The purpose of this study was to examine young children’s views about shadows. Young children hear references to or are involved in many scientific experiences in their everyday lives, and shadows are a part of children’s everyday experiences. Young children may have constructed their knowledge about shadows through their daily experiences. Therefore, a total of 32 children, of which one-half were four years old and one-half were five years old, were individually interviewed twice to elicit their views and understanding of shadows. Data were collected by a mixture of picture-pointing, verbal explanation, and manipulation, and were analysed both quantitatively and qualitatively. We focused on five facets of children’s ideas about shadows: ideas about the source of light, shadow orientation, shadow shape, shadow size, and shadow intensity. The five year olds performed significantly better on production of shadows, production of shadow shape, and production of shadow size, and also gave more reasonable explanations for their choices than did the four year olds, showing a better understanding of the concept of shadows. Another significant finding of the study was that young children have a much more sophisticated understanding of shadows than Piaget originally suggested and than their verbal explanations imply.

Introduction

The main purpose of this study was to develop a multiple-method interview instrument to explore young children’s ideas about shadows. Since what young children say in an interview situation might not be a fair reflection of the conceptual content in their minds when confronted with questions beyond their comprehension (DiGennaro, 1977; Hughes & Grieve, 1993; Schoultz, Säljö, & Wyndhamn, 2001; Siegal, 1991), a combination of verbal and non-verbal elicitation techniques was considered the most reliable and non-threatening way of penetrating cognitive structure (Driver & Erickson, 1983). Another purpose of this study was to explore young children’s views about shadows from multiple facets, including orientation, intensity, shape, and size, in order to fully understand their thinking.
Methodology Reconsidered

Recent research on infants’ physical knowledge has undergone a breakthrough due to methodological innovations. Using new research paradigms, it has been found that infants display cognitive abilities at an earlier age than Piaget claimed. For example, Piaget (1974) proposed that infants younger than nine months old do not realise that objects continue to exist when occluded (a concept of object permanence). Baillargeon (1993), using a novel research paradigm, found that infants as young as 3.5 months demonstrate awareness of the existence of occluded objects.

There are some significant differences between Piaget’s approach and the new research paradigm for the study of infants. Piaget proposed his theory about infants’ physical knowledge based on observation of his own children’s manual search behaviour. However, infants may not display their cognitive abilities due to a lack of coordination between their sensory and motor skills. The new experimental approaches were devised to surmount problems arising from Piagetian-inspired research that required infants to demonstrate their abilities by means of manual searches. These new paradigms used infants’ sucking and observational behaviour to infer their cognitive abilities, because these are behaviours they are quite capable of performing (Baillargeon, 1993).

In his study of children aged four and five years, Piaget used clinical interviews to investigate their ideas about the physical world. Based on children’s verbal expressions, Piaget developed his theory of children’s conceptions of the world. However, four and five year olds have difficulty understanding ‘Wh- questions’, and especially ‘Why questions’ (DiGennaro, 1977). When confronted with questions beyond their comprehension, children seem to resort to particular means to disguise their lack of knowledge (DiGennaro, 1977). Even though children cannot understand questions, they will try to answer them as well as they can (DiGennaro, 1977; Hughes & Grieve, 1993). Hughes and Grieve (1993) argued that the form of questioning used in Piagetian tasks demonstrates less about children’s thinking than about their efforts to make sense of what is being asked of them, no matter how bizarre. Schoultz et al. (2001) suggested that it was important not to assume that the words uttered by children in an interview situation are a true reflection of the conceptual content of their mind. Some researchers have also challenged the appropriateness of using the question and answer technique, and especially the focus on ‘how’ and ‘why’ type questions for some ethnic groups, even if it is prevalent in science education research (cited in Fleer, 1999).

In summary, very young children have difficulty understanding ‘Wh- questions’, and they are also incapable of answering these types of questions. Therefore, it is inappropriate to use only children’s verbal responses to infer their ideas about the physical world.

Children’s Conceptions about Shadows

Young children hear references to or are involved in many scientific experiences in their everyday lives. Shadows are a part of children’s everyday experiences. Young
Taiwanese Children’s Views and Understanding

children may have constructed their knowledge about shadows through their daily experiences. However, few studies have been done about young children’s conceptions of shadows, and particularly the conceptions of very young children (aged below six). Some of the earliest accounts of children’s ideas about shadows can be found in Piaget’s Conception of Physical Causality (Piaget, 1930) and Conception of Space (Piaget & Inhelder, 1967). In both books, Piaget identified four different stages or levels of concept development for children aged five and over. The four stages of physical explanations of shadows are as follows: The shadow of an object is regarded as emanating from both internal (the shadow emanates from the object) and external sources; the shadow emanates from the object; the shadow emanates from the object, but the emanation drives away the light; and the formation of shadows is due to the light being blocked by the objects. Piaget proposed that children in Stage 1 (five years old) and Stage 2 (six to seven years old) could not predict the orientation of shadows.

Regarding shadow shape, Piaget and Inhelder (1967) asked children of ages five to 12 to predict shadow shapes of different objects from different perspectives. They found that children of ages five and six depicted shadow shapes only from their general direction without regard for perspective.

Although Piaget did not interview children below age five, he assumed that their conceptions of shadows were at the same developmental stage as those of children at the age of five (Piaget, 1930; Piaget & Inhelder, 1967). A question worth considering is whether children below the age of five have the same ideas about shadows as children aged five.

After Piaget, most studies about shadows still investigated children older than five years old. For example, Guesne (1985) asked children aged 10–15 to explain the definition and formation of shadows, and found that most of the 10-year-old to 11-year-old children and some of the 13-year-old and 14-year-old children regarded shadows as reflections of objects.

Feher and Rice (1988) placed pinholes and opaque objects (a bead and a ball) in front of a cross-shaped light source to elicit children’s conceptions of shadows. They asked 40 children aged eight to 14 to predict the shape of a shadow, and to explain how the shadow was formed. They found that only about one-quarter of the children could predict shadow shape correctly, or could correctly explain how the shadow was formed.

Segal and Cosgrove (1993) conducted a study to trace the development of five-year-old children’s thinking about light and shadows in a five-week teaching programme. They provided children with many opportunities to explore shadows, and to talk about shadows. Initially, many children talked about the shape and form of their own shadows without mentioning the sun or other light sources. After a brief sojourn outdoors, they started to talk about the role of the sun in shadow formation. However, many children personified their human shadows in conversation. Besides, their finding was consistent with Piaget’s that children think shadows belong to the object, and that light is for shadows to push out or to be seen by.

The only related study that has investigated children below the age of five was conducted by Fleer (1996), but that study focused on children’s ideas about light
and dark rather than specifically focusing on shadows. From the transcript provided, the teacher employed many ‘Wh- questions’ to elicit children’s implicit knowledge about light, but the children were not able to answer the questions. Fleer assumed from this that those questions may have been beyond the children’s ability to comprehend. I wondered about the reasons why the children could not answer the teacher’s questions. Was it because they did not understand the questions, because they were not able to express themselves, or because they did not understand the concepts?

In summary, most of the studies I have reviewed only investigated children’s concepts about the formation and the shape of shadows. Besides, most of the studies investigated children aged five years old and over. Finally, most of the studies inferred children’s conceptions of shadows from their verbal explanations. However, to infer young children’s cognitive abilities only through verbal explanations may underestimate their cognitive abilities. We need diverse methods to investigate young children’s ideas about shadows.

Based on this lack of research on young children, and the limited methods used to elicit children’s ideas about shadows, this study was designed to use a broader and more appropriate range of methods to specifically address the following questions:

1. Can we understand young children’s views about shadows better using diverse methods than by using only verbal explanations?
2. How aware are four-year-old and five-year-old children of shadows, and what are their views about the relationship between light sources and shadow orientations, shadow intensity, shadow sizes, and shadow shapes?
3. Are there differences between four and five year olds’ ideas about different facets of shadows?

Methodology

In order to address these research questions, young children’s ideas about shadows were elicited using a multiple-method interview instrument administered in the form of semi-structured one-on-one interviews. A combination of verbal and non-verbal elicitation techniques was employed to ensure some degree of methodological triangulation, and to provide children with opportunities to respond according to their own explanatory strengths. A combination of these two techniques was considered the most reliable and non-threatening way of penetrating cognitive structure (Driver & Erickson, 1983).

Participants

Both a private kindergarten (teaching ages ranging from three to five years) and a public kindergarten (teaching ages ranging from four to five years) in Pingtung, southern Taiwan, were approached and invited to cooperate with the research. 32 children from these two kindergartens were selected through stratified random sampling:
16 children four years old (mean age = 4.6 years, eight male and eight female), and 16 children five years old (mean age = 5.5 years, eight male and eight female).

**Materials**

The stimulus materials of the two tasks were designed by Chen and Chang (2007) to explore children’s ideas about shadows. Both of the tasks had been used previously in a pilot study and were revised accordingly.

The stimulus materials for the first task consisted of 10 items, each depicted on two separate cards by means of a colour picture (see Appendix). Each pair of cards contained a correct and an incorrect shadow situation. All of the cards were used to explore children’s ideas about different facets of shadows: ideas about source of light, shadow orientation, shadow intensity, shadow shape, and shadow size.

The second task, a manipulative task, included 19 items. The materials used in the second task included different kinds of light sources (lighters, candles, flashlights, bulbs), various objects (pieces of cardboard, blocks, bottles, boxes), and a box made of acrylic fibre for making shadows (Figure 1).

**Procedure**

Children were tested twice individually by the researcher during 15-min sessions.

At the beginning of the first test, children were presented with a picture and were required to say what they saw in the picture. The second picture of the pair was not presented until the child mentioned the shadow in the picture. They were then asked to pick out the picture that depicted the correct shadow situation, and then justify their choice. Ten pairs of pictures were presented in the first interview. The order of the presentation of the pictures was balanced, and the arrays of the 10 pairs of pictures on the desk varied for each individual child.

At the beginning of the second test, the children were shown a variety of artificial light sources and objects, including both opaque and transparent objects. They were then asked to use the artificial light to produce a shadow, and to produce shadows of different orientations, intensities, sizes, and shapes in a box.

![Figure 1. The Shadow Box](image)
The first session was both audio-taped and video-taped, and the second session was videotaped. All the audiotapes and videotapes were transcribed for later rating.

Scoring of the Data

Both the audio-tapes and video-tapes were transcribed, and scores were assigned for the performance on both tasks.

Performance on picture-pointing. Children received one point for each item if they pointed to the correct picture on the first task.

Justifications for picture-pointing. Children’s justifications for their choices were transcribed. Based on all the children’s explanations for each item in the first task, the author developed a scoring system using a three-point scale: 0 = no response, ‘not sure’, or semantic ambiguities; 1 = response indicates awareness of shadow; and 2 = response indicates existence of basic scientific knowledge. Subsequently, two graduate students majoring in early childhood education were trained to assign the scores. The children’s justifications for each choice were scored by two independent raters who transcribed their responses. Discrepancies were resolved through discussion with a third judge. The inter-rater agreement between the two raters for each item in the first task was 0.82–0.94.

Shadow production. The scoring of the non-verbal behaviour of shadow production for some items was divided into two categories: successful production of a shadow (score 1), and failure to produce a shadow (score 0). Other items of the task were divided into three categories: successful production of a shadow (score 2), successful production of a shadow after several attempts (score 1), and failure to produce a shadow (score 0). Children’s non-verbal behaviour was also rated by two raters, and the inter-rater agreement was 0.87–1.00.

Results and Discussion

Data were collected through diverse methods, including picture-pointing, verbal explanations, and shadow-making, and were triangulated and analysed to determine the children’s awareness of shadows, and their understanding of the relationship between light sources and orientations, intensity, shape, and size of shadows. The proportions of the children’s correct responses to the picture-pointing task are presented in Table 1 and Figure 2, and their levels of explanation are presented in Table 2 and Figure 3. The proportions of the children’s successful shadow production are presented in Table 3 and Figure 4.
Awareness of Shadows and Ability to Make Shadows

The results show that 14 of the 16 (87.5%) five year olds and 12 of the 16 (75%) four year olds are aware of daytime shadows, and a comparison of these two age groups indicated no significant difference ($\chi^2 = 0.82, p > .05$). Nine of the 16 (56.3%) five year olds and 10 of the 16 (62.5%) four year olds are aware of night shadows, and a comparison of these two age groups also indicated no significant difference ($\chi^2 = 0.13, p > .05$). Likewise, a comparison between the levels of explanations which the
four year olds and the five year olds gave for night shadows was not significant (Mann–Whitney U test = 104, \( p > .05 \)). Most children’s justification for evening shadows was that ‘there was the moon or lamps’, and for no shadows in the evening was that there was ‘no sun’ or that it was ‘too dark’. A typical justification for no shadows at night is shown in the following dialogue:

Researcher: Are there shadows at night?
Child: No.

Table 1. Number and proportion of children’s correct responses in the Picture Task

<table>
<thead>
<tr>
<th>Concept</th>
<th>Item</th>
<th>Age (years)</th>
<th>n</th>
<th>%</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>2</td>
<td>5</td>
<td>14</td>
<td>87.5</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>56.3</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>4</td>
<td>5</td>
<td>14</td>
<td>87.5</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>50</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>31.3</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>18.8</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>43.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>5</td>
<td>13</td>
<td>81.3</td>
<td>&gt; .05</td>
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<tr>
<td></td>
<td>4</td>
<td>9</td>
<td>9</td>
<td>56.3</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>9</td>
<td>5</td>
<td>16</td>
<td>100</td>
<td>&gt; .05</td>
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<tr>
<td></td>
<td>4</td>
<td>14</td>
<td></td>
<td>87.5</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Number and proportion of children’s highest level of explanations in the Picture Task

<table>
<thead>
<tr>
<th>Concept</th>
<th>Item</th>
<th>Highest level of justification</th>
<th>Age (years)</th>
<th>n</th>
<th>%</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>11</td>
<td>68.8</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>2</td>
<td>12.5</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>31.3</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>13</td>
<td>81.3</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>7</td>
<td>43.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>12.5</td>
<td>&lt; .01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1</td>
<td>6.3</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>31.3</td>
<td>&gt; .05</td>
</tr>
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<td></td>
<td></td>
<td>4</td>
<td>4</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>7</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>31.3</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
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<tr>
<td></td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>62.5</td>
<td>&lt; .01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>9</td>
<td>2</td>
<td>5</td>
<td>13</td>
<td>81.3</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>7</td>
<td>43.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Number and proportion of children’s success on shadow production in the Manipulative Task

<table>
<thead>
<tr>
<th>Concept</th>
<th>Content</th>
<th>Age (years)</th>
<th>n</th>
<th>%</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Front</td>
<td>5</td>
<td>12</td>
<td>75</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>4</td>
<td>3</td>
<td>18.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>5</td>
<td>12</td>
<td>75</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>4</td>
<td>3</td>
<td>18.8</td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>Choose a transparent object</td>
<td>5</td>
<td>4</td>
<td>25</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td>Move object further from the light source</td>
<td>4</td>
<td>2</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Move object closer to the light source</td>
<td>5</td>
<td>1</td>
<td>6.3</td>
<td>&gt; .05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>Enlarge</td>
<td>5</td>
<td>5</td>
<td>31.3</td>
<td>&gt; .05</td>
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<td></td>
<td>Diminish</td>
<td>4</td>
<td>2</td>
<td>12.5</td>
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<td>5</td>
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<td>&lt; .05</td>
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<td></td>
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<td>4</td>
<td>1</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>Square</td>
<td>5</td>
<td>14</td>
<td>87.5</td>
<td>&lt; .01</td>
</tr>
<tr>
<td></td>
<td>Round</td>
<td>4</td>
<td>6</td>
<td>37.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>13</td>
<td>81.3</td>
<td>&lt; .01</td>
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<td></td>
<td></td>
<td>4</td>
<td>3</td>
<td>18.8</td>
<td></td>
</tr>
</tbody>
</table>
The highest level of justification for night shadows was:

Researcher: Are there shadows at night?
Child: Yes.
Researcher: Why will there be shadows at night?
Child: Because there is light from lamps.

As for the production of shadows, 13 of the 16 (81%) five year olds succeeded in producing shadows, but only six of the 16 (38%) four year olds succeeded in this task. A chi-squared analysis indicated a significant difference between the two age groups ($\chi^2 = 6.35, p < .05$).

Comparing the children’s awareness of night shadows in the Picture Task, and their ability to make shadows in the Manipulative Task, of the 13 children five years old who were able to produce shadows, eight gave the explanation that ‘there are shadows at night as long as there is the moon or a lamp’, three of them gave the explanation that ‘there are no shadows at night because there is no sun or it is too dark’, and only one gave no explanation. In contrast, of the six four year olds who were capable of making shadows, three of them gave the explanation that ‘there are shadows at night as long as there is the moon or a lamp’, one gave the explanation that ‘there are no shadows at night because there is no sun or it is too dark’, and the other two gave no explanation.

Those who thought there were shadows at night because of the moon or lamps, and who were able to make shadows, may have some knowledge about the relationship between light and shadows. In contrast, those who thought there were shadows at night because of the moon or lamps, but who were unable to make shadows, may have experience of night shadows but do not have knowledge about the relationship between light and shadows. As for those children who think that there are shadows at night but gave no explanation why, and those who think there are no shadows at night because there is no sun or because it is too dark but who were able to make shadows, these children may not be good at verbal expression but may have some knowledge about the relationship between light and shadows.

These findings suggest that a considerable proportion of five year olds have some knowledge about the relationship between light and shadows. Piaget (1930) found that even children aged eight might say that shadows would be formed without light. The present results suggest that our five year olds are more mature in their interpretation of the phenomenon of shadows than Piaget’s findings suggest.

**Shadow Orientation**

Do four and five year olds understand the relationship between light source and shadow orientation? To answer this question, we used a Picture Task and a Manipulative Task to investigate.
For one pair of pictures in which three children are standing side by side outdoors under the sun (Appendix, Picture 2), most of the four and five year olds chose the picture showing the correct shadow orientation. However, the five year olds made significantly more correct choices (Mann–Whitney $U = 80, p < .05$), and also gave a significantly higher level of justification than the four-year-olds (Mann–Whitney $U = 11.25, p < .05$). The highest level of justification was as follows:

Researcher: Which picture’s shadows are correct?
Child: [Pointing to the correct one] This one.
Researcher: Why are they correct?
Child: [Pointing to the correct one] Because all of the shadows are at the back; [pointing to the wrong one] one shadow is at the front and the other two are at the back. They should be on the same side.

For another pair of pictures in which three children are standing outdoors in a triangle under the sun (Appendix, Picture 3), the five year olds did not make more correct choices than the four year olds, but they gave a much higher level of justification for shadow orientation (Mann–Whitney $U = 88, p < .05$). The highest level of justification was as follows:

Researcher: Which picture’s shadows are correct?
Child: [Pointing to the correct one] This one.
Researcher: Why are they correct?
Child: [Pointing to the correct one] Because all of the shadows should be in the same direction.

Are four and five year olds able to predict shadow orientation? Are they able to produce shadows in the direction requested? A comparison of the total score of predictions revealed a significant difference in performance for the two age groups ($t = 3.29, p < .01$). Most of the five year olds predicted the direction of shadows correctly, whereas most of the four year olds did not. A comparison of the total score of manipulation between the two age groups also revealed a significant difference ($t = 3.44, p < .01$).

Are children’s responses consistent across the Picture Task and the Manipulative Task? Comparing the children’s performances for Picture 2 with their performances in prediction and manipulation revealed no significant difference ($\chi^2(2, n = 32) = 5.69, p > .05$, Friedman’s test).

Nevertheless, comparisons between the children’s performance for Picture 3 and prediction and production in the manipulative task revealed a significant difference ($\chi^2(2, n = 32) = 17.49, p < .01$, Friedman’s test). A post-hoc Wilcoxon signed-ranks test indicated that the children’s performance in the Picture Task was significantly worse than their performance in both prediction and production of the Manipulation Task (both $p < .0167$).

Four of the 16 (25%) five year olds not only pointed to the right picture and gave a higher level of justification for Pictures 2 and 3, but also predicted and produced the shadow orientation correctly. In contrast, none of the four year olds could achieve this. These four five year olds seem to understand the relationship between light source and shadow orientation.
Shadow Intensity

Do children understand that the strength of light, transparency of the object, and the distance between objects and light source influence shadow intensity?

**Strength of light.** Do children notice that shadow intensity is different on a sunny day and on a cloudy day? A comparison of the four and five year olds’ responses about shadow intensity on a sunny day (Appendix, Picture 4) revealed no significant differences (Mann–Whitney $U = 104, p > .05$), but a comparison of their justifications in this item revealed a significant difference (Mann–Whitney $U = 81.5, p < .05$). The highest level of justification was as follows:

Researcher: [Presenting two pictures of shadows on a sunny day] Which picture’s shadow is correct?
Child: [Pointing to the correct one] This one.
Researcher: Why is it correct?
Child: Because this shadow is black.
Researcher: Why is the black shadow correct?
Child: Because when the sun is out, the shadow should be black.

For the shadow on a cloudy day (Appendix, Picture 5), a high proportion of children chose the wrong picture. A comparison between four and five year olds’ choices revealed no significant difference (Mann–Whitney $U = 96.00, p > .05$), but the comparison between their verbal explanations revealed a significant difference (Mann–Whitney $U = 65.5, p < .01$).

An example of a high-level justification is as follows:

Researcher: [Presenting two pictures of shadows on a cloudy day] Which picture’s shadows are correct?
Child: [Pointing to the correct one] This one.
Researcher: Why are they correct?
Child: Because the shadow will become pale on a cloudy day.

One of the four year olds (6.25%) and five of the five year olds (31.25%) who chose the right picture explained that there are no shadows on a cloudy day. Only one of the four year olds (6.25%) and two of the five year olds (12.5%) who chose the right picture explained that shadows on a cloudy day are paler. Three of the four year olds (18.75%) and six of the five year olds (37.5%) who chose the wrong picture explained that all shadows should be black.

A comparison between the children’s responses to the pictures of sunny-day and cloudy-day shadows revealed a significant difference ($Z = -2.67, p < .01$, Wilcoxon test). Significantly more children gave correct responses to the picture of a sunny day than to that of a cloudy day. More than half of the four year olds and 81.3% of the five year olds chose the right picture on a sunny day, but only 25% of the four year olds and half of the five year olds chose the right picture on a cloudy day. The proportion of children who chose pictures correctly decreased from the sunny day to the cloudy day because many children thought all shadows should be black. Some children totally ignored the pale shadow on a cloudy day, whereas others did not
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observe it correctly. It seems that young children tend to notice the conspicuous aspects of a phenomenon but ignore the inconspicuous aspects. Shadows are formed when light is blocked. There is light even on a cloudy day, and hence shadows can be formed on a cloudy day.

Transparency of objects. Do children notice that transparent objects allow some of the light to pass through, and hence have pale shadows (Appendix, Picture 6)? A comparison of four and five year olds’ responses about the shadows of transparent objects revealed no significant difference (Mann–Whitney \( U = 120, p > .05 \)), and the comparison between their verbal explanations also revealed no significant difference (Mann–Whitney \( U = 120, p > .05 \)). In fact, most children did not give explanations, or their explanations were ambiguous. Four of the four year olds (25%) and five of the five year olds (31.25%) pointed to the wrong picture and explained that all shadows should be black.

Are children able to produce pale shadows on request? A comparison of the four and five year olds’ performance in this task revealed no significant difference (Mann–Whitney \( U = 114, p > .05 \)). Only one of the four year olds and none of the five year olds chose transparent objects to produce pale shadows, and one of the four year olds and four of the five year olds managed to do so after several attempts.

A comparison of the children’s performance on the picture task and the manipulative task showed no significant difference (\( Z = -0.535, p > .05 \), Wilcoxon test). Only two five year olds chose the right picture and chose a transparent object to produce a pale shadow. However, these two children did not justify their choices, and did not succeed in producing pale shadows until they had tried several times. The only four year old who chose a transparent object to make a pale shadow did not make a correct response on the picture task about the shadow of a transparent object. Her choice of a transparent object to produce a pale shadow may have been by chance.

Chang and Lee (2004) investigated 1,299 third to sixth graders’ ideas about light, and found that 64.8% thought that transparent objects have shadows; 30.8% of them viewed the shadows of transparent objects as pale, while 24.2% viewed them as black. The proportion of our five year olds who viewed shadows as black is a little higher than the proportion of third to sixth graders in Chang and Lee’s (2004) study.

Distance between objects and light source. If two people are at a different distance from the light source, the intensity of their shadows is different (Appendix, Picture 7). A comparison of the four and five year olds’ responses to this item of the picture task revealed no significant difference (Mann–Whitney \( U = 96, p > .05 \)), but the comparison between their verbal explanations revealed a significant difference (Mann–Whitney \( U = 88, p < .05 \)). None of the four year olds justified their choices, while five of the five year olds (31.25%) explained that the shadow should not be so big. It seems that those five year olds only noticed the shadow size, but did not notice the shadow intensity.
When the children were asked to make a shadow darker in the manipulative task, the performance of the four and five year olds did not differ significantly \((Mann–Whitney U = 120.5, p > .05)\). Only one five year old succeeded in this task.

Similarly, the four and five year olds did not differ significantly on their performance in making the shadow intensity paler \((Mann–Whitney U = 104, p > .05)\). Only two five year olds succeeded in this task immediately upon request, while another five year old succeeded after several attempts.

Taken together, most of the children failed to change shadow intensity to be either darker or paler, with only one five year old succeeding. Another five year old succeeded in making the shadow intensity paler immediately upon request, but failed to make the shadow intensity darker. Furthermore, another five year old only succeeded in making the shadow intensity paler after several attempts. The way in which these three children changed the shadow intensity was different: two of them moved the flashlight back and forth, while the other moved the object back and forth.

A comparison of the children’s performance in the picture and the manipulative tasks indicated a significant difference \((\chi^2 = 8.67, p < .05, \text{Friedman test})\). The children’s performance in the picture task was significantly better than their performance in the manipulative task.

Although the children gave more correct responses in the picture task than the manipulation task, the basis of their choices in the picture task was not clear from their explanations. Their responses to the manipulative task indicated that only one of them seemed to understand that the distance between objects and the light source have an effect on the intensity of the shadow.

**Shadow Size**

Do young children understand that both the object size and the distance between objects and the light source have an effect on shadow size?

**Shadows of two people of different heights.** Do young children know that the shadow size of two people of different heights is different (Appendix, Picture 8)? A comparison of the four and five year olds’ responses about shadow size indicated no significant difference \((Mann–Whitney U = 96, p > .05)\), but the comparison between their justifications revealed a significant difference \((Mann–Whitney U = 54.5, p < .01)\). A high proportion (81.3%) of the four year olds did not answer, said ‘I don’t know’, or gave ambiguous explanations. In contrast, more than 50% of the five year olds explained that the shadow of an adult should be larger than that of a young child.

**Changing shadow size.** Children were asked to produce the shadow of a block, and then asked to enlarge the shadow. A comparison of the performance of the four and five year olds in this task indicated no significant difference \((Mann–Whitney U = 105, p > .05)\). Two of the four year olds (12.5%) and four of the five year olds (25%)
succeeded in enlarging a block shadow immediately upon request. Another five year old succeeded in enlarging the shadow after several attempts.

A comparison of the children’s performance in the diminution of a shadow also revealed no significant difference between the two age groups (Mann–Whitney $U = 96.5, p > .05$). One of the four year olds (6.3%) and four of the five year olds (25%) succeeded in diminishing the shadow of a block immediately upon request. Another five year old succeeded in diminishing the shadow after several attempts.

A comparison between the children’s performance in the picture task and in the enlargement and diminution of shadows in the manipulative task indicated a significant difference ($\chi^2 = 10.09, p < .05$, Friedman test). A post-hoc Wilcoxon signed-ranks test indicated that the children’s performance in the diminution of shadows in the manipulative task was significantly worse than their performance in the picture task ($p < .0167$).

Five five year olds succeeded in both enlarging and diminishing the shadows, but only one four year old succeeded in both tasks. These six children also chose the correct picture, and their explanations were rated at a higher level. Based on their performance in both the Picture Task and the Manipulative Task, these six children might know that shadow size is affected by the distance between objects and the light source.

**Shadow Shape**

A comparison of the four and five year olds’ responses to shadow shape in the Picture Task (Appendix, Picture 9) indicated no significant difference (Mann–Whitney $U = 112, p > .05$), but a comparison of their explanations revealed a significant difference between the two age groups (Mann–Whitney $U = 83, p < .05$). Seven of the four year olds (43.8%) and 13 of the five year olds (81.35%) could justify the correspondence between the objects and their shadows.

The comparisons of the four and five year olds’ performance on making square and round shadows indicated significant differences (Mann–Whitney $U = 64, p < .01$ for the square shadow; Mann–Whitney $U = 48, p < .01$ for the round shadow). The results suggest that the five year olds are more capable of making both square and round shadows than are the four year olds.

Most of the children chose a ball to make a round shape, with only three children choosing a cup. Those who chose a ball all succeeded in making a round shape, provided that they also chose a light source. However, only one of the three children who chose a cup succeeded in making a round shape. It is easier to make a round-shaped shadow with a ball than with a cup because no matter where the light source is, the shadow of a ball is round; but the shadow of a cup is not necessarily round. It seems that children notice an object shape from its most conspicuous aspect. Piaget and Inhelder (1967) found that children aged five and six depict an object’s shadow from its general direction without regard for the object’s position (p. 197). In Piaget and Inhelder’s study, children were asked to draw the shadow of a given object. In this study, children were free to choose an object to make a round shape. Obviously,
children around age five from both studies seem to notice the conspicuous part of an object.

A comparison between the children’s performance in the Picture Task and in making square and round shadows indicated a significant difference ($\chi^2 = 22.29$, $p < .01$, Friedman test). A post-hoc Wilcoxon signed-ranks test indicated that the children’s performance in making both square and round shadows was significantly worse than their performance in the picture task (both $p < .0167$).

Why did some children choose pictures correctly, but fail to make shadows of different shapes? Since the shadows of the animals were depicted from their general direction in our pictures, and were isomorphic, it was easier for the children to match the animals and their shadows without understanding how the shadows were formed. In contrast, children must have a basic knowledge of how shadows are formed in order to produce shadows, and to produce different shapes of shadows successfully.

**Conclusion**

This study employed diverse methods, including picture-pointing, verbal explanations, and shadow-making, to investigate very young children’s understanding of the relations between light source and orientation, intensity, shape, and size of shadows in order to describe a broader range of their views about shadows.

Most previous studies have asked children to explain such questions as ‘What is a shadow?’ or ‘Why is there a shadow?’ (Feher & Rice, 1988; Guesne, 1985; Piaget, 1930). In the present study, children were not required to answer these two questions; instead, they were required to answer other questions. Because the pictures and questions in my interview were more contextualized than in other studies, the children were more capable of displaying their ideas about shadows. Cummins (1984) pointed out that paralinguistic and situational cues are important for comprehension.

Besides, only in this study were children required to make shadows to display their capabilities. In trying to make the shadows, some children were unsuccessful because they only used a light source (such as a flashlight, candle, light bulb, or lighter) whereas other children only used objects (such as a block, box, or bottle). Still others used both a light source and an object, but were still unable to make shadows.

Obviously, these three groups of children do not understand the relationship between light and shadows. Nevertheless, these children only constituted a small percentage of the five year olds. As a matter of fact, over 85% of the five year olds succeeded in making shadows, compared with only 37% of the four year olds.

Taking together the children’s performance in both the Picture Task and the Manipulative Task, 50% of the five year olds were not only capable of making shadows, but also gave a higher level of justification in the picture-pointing. In contrast, only 19% of the four year olds performed well in both tasks. Obviously, many more five year olds than four year olds displayed some understanding of the relationship between light and shadows.
As for shadow orientation, 25% of the five year olds displayed some understanding of the relationship between light source and shadow orientation. These children could not only justify their choices in the picture task, but could also predict and produce shadow orientations correctly. In contrast, none of the four year olds displayed an understanding of the relationship between light source and shadow orientation.

The present finding—that a considerable proportion of five year olds can predict and produce shadow orientations correctly—runs counter to Piaget’s (1930) claim that children below the age of eight do not have the ability to predict shadow orientation correctly. This confirms previous findings in the literature, referred to in the Introduction, which show that Piaget underestimated the cognitive abilities of young children.

As Siegler (1998) has argued, the immature reasoning that children display in many situations may not in fact be immature reasoning at all, but may rather be a result of the verbal methods used by both Piaget and the replication studies, which misrepresent the children’s cognitive abilities. The fact that the children cannot explain their reasoning may not mean that the reasoning itself is deficient (Siegler, 1998, p. 52). Throughout their development, children seem to have basic understandings that are not evident in their performance in Piaget’s problems. Many studies that employ more sensitive measures demonstrate that children’s early understandings are extremely sophisticated (Siegler, 1998, p. 53).

As for shadow intensity, we investigated children’s understanding in terms of the amount of light, the distance between objects and the light source, and the transparency of objects. When the light is dim or is shed on transparent objects, the pale shadows of objects seem to be ignored by four and five year olds. As the distance between the objects and the light source changes, the shadow intensity also changes. Young children also seem to ignore this phenomenon. Perhaps only when shadows are black and more salient will young children notice them.

Children tend to notice salient features of objects or phenomena and ignore other features or distort what they see. As Piaget mentioned, preoperational thinking tends to focus on only one dimension of a problem, and ignores others. From information-processing perspectives, since there are more stimuli impinging on our sensory systems than we happen to notice, people generally control which stimulus has the most pronounced effect on them (Pashler, 1995). Since black shadows are more salient, they are much easier to notice than pale shadows.

Most of the four and five year olds in this study seemed to understand that shadow size should be in proportion to the objects, but they appeared to be unaware that the size of an object would change as the distance between the light source and the object changed. From the performance in both the Picture Task and the Manipulative Task, we found that only one four year old and five five year olds seemed to understand both the relationship between shadow size and object size, and the relationship between shadow size and the distance between the light source and the objects.

The shadow of the object represents its shape to some extent. Most of the four and five year olds picked out the correct shadow shape, but perhaps some of these children only matched the shadow shape and the animal without actually understanding
that the shadow shape corresponds to the animal’s shape from certain perspectives, as a large proportion of the four year olds could not produce different shadow shapes as requested. The five year olds seemed to understand the relationship between object shapes and shadow shapes better than the four year olds because a significantly higher proportion of the five year olds could produce different shapes of shadows as requested. Over 80% of the five year olds knew that shadow shape corresponds with object shape. However, young children seem to view shadow shape from its most conspicuous direction, as Piaget and Inhelder (1967) claimed.

Implications

A major finding of this study is that the conception of shadows of four year olds is quite different from that of five year olds. Five year olds appear to have a better understanding of the relationship between light source and shadow orientation, shadow shape, and shadow size than four year olds. However, since the children’s performance on different facets of shadow knowledge was quite different, to define all facets of shadow views at the same developmental stage can be a problem.

The other major finding of this study is that five year olds display more mature ideas about shadows than Piaget claimed. Piaget used verbal explanations to infer children’s knowledge about shadows, but I not only used the children’s verbal explanations, but also observed their manipulative behaviour. As Karmiloff-Smith’s (1997) representational redescription model has proposed, the representations of children at level E2 are accessible to consciousness but not to verbal report (p. 22). In other words, children at level E2 understand what their representation is but they cannot express it. Therefore, it is more appropriate to use diverse methods to investigate young children’s cognitive abilities, rather than to use only verbal explanations.

As for teachers of young children, they should not only listen to what is said, but should also observe what the children do in their learning, in order to evaluate their cognitive abilities appropriately. In addition, teachers of young children should make sure they understand what the children know about shadows, and develop the science curriculum on the basis of their understanding, in order to challenge their thinking about shadows.

Besides, the children in this study were more capable of displaying their ideas about shadows because the pictures and questions in my interview were more contextualized than in other studies. I therefore suggest that the science curriculum for young children should be related to their daily experience in order for them to have a better learning experience.

Finally, although very young children construct their physical knowledge in their daily lives, they seem to notice salient features and ignore inconspicuous features. Those who performed better in this study usually had parents who talked to them about their shadow experiences. Based on this, I suggest that kindergarten or preschool teachers provide children with opportunities to explore shadows, and discuss what they observe with them. This may help very young children to notice the inconspicuous features and hence obtain the whole picture of the phenomenon.
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References


Appendix. Ten pairs of pictures in the Picture Task

1. (Show the left picture)
   What do you see in this picture?
   What else?
   (If the child did not mention the shadow, point to the shadow)
   What’s this?
   Is it a sunny day or a cloudy day in this picture?
   (Show the right picture, and put the two pictures side by side)
   Which picture’s shadow is correct?
   Why is it correct?

2. Is it a sunny day or a cloudy day in these two pictures?
   Is it in the daytime or at night?
   Which picture’s shadows are correct?
   Why are they correct?

3. Is it a sunny day or a cloudy day in these two pictures?
   Is it in the daytime or at night?
   Which picture’s shadows are correct?
   Why are they correct?

4. Is it a sunny day or a cloudy day in these two pictures?
   Is it in the daytime or at night?
   Which picture’s shadow is correct?
   Why is it correct?

5. Is it a sunny day or a cloudy day in these two pictures?
   (If the child says “a sunny day”, the experimenter will say “Look at the cloud in the sky”.)
   Which picture’s shadows are correct?
   Why are they correct?

6. Look at these two pictures carefully.
   Which picture’s shadows are correct?
   Why are they correct?

7. Look at these two pictures carefully.
   Which picture’s shadows are correct?
   Why are they correct?
Appendix. (continued)

8. Which picture’s shadows are correct? Why are they correct?

9. Which picture’s shadows are correct? Why are the shadows in this picture correct?

10. Is it in the daytime or at night? Are there shadows at night? Why will there be shadows at night? How do you know about these?