopper 1999; Braisby, Dockrell, & Best, 1999; Deák & Wagner, 2003). Children have particular difficulties in the acquisition of terms that are morphologically complex (Anglin, 1993) and those that involve complex semantic representations (Nelson, 1996). Learning science terms poses particular challenges for acquisition (Vygotsky, 1978; Meyerson, Ford, Ward, & Jones, 1991) because such terms are 'conceptually complex' and can be understood at various levels of abstraction. Children often lack the necessary conceptual knowledge required for the comprehension of scientific terms and this limits their ability to learn the relevant vocabulary (Meyerson, et al, 1991). The current study examined the extent to which children can acquire the meaning of a complex scientific term following a fortuitous exposure to the term. Multiple methods of word knowledge assessment were used to tap into the nature of children's developing representations.

The focus of many previous investigations of children's word learning has been on the rapid acquisition of word meanings in the pre-school years. Laboratory studies have shown that pre-schoolers acquire word meanings with remarkable ease and rapidity, from as little as one incidental exposure (Carey & Bartlett, 1978; Rice & Woodsmall, 1981). There is converging evidence to show rapid word learning, oftentimes referred to as *fast mapping*, in the pre-school period depends on an intimate relationship between the context in which a new word is acquired and the cognitive strategies and predispositions that the child brings to the learning task (Baldwin 1991, Booth & Waxman 2002; Bowey 1996; 2001; Clark & Wong 2002; de Jong, Sevele, & van

### REAL WORLD WORD LEARNING 3

Veen 2000; Hoff & Naigles 2002). By the end of the pre-school period, children have a range of cognitive, linguistic and social competencies in place, such as knowledge about words and the world, to support vocabulary learning. These competencies will allow them to “capitalize effectively on the information-rich social context within which word learning occurs” (Baldwin & Moses 2001: 318). However, there is still a lot of lexical learning to be done; the six-year old child possesses only one-sixth of the words that will be known by the end of formal schooling (Bloom, 2000: 318). Moreover, some of the vocabulary children encounter at school, such as scientific vocabulary, presents challenges for acquisition (Wilson, 1998). Thus, an adequate understanding of children’s word learning ought to include an understanding of lexical acquisition in later development.

Despite the impressive word learning feats of younger children, it is important to acknowledge that lexical acquisition is a complex phenomenon that extends beyond the simple mapping of meanings to word forms (Deák, 2000; Deák & Wagner, 2003). Deák and Wagner (2003) suggested that fast mapping may explain a kind of word learning that occurs in highly controlled or simplified situations, or with a narrow range of word types (i.e., count nouns). Moreover, fast mapping may facilitate the acquisition of minimal knowledge of word meanings, which is unstable, partial and fragmentary. However, little is known about how quickly children acquire accurate and more complete understandings of word meanings, or the kinds of input (i.e., informational support) needed to support extended mappings. Therefore, it is important that future word learning research moves beyond investigations of fast mapping to consider children’s acquisition of different kinds of lexical items in varying word learning environments. Scholars have argued that the investigation of word learning in naturalistic contexts helps us expand our understanding of the kinds of input that drives lexical acquisition and the nature of word meaning representations that develop (Nelson, 1988; 1990; L. Bloom, 1997).

## REAL WORLD WORD LEARNING 4

The semantic complexity of words children encounter plays a critical role in word learning success. Previous research indicates that school-age children do not do well in acquiring science terms from brief, incidental exposures. A study conducted by Braisby, Dockrell, and Best (1999) demonstrated that four- to seven-year old children struggled to acquire novel science terms from single, incidental exposures, presented during a videotaped science lesson. Few children produced the new terms and only a minority (7%) demonstrated lexical learning on a multiple-choice comprehension task. Thus, brief, incidental exposures found to support early word learning do not apparently provide good learning opportunities for the acquisition of science terms, nor do they appear to provide children with sufficient information to begin the acquisition process. In contrast, educational studies have shown that extended opportunities to explore the meaning of a science term, such as when terms are exposed on multiple occasions or word meanings are discussed, are more successful (Lloyd & Contreras, 1987; McGuigan, 1990; Rix & Yiannaki, 1996). However, when children's representations of science terms are examined in detail, erroneous understandings often remain (Williams & Tolmie, 2000). Overall, investigations of the acquisition of science terms in realistic contexts would further our understanding of the processes underpinning later acquisition and the durability of representations that children develop.

The methods and measures used to explore lexical acquisition play a central role in what we conclude about the nature of children's word learning. There are no formal criteria to judge when a word is known (Beck & McKeown, 1991). However, when a child acquires a new word they must identify the sound in the speech stream to encode a phonological representation and then establish a mapping between the word and concept: ultimately a detailed semantic representation is developed for the new term with knowledge of its morphosyntactic features (Dockrell & Messer, in press). Learning a new word also involves the formation of, or links to a conceptual domain. However, many previous investigations measure only shallow lexical

knowledge, such as word recognition knowledge (Ralli, 1999). Furthermore, assessments are typically made immediately after word exposure, rather than after a delayed time period. Consequently, we know little about the kinds of word-related knowledge acquired, and the extent to which knowledge is retained over time.

Lexical knowledge needs to be investigated with a range of word knowledge assessments to ascertain what has been acquired (Beck & McKeown, 1991). These measures should include both production and comprehension, moving beyond the conventional forced choice multiple-choice comprehension task (Anglin, 1993). Production and requests for definitions of a term provide a stringent test of word knowledge but alone may prove to miss partial meanings and distort our interpretation of the child's representations (Dockrell & Messer, *in press*; Funnell, Hughs, & Woodcock, *submitted*; Keil & Batterman, 1984). Creative ways of tapping semantic representations need to be considered. Recent research has established that drawing-based assessments are useful for tapping semantic knowledge among school-age children (McGregor, Friedman, Reilly, & Newman, 2002). The authors found that five- to seven-year old children provide accurate drawings of entities for which they had acquired extensive semantic knowledge (as reflected in their ability to accurately define and name words). Less accurate drawings were typically produced for terms for which knowledge was fragile (as reflected by inaccurate definitions and semantic naming errors).

Assessing knowledge across a range of tasks provides information about the child's representations but does not, on its own, provide information about what would be typically expected in when a term is fully established in the lexicon. Comparison with adults' performance allows us to address this gap. Surprisingly, child-adult comparisons are seldom made in lexical acquisition research (but see Gillette, Gleitman, Gleitman, & Lederer, 1999 as an important example of the value of using adult participants in studies). Such data allow an examination of the ways in which the children's representations may be incomplete. This provides an objective

## REAL WORLD WORD LEARNING 6

benchmark of the status of the child's lexical entry. In sum, an understanding of later lexical acquisition will require the use of converging methods to evaluate the nature of children's representations of words and how these change over time.

### *Rationale*

The present study aimed to extend our understanding of lexical acquisition in the school-age child by using a naturally occurring event to tap into children's developing representations of a science term. The study examined children's knowledge of the term, eclipse, before and after a partial solar eclipse that was visible throughout Europe in the summer of 1999. There was considerable media interest at the time, but no formal educational instruction occurred since children were on their long summer holidays. The media exposure to the eclipse allowed an evaluation of the changes in children's knowledge of the term eclipse and an investigation of their developing representations.

Multiple tasks were developed to tap knowledge of eclipses and of entities related to space (sun, moon, earth and planets in general). To evaluate the differential impact of exposure, knowledge of the term, eclipse was contrasted with another space term, comet, that was not relevant to the eclipse. Generalisation of the concept of eclipse was assessed by examining participant's knowledge of a lunar eclipse. Children's knowledge was evaluated at three time points; two weeks prior to the eclipse, immediately following the eclipse (baseline), and again five months after the eclipse. The final test point allowed an evaluation of the extent to which any changes in the children's knowledge of the term had endured over time. Learning was also monitored by comparing children's performance to that of adult controls at the first two points of testing.

## Method

### *Participants*

The participants were 30 children (mean age = 6;7, range = 4;2 to 10;2) and 15 adult controls, from a rural area of Northwest England. Of the child participants, 12 were male and 18 female. One child was unavailable for the last testing session and thus 29 children were tested at the five-month post-test.

As children were drawn from a wide age range, they were categorized into two groups that reflected key stages of the English National Curriculum (DfEE, 1999). Group 1, henceforth called *younger children*, comprised four- to six-year old children ( $n = 15$ ,  $M = 5;2$  years) whereas Group 2, henceforth called *older children*, comprised seven- to ten-year old children ( $n = 15$ ,  $M = 8;3$  years).

### *Materials*

Four tasks were developed to tap participant's knowledge of comets, eclipses and space items (sun, moon, earth and planet).

*Picture-naming task.* The picture-naming task required participants to name colour photographs of a solar eclipse, lunar eclipse, comet, sun, moon, earth and another planet. To score correctly, children had to produce the correct term (i.e., eclipse, comet, sun, moon, earth and planet).

*Multiple-choice comprehension task.* Participants were required to select a photograph of a solar eclipse, lunar eclipse, comet, sun, moon, earth and planet, displayed alongside three distracter items. Distracter items were either conceptually or semantically related to the target items. For example, for the solar eclipse item, distracter pictures included a hot-air balloon passing in front of the moon (picture of the same concept) and pictures of the moon and a planet (two pictures of entities from the same semantic domain).

## REAL WORLD WORD LEARNING 8

*Drawing task.* Participants were required to draw an eclipse, a comet and eclipse-related entities (sun, moon, earth and planet) using colouring crayons. Drawings were coded as high accuracy, low accuracy or missing when no drawing was provided. High accuracy drawings were those that clearly resembled the target item (e.g., yellow circle for the sun), whereas low accuracy drawings were those that were unidentifiable (e.g., ambiguous shape or scribbles). High accuracy drawings were used in the subsequent drawing analysis.

*Solar system task.* A model solar system was used to assess deeper knowledge of eclipses and the sun, moon earth and other planets. Participants were required to select the appropriate referents from the model, which comprised replicas of the sun, earth, moon and nine planets. Each entity was coloured appropriately (e.g., earth depicted the sea and countries in blue and green, respectively), and of an appropriate size in relation to other entities in the model (e.g., the sun was several times larger than other entities). Moreover, the entities were positioned in a manner which might resemble their position in the solar system (e.g., the nine planets of our solar system were placed in a curved line, away from the sun in their appropriate order). Thus, the selection of the space items required knowledge about the colour, size and positioning of the entities. Eclipse knowledge was assessed by asking participants to select the entities involved in an eclipse (i.e., sun, moon and earth) and make an eclipse by placing the sun, moon and earth in the appropriate alignment (i.e., moon placed between the sun and the earth). As the eclipse assessment examined knowledge of entities involved in an eclipse, responses in which an incorrect entity was selected, but labelled with an appropriate name (e.g., planet labelled as the moon), were coded as correct.

### *Procedure*

As the testing took place during the school holidays, it was not possible to recruit children from schools. The first author therefore recruited children by contacting parents in the vicinity to



ask whether they had a child of primary-school age who could take part in her doctoral research which explored children's understandings of science concepts.

At the baseline-test, child participants were introduced to the experimenter as someone who wanted to play some games about space. During subsequent visits the experimenter informed children that she had returned to play more games about space. Children were tested in a quiet area of their home, away from other children. Only two parents requested to be present during testing. When present, parents sat out of the child's view. An identical method of testing was followed across each time of testing. In each 10-15 minute testing session, participants completed the tasks in the following order: picture-naming, multiple-choice comprehension, drawing and solar system task. Knowledge of the space items was assessed before knowledge regarding eclipses and comets using the requests outlined in Table 1.

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### Results

The results focus on children's developing representations of the term eclipse in relation to the control term, comet, and also entities related to space (sun, moon, earth and planet). For the analysis, correct responses to each of the items were assessed as a function of time of testing (e.g., baseline to the two-week post-test) and child-adult differences at baseline and the two-week post-test. For the time of testing analysis, we focused on knowledge change between baseline and the two-week post-test because statistically reliable differences were observed between the baseline-test and two-week post-test, but not between the two-week post-test and the five-month post-test. There were no statistically reliable effects of gender and only one effect of age pertaining to learning gains on the picture-naming task, which is reported below. Therefore, the

main analysis is based on effects of learning for *all* children as opposed to *older children* and *younger children*, or girls and boys.

Regarding the statistical analysis, for the eclipse items (solar and lunar) and comet items, learning gains were measured using McNemar tests, which assessed the proportion of children who performed unsuccessfully at the baseline-test, but successfully at the two-week post-test. For the space items (sun, moon, earth and planet), the correct scores obtained by each participant were aggregated (potential range = 0 to 4) from which the mean correct responses were compared using t-tests. The gap between adults and children's knowledge at the baseline-test and the two-week post-test was assessed with Chi square tests (for the eclipse and comet items) and t-tests (for the space items).

#### *Picture-naming*

Table 2 reports correct responses from children and adults on the picture-naming task.

*Eclipse items.* Between the baseline-test and the two-week post-test, there was an effect of learning for the solar eclipse item,  $T = 4.65$ ,  $p < .05$ ,  $d = 1.58$ , but not for the lunar eclipse item,  $T = 2.20$ ,  $p = ns$ . On this stringent measure of word assessment, learning gains occurred for older children,  $T = 5.81$ ,  $p < .05$ , but not younger children,  $T = 0.26$ ,  $p = ns$ . Also, there was a gap between adult-level and child-level responding at the two-week post-test,  $X^2(1, N = 45) = 4.14$ ,  $p < .05$ ,  $d = -0.63$ , as well as at the baseline-test,  $X^2(1, N = 45) = 19.39$ ,  $p < .001$ ,  $d = -1.74$ .

*Comet item.* There were no effects of comet learning between the baseline-test and the two-week post-test,  $T = 0.50$ ,  $p = ns$ , and adults outperformed children at both the baseline-test,  $X^2(1, N = 45) = 18.71$ ,  $p < .001$ ,  $d = -1.68$ , and the two-week post-test,  $X^2(1, N = 45) = 14.01$ ,  $p < .05$ ,  $d = -1.35$ .

*Space items.* Children's performance increased between the baseline-test and the two-week post-test,  $t(29) = -4.62$ ,  $p < .01$ ,  $d = 1.00$ . The gap that occurred between children's and

adults responses at the baseline-test,  $t(43) = -5.15, p < .001, d = -1.55$ , was no longer apparent at the two-week post-test,  $t(43) = 1.61, p = ns$ .

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*Multiple-choice comprehension*

Table 3 shows the proportion of children and adults who responded correctly to the eclipse and comet items and space items.

*Eclipse items:* Between the baseline-test and the two-week post-test, there was an effect of learning on the solar eclipse item,  $T = 4.03, p < .05, d = 1.28$ , but not the lunar eclipse item,  $T = 2.40, p = ns$ . The adult-child comparison data revealed that there was a gap between adult and child responding at baseline,  $X^2(1, N = 45) = 19.68, p < .001, d = -1.74$ , but not at the two-week post-test,  $X^2(1, N = 45) = 1.0, p = ns$ .

*Comet item.* Children’s performance did not significantly increase on the comet item,  $T = 0.69, p = ns$ , and adults outperformed children at both the baseline-test,  $X^2(1, N = 45) = 19.68, p < .001, d = -1.75$ , and the two-week post-test,  $X^2(1, N = 45) = 6.42, p < .05, d = -0.81$ .

*Space items.* There was an increase in correct responses relating to the space items between the baseline-test and the two-week post-test,  $t(29) = -3.01, p < .01, d = 1.85$ . Also the gap between children’s and adults performance that was apparent at the baseline-test,  $t(43) = -2.46, p < .05, d = - 2.14$ , was no longer present at the two-week post-test,  $t(43) = -1.83, p = ns$ .

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INSERT TABLE 3 ABOUT HERE

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*Drawing*

Table 4 reports the high accuracy drawings produced by children and adults across times of testing.

*Eclipse item.* The proportion of children’s high accuracy drawings increased between the baseline-test and the two-week post-test;  $T = 6.82, p < .01, d = 1.31$ . Also, the gap between children’s and adults accurate drawings apparent at the baseline-test,  $X^2(1, N = 45) = 23.52, p < .001, d = -2.09$ , was also present at the two-week post-test,  $X^2(1, N = 45) = 4.14, p < .05, d = -0.63$ .

*Comet item.* No differences emerged in high-accuracy comet drawings produced between the baseline-test and the two-week post-test,  $T = 0.94, p = ns$ , and adults outperformed children on the comet drawing assessment at the baseline-test,  $X^2(1, N = 45) = 25.71, p < .001, d = -2.30$ , and the two-week post-test,  $X^2(1, N = 45) = 16.44, p < .001, d = -1.51$ .

*Space items.* The drawing assessment did not yield effects of learning or differences between children and adults.

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*Solar system*

Table 5 reports the correct responses produced by children and adults on the solar system task. The solar system task did not assess comet knowledge because of the nature of the display.

*Eclipse items.* Between baseline and the two-week post-test, there was a significant increase in the proportion of children who correctly selected the entities that make an eclipse,  $T = 10.22, p < .001, d = 1.76$ , and were able to ‘make’ a solar eclipse using these items,  $T = 11.13, p < .01, d = 1.86$ . Also, the gap between children’s and adults knowledge reduced between the baseline-test and the two-week post-test; although, at baseline, adults performed better on the

selection of entities item,  $X^2(1, N = 45) = 21.52, p < .001, d = -1.91$ , and making an eclipse item,  $X^2(1, N = 45) = 23.52, p < .001, d = -2.09$ , there were no differences in child-adult performance at the two-week post-test on the selection of entities item,  $X^2(1, N = 45) = 1.60, p = ns$ , and making an eclipse item,  $X^2(1, N = 45) = 1.60, p = ns$ .

*Space items.* Children's knowledge of the space items increased after exposure to the eclipse,  $t(29) = -4.26, p < .001, d = 0.60$ . However, the gap between children's and adults correct responses observed at the baseline-test,  $t(43) = -2.35, p < 0.05, d = -0.80$ , was also observed at the two-week post-test,  $t(43) = -3.28, p < .01, d = -0.60$ .

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### Discussion

The study was designed to further our understanding of lexical acquisition in the school-age child by investigating children's acquisition of a science term in a real world context. Our aim was to tap into the nature of understandings children acquire about meanings of science terms and the extent to which they resemble adult-level representations. The results of the study raise important questions about the study of lexical acquisition and the measurement of lexical knowledge from both a psychological and pedagogical perspective.

Across the tasks, there was converging evidence indicating that the solar eclipse was a successful word-learning context; children acquired extensive knowledge about eclipses, but not comets, and eclipse knowledge was retained over time. Children made substantial learning gains during the evaluation period both in terms of production and acquisition of knowledge related to eclipses. In addition, as evidenced by the effects of learning on the space items, children acquired knowledge about entities from the semantic domain to which science terms relate.

The adult-child comparison data aimed to identify gaps in children's understanding of the term eclipse. The reduction of discrepancies between children's and adult's successful responding on the multiple-choice comprehension and solar system tasks between the baseline-test and the two-week post-test indicated that children increased their understanding of eclipses. However, adults' performance on the drawing task and picture-naming task remained significantly more accurate throughout the course of the study. The finding that adults continued to outperform children on the picture-naming task provides further support to the claim that production knowledge is acquired later, once semantic knowledge is in place (McGregor, et al, 2002).

The findings suggest that children are developing rich representations of the term eclipse. However, to ascertain the completeness of children's eclipse concept knowledge in comparison to adults, it would be necessary to administer more complicated tasks for which participants did not perform at ceiling level. Interestingly, the lunar eclipse data, which assessed whether knowledge about eclipses extended to lunar eclipses, indicated that children's eclipse knowledge (and indeed adults eclipse knowledge) was not fully developed. That is, children and adults performed poorly on the lunar eclipse items (multiple-choice task and picture-naming task), indicating that eclipse knowledge was limited to solar eclipses.

Overall, the data indicated that an account of lexical acquisition in later development needs to take into consideration the types of words children encounter (e.g., science terms) and the nature of understandings that are associated with knowing these words. The acquisition of science terms clearly extends beyond the mere mapping of a word to a referent (Deák & Wagner, 2003). Thus, to find out what the child has acquired, it is necessary to employ multiple methods of assessment, including the administration of multiple word knowledge tasks (Beck & McKeown, 1991; Ralli, 1999) and the inclusion of an adult control group (Gillette, et al, 1999).

Mismatches between different modes of assessment help us establish what the child has and has not learned.

The administration of multiple tasks not only help us identify different aspects of children's learning, but also which measures best assess word knowledge. While multiple-choice tasks do not offer any indication as to how well a word is known (Kameenui, Dixon & Carnine, 1987), our data indicate that the drawing and solar system tasks were useful diagnostic tools for assessing science concept knowledge. Indeed, drawings are appropriate educational assessment tasks (Driver, Squires, Rushworth, & Wood-Robinson, 1994) that can be used in research settings to tap knowledge of words in general (McGregor, et al, 2002) and scientific concepts in particular (Gross & Teubal, 2001). Moreover, observations of science instruction in the classroom show that visual teaching aids (i.e., such as the model solar system) are useful tools for eliciting children's understandings of, and teaching science concepts (Ogborn, Kress, Martina, & McGillicuddy, 1996; Best, Dockrell & Braisby, submitted). Arguably, visual aids provide a scaffold to support children's understandings of science-related concepts.

The current research does not address the issue of *what* supported children's successful eclipse-related learning. The extended exposure to the eclipse was effective in helping children acquire both lexical and conceptual knowledge. However, because the solar eclipse was an uncontrolled exposure, it was not possible to identify which aspects of the exposure aided learning (e.g., multiple exposures to the term eclipse, or the observation of the eclipse process). From both word learning and pedagogical perspectives, it is important that future research identifies the kinds of word exposure contexts that support children's acquisition of science terms (e.g., Best, 2003).

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Table 1

*Instructions for task completion*

| Task                             | Purpose                  | Instructions   |
|----------------------------------|--------------------------|--|
| Picture-naming                   | Name pictures            | “What is this?”  |
| Multiple-choice<br>comprehension | Select pictures          | “Can you find the [name entity] e.g., eclipse?”                  |
| Drawing                          | Draw entities            | “Can you draw [name entity] e.g., an eclipse?”                   |
| Solar system                     | Find entities            | “Can you find the [name entity] e.g., sun?”                      |
|                                  | Find eclipse<br>entities | “Can you find the things that are needed to<br>make an eclipse?” |
|                                  | Make an eclipse          | “Can you make an eclipse with these things?”                     |

Table 2:

*Correct scores on the picture-naming task*

| Time       | Solar eclipse     |       | Lunar eclipse     |       | Comet             |       | Domain items  |               |
|------------|-------------------|-------|-------------------|-------|-------------------|-------|---------------|---------------|
|            | Child             | Adult | Child             | Adult | Child             | Adult | Child         | Adult         |
|            | <i>Proportion</i> |       | <i>Proportion</i> |       | <i>Proportion</i> |       | <i>M (SD)</i> | <i>M (SD)</i> |
| Baseline   | .13               | .80   | 0                 | .13   | .10               | .73   | 2.3 (0.9)     | 3.7 (0.5)     |
| Two-week   | .76               | 1.0   | .13               | .20   | .16               | .73   | 3.2 (0.8)     | 3.6 (0.6)     |
| Five-month | .62               | ---   | 0                 | ---   | .20               | ---   | 2.7 (0.8)     | ---           |

Table 3

*Correct scores on the multiple-choice comprehension task*

| Time       | Solar eclipse     |       | Lunar eclipse     |       | Comet             |       | Domain items  |               |
|------------|-------------------|-------|-------------------|-------|-------------------|-------|---------------|---------------|
|            | Child             | Adult | Child             | Adult | Child             | Adult | Child         | Adult         |
|            | <i>Proportion</i> |       | <i>Proportion</i> |       | <i>Proportion</i> |       | <i>M (SD)</i> | <i>M (SD)</i> |
| Baseline   | .70               | 1.0   | .50               | .80   | .23               | .93   | 2.5 (0.7)     | 4.0 (0)       |
| Two-week   | 1.0               | 1.0   | .70               | .80   | .66               | 1.0   | 3.8 (0.4)     | 4.0 (0)       |
| Five-month | .93               | ---   | .55               | ---   | .36               | ---   | 3.8 (0.7)     | ---           |

Table 4

*Correct responses on the drawing task*

| Time       | Eclipse           |       | Comet             |       | Domain items  |               |
|------------|-------------------|-------|-------------------|-------|---------------|---------------|
|            | Child             | Adult | Child             | Adult | Child         | Adult         |
|            | <i>Proportion</i> |       | <i>Proportion</i> |       | <i>M (SD)</i> | <i>M (SD)</i> |
| Baseline   | .23               | 1.0   | .20               | 1.0   | 3.2 (0.8)     | 2.8 (1.0)     |
| Two-week   | .73               | 1.0   | .36               | 1.0   | 3.4 (0.8)     | 3.0 (0.8)     |
| Five-month | .72               | ---   | .44               | ---   | 3.3 (0.8)     | ---           |



Table 5

*Correct responses on the solar system task*

| Time       | Eclipse entities  |       | Alignment         |       | Domain items  |               |
|------------|-------------------|-------|-------------------|-------|---------------|---------------|
|            | Child             | Adult | Child             | Adult | Child         | Adult         |
|            | <i>Proportion</i> |       | <i>Proportion</i> |       | <i>M (SD)</i> | <i>M (SD)</i> |
| Baseline   | .26               | 1.0   | .23               | 1.0   | 2.4 (1.0)     | 3.2 (1.0)     |
| Two-week   | .90               | 1.0   | .90               | 1.0   | 3.0 (0.8)     | 3.8 (0.4)     |
| Five-month | .86               | ---   | .89               | ---   | 2.9 (1.1)     | ---           |

*Note.* Eclipse entities = selection of entities that make an eclipse; Alignment = placing sun, moon and earth in the form of a solar eclipse