Does Eye Gaze Indicate Implicit Knowledge of False Belief?
Charting Transitions in Knowledge

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Three-year-olds sometimes look to the correct location but give an incorrect verbal answer in a false belief task. We examined whether correct eye gaze among 3- to 5-year-old children indexed unconscious knowledge or low confidence conscious knowledge. Children “bet” counters on where they thought a story character would go. If children were conscious of the knowledge conveyed by their eye gaze then they should have bet modestly on their explicit answer (i.e., been unsure whether this answer or the answer conveyed through eye direction was correct). We found that children bet very highly on the location consistent with their explicit answer, suggesting that they were not aware of the knowledge conveyed through their eye gaze. This result was supported by a number of conditions that showed that betting was a sensitive measure of even small degrees of uncertainty. The results shed light on false-belief understanding, the implicit–explicit distinction, and transitional knowledge. We argue that the transition to a full understanding of false belief is marked by periods of implicit knowledge and explicit understanding with low confidence.

Key Words: false belief; implicit knowledge; explicit knowledge; eye gaze; verbal performance; transitions; certainty; theory of mind.

It is common to find that some measures reveal earlier understanding than other measures on tasks designed to tap the same insight. For instance, testing object permanence by infants’ reaching behaviors, versus looking times, places understanding as late as 8 months or as early as 4 months (see, respectively, Piaget, 1968, and Baillargeon, 1987). A similar advantage for looking over reaching has been obtained for infants’ performance on A not B tasks (Ahmed & Ruffman, 1998; Diamond, 1990; Hofstadter & Reznick, 1996). Interpretations of such discrepancies are numerous. For instance, some argue that looking and reaching tasks index an identical insight—object permanence—and that reaching measures underestimate infants’ understanding because of additional demands on planning ability (Baillargeon, DeVos, & Graber, 1989), inhibitory ability (Diamond, 1988), or atten-

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tion (Harris, 1989; Horobin & Acredolo, 1986), among others. Other interpretations hinge on the idea that the two types of measures index fundamentally different types of knowledge. For instance, looking and reaching might differ in the gradedness of the representation required for success (Munakata, McClelland, Johnson, & Siegler, 1997) or in the extent to which explicit knowledge is required (Ahmed & Ruffman, 1998). Appealing to implicit knowledge when infants show correct looking is, in fact, a very popular option in the infancy field (although see Haith & Benson, 1998). Yet there is typically no attempt to define what is meant by the term “implicit” except “earlier developing.”

Dissociations between measures meant to measure the same phenomenon are not restricted to studies of infancy or object permanence. For instance, Clements and Perner (1994) obtained a dissociation between performance on a looking measure and a verbal measure on a false belief task. In their task, a story character hid an object in a left-hand location and went away, and the object was moved to a right-hand location. Clements and Perner videotaped children’s eye movements as they watched the story. Just before the story character returned, the child heard a prompt. The narrator of the story announced that the story character was about to return and then wondered aloud, “I wonder where he’s going to look?” This was not a direct question to the child regarding where the character would look, but rather a means of determining whether the child anticipated the story character returning to the initial left-location. They reported that children’s eye movements revealed an earlier sensitivity to false belief than did their explicit responses. That is, 3-year-olds looked to the correct (left-hand) location even though they said the story character would go to the incorrect (right-hand) location when asked directly. In a true belief condition in which the story character saw the object moved from the left-hand box to the right-hand box, children looked to the right-hand box. This condition helps rule out alternative explanations of eye gaze (e.g., children simply retrace the story events and look to the left-hand location because this is where the character first placed the object).

These results led Clements and Perner (1994) to suggest that children develop an implicit or unconscious understanding of false belief at an earlier age than they develop an explicit or conscious understanding. Such suggestions have been made in other areas of development. For instance, Alibali and Goldin-Meadow (1993) found that just before children come to pass a conservation task, they begin to show understanding of the concept in their manual gestures. They also suggested that such signs of “implicit” knowledge mark periods in which children are ready to profit from instruction as in Vygotsky’s (1978) zone of proximal development. Indeed, Karmiloff-Smith (1992) argues that many cognitive abilities, everything from piano playing, to drawing, to balancing blocks on a beam, may develop initially in only an implicit form and then become increasingly explicit. To date, however, appeals to the implicit–explicit distinction have been intuitive. We know of no evidence to show that any of the so-called implicit insights that researchers have identified in children are genuinely unconscious, including the data on eye gaze and false belief discussed above.
Here we examine the claim that eye direction reveals implicit knowledge more systematically. Some theorists hold that there are substeps on the way from implicit to explicit knowledge (e.g., Karmiloff-Smith, 1992). Dienes and Perner (1999) outline a number of levels of implicitness, with only the final level appealing to notions of consciousness. Thus, one might explicitly represent a property (e.g., of being a cat), without predicating (connecting) this property to a particular individual. This is a case in which the individual and the predication are left implicit. Alternatively, one might explicitly represent the property and to whom the property is predicated, but might not explicitly represent whether these aspects are “facts” or not. This is a case in which factuality is left implicit. Finally, one might explicitly represent the property, individual, predication, and factuality, but leave implicit the “attitude of knowing” (i.e., that it is oneself who represents these things: “I know that $x$ is a fact”). In this sense of implicitness, one would not be conscious of the knowledge that one holds.

In the present study it is this last metacognitive aspect of the implicit–explicit distinction discussed by Dienes and Perner (1999) that we investigate. The notion of metacognitive insight into knowledge is based on Cheesman and Merikle’s (1984) distinction between the objective and subjective threshold of consciousness. The objective threshold concerns whether individuals are above chance on some task. The subjective threshold concerns whether individuals believe they are guessing, suggesting they lack metaknowledge about their knowledge (i.e., they do not know that they know). Dienes and Perner (1994) argue that knowledge below the subjective threshold is likely to provide the clearest evidence that knowledge is unconscious (see also Shanks & St. John, 1994). The Dienes and Perner view can also be related to the view espoused by the higher order thought theory (e.g., Carruthers, 1996; Rosenthal, 1986) that consciousness is unambiguously specified when one can think about one’s own thoughts or knowledge. We can apply these ideas to the false belief research by Clements and Perner (1993). The eye gaze data suggest that children were above the objective threshold in understanding false belief. However, no data were obtained to evaluate whether they were aware of the knowledge implied by their eye gaze.

In the present study we measured the subjective threshold by giving both true and false belief tasks and asking children to “bet” plastic counters on where they thought the story character would search for objects. Betting is a kind of confidence measure that is based on the confidence rating procedure used to establish implicit knowledge in implicit learning tasks (e.g., Dienes, Altmann, Kwan, & Goode, 1995). Like a verbal question, betting requires conscious processing because children were directly asked where the story character would go. However, unlike standard explicit measures that allow only dichotomous responses, the betting measure allows children to indicate greater or lesser certainty. If eye gaze indexes conscious knowledge (above the subjective threshold), but the knowledge is held with little confidence, children should bet some (albeit few) counters on the left-hand location (where they look) as a way of indicating the character might go to that location. This might be a transitional stage indicating
some conscious knowledge but low confidence. However, if eye gaze indexes unconscious knowledge (below the subjective threshold), then children should bet no counters on the left-hand location. They should instead bet on the right-hand location where they say the character will go.

In sum, any difference between eye gaze and betting can best be understood as due to the greater use of implicit knowledge on the eye gaze measure and explicit knowledge on the betting measure. It simply is not plausible to argue that the measure of eye gaze would tap conscious knowledge to a greater extent than the measure of betting, and hence, that an advantage of eye gaze over verbal performance indicates that the knowledge conveyed through eye gaze is mainly conscious.

The validity of the betting measure hinges on whether it can be shown that it is a sensitive measure of children's certainty. For this reason we included control conditions in the form of probabilities tasks. For instance, children were shown a bag containing 10 red objects (that could go down the red but not the green slide). They were asked to bet counters on which slide they thought the object would come down and were asked to make similar predictions for a bag containing 0 red objects and 10 green objects (that could only go down the green slide) and for 9 red objects and 1 green one. The key difference was between betting in the false belief, 10–0 and 0–10 conditions relative to the 9–1 condition. The question was whether children would bet differently when they had complete confidence in the result, in contrast to when a relatively small element of uncertainty was introduced (the 9–1 task). If children did bet differently this would show that betting is a sensitive measure of even slight changes in certainty. Children's betting in the false belief condition could then be examined knowing that heavy betting on one location should decrease when a child has even slight uncertainty about where the story character will look for the object.

We reasoned that the control condition should be effective because previous research has shown that young children have some skill in estimating probabilities. Huber and Huber (1987) found that children aged 3 and 4 years correctly estimated probabilities on 83% of trials. Likewise, there is evidence that betting measures are sensitive to confidence. Miller, Brownell, and Zukier (1977) found that betting was a good measure of certainty in 7- and 11-year-old children, the youngest groups they tested.

For a portion of the children in our study we also included an ambiguous probabilities task. One could argue that betting in the probabilities tasks was not based on certainty about outcome, but simply on a matching procedure in which the child placed counters at each location in a similar configuration to what was seen in the bag. In the ambiguous condition there was only one shape in the bag. The child was told that it could be green or it could be red. In this task a matching strategy should lead the child to place all counters by a particular slide (consistent with the object that they guessed was in the bag) rather than putting counters next to both slides. In contrast, if betting was based on confidence the child should place counters next to both slides.
EXPERIMENT 1
Method

Participants

Participants included 52 3-year-olds (mean = 3.52 years; range = 3.01 to 3.96 years; 32 girls and 20 boys), and 33 4- and 5-year-olds (mean = 4.37 years; range = 4.00 to 5.33 years; 9 girls and 24 boys). Children were from middle-class nurseries and a primary school in a predominantly White area of a mid-sized city in the United Kingdom.

Materials

Figure 1 illustrates the apparatus. Belief and probabilities tasks employed a box containing two slides. The slide openings at the rear of the box were adjacent and the distance between the slide openings at the front of the box was 40 cm. One slide allowed only cubes to be inserted and the other allowed only balls. Green balls and red cubes were used in the probability tasks and the slides were identified using an appropriately colored shape fitted around the slide’s opening (green circle for the slide for green balls, red square for the slide for red cubes).

Small round boxes (one green, one red) were used for the true belief task, and large square boxes (one green, one red) were used for the false belief task. Small dolls that could be inserted into the slides were used for the protagonists in the belief tasks, a different one for each task.

Procedure

Each child was given four tasks in a training phase, then a true and a false belief task, and three probability tasks. In addition, 37 children were given the ambiguous probability task. This task was devised as a control condition after testing had begun but the children tested were of the same age and ability as the other children (i.e., their data on all other tasks were very similar). The order of
the belief and probabilities blocks was counterbalanced, as was the order of tasks in the belief block. In the probabilities block the 10–0 task was given first, then the 9–1 task, and the 0–10 task. For those children who received it, the ambiguous task was given last. The training phase was given to demonstrate to children that counters bet on the correct outcome would be doubled, whereas counters bet on an incorrect outcome would be lost. For each trial of all tasks the child was given 10 new counters to bet. Testing was conducted in two sessions with children receiving one block of trials in each session. The Appendix provides a verbatim script for each task.

Training. To motivate children to win as many counters as possible, they were each shown a sheet with stars on it and told that this represented the highest number of stars won by anyone from their class. The child’s stated goal was to surpass this total. Counters won corresponded directly to stars. Two cups were used in training, one with a marble underneath. The marble was placed under one of the cups while the cups were hidden from the child’s view by a screen. The screen was then removed and the child was told that they were to place their counters next to the cup the marble was under and if they did not know which cup the marble was under to place their counters next to both cups. There were four trials. In two trials the cups were transparent and in two trials the cups were opaque. Children who failed to place counters next to both opaque cups on at least one training trial were eliminated. One child was eliminated on these grounds, leaving 84 children. If a child had either won or lost all three of the first training trials, the fourth trial was fixed so that each child had an experience of both winning and losing counters.

Belief tasks. Children were given a true and a false belief task (counterbalanced). In each case there was a prerecorded narrative on audiotape that accompanied the experimenter acting out the story events (see the Appendix). The two tasks differed only in the characters used, the boxes used, and the fact that the protagonist saw the object transferred from one location to the next only in the true belief task. At the beginning of testing children were shown that the story character slides down the left-hand slide when he wants to look in the left-hand box and the right-hand slide when he wants to look in the right-hand box. Children were videotaped as they watched the story unfold.

In each story the narrative included a prompt meant to elicit anticipatory looking. The narrator announced that the story character was about to return and wondered aloud, “I wonder which slide Ed will come down?” Videotapes of the child’s eye movements for the 4-s period following the prompt were later analyzed to determine how long they looked to the left- and right-hand locations when anticipating Ed’s return. Videotapes were viewed in slow motion and looking time was analyzed frame-by-frame, accurate to 0.04 s. The child was then given two explicit measures of understanding (in a counterbalanced order). These were the standard explicit question (“Which slide will Ed come down?”) and the betting question (“Put your counters next to the slide where Ed will come down. If you do not know where Ed will come down put counters next to both slides.

...
You can put the same number next to both slides or a different number.”). Finally, the child was asked three memory questions (see the Appendix). The outcome of the first belief task (i.e., which slide the character came down) was not revealed to the child until they had completed the second belief task.

Probabilities tasks. The probability tasks used the same apparatus and were also narrated on audiotape. The experimenter showed children a container holding red squares and/or green balls and demonstrated that the red slide would only accommodate squares whereas the green slide would only accommodate balls. In each task the child was told that the protagonist (e.g., Nick) would not tell them which shape he was going to put down the slide and that the child had to guess. The child was shown how many of each kind of object were in the bag. Nick then secretly selected an object and the child was given the eye gaze prompt (i.e., “I wonder which slide the shape will come down?”). In the ambiguous task the child was shown a bag and told, “You haven’t seen this bag before. In this bag there is a shape. It might be a ball or it might be a square.” Nick then secretly took the shape out of the bag and said, “I will put the shape down the slide now” and the narrator said, “I wonder which slide the shape will come down?” For each of the probabilities tasks, after the eye gaze prompt, the child was then given either the standard explicit question or the betting explicit question in a counterbalanced order (see the Appendix).

Coding. Children were counted as passing the explicit measure if they correctly indicated where the story character would go when asked the standard explicit question in both the true and false belief task, and otherwise as failing. Eye gaze was counted as correct if over the 4-s time window children looked more to the correct (right-hand) location in the true belief task and, in addition, they looked more to the correct (left-hand) location in the false belief task. They were counted as failing for any other pattern. Note that the method of scoring eye gaze, where correct performance comprises looking more to the correct location, is analogous to that for the explicit measure. With the explicit measure children are compelled to choose one location over the other even if they feel that the character is nearly as likely to go to the other. As a check, however, we examined the degree of difference between looking at the correct location and looking at the incorrect location in each task. Over the two tasks and the 61 children eventually included in the final analyses, there were only 5 of 122 occasions when the difference between looking at the two locations was 0.15 s or less. In general, then, children showed clear preferences. One rater rated all children’s eye gaze and a second rater (blind to the condition) rated 15% of videotapes. Using the pass–fail criterion, there was perfect interrater agreement.

Results

Eye gaze versus the explicit question. Like Clements and Perner (1994), we found that children showed correct eye gaze earlier than they gave correct answers to the standard explicit question. There were 40 children who passed the eye gaze measure but not the explicit measure and only 5 who obtained the opposite pattern, McNemar’s $\chi^2(1, n = 45) = 27.22, p < .001$. 
We then reduced the sample by eliminating the 8 children who failed the standard explicit question of the true belief task because these children demonstrated very basic task-related difficulties in understanding. The remaining sample consisted of 76 children (48 3-year-olds and 28 4- to 5-year-olds). The eye gaze of these children is shown in Table 1.

**Betting as a measure of certainty.** In the false belief task we looked at betting on the left-hand location for children who said the character would return there and the right-hand location for children who said the character would return there. The same was done for the ambiguous task. In addition, we examined betting on the right-hand location in the true belief task, the red (left-hand) location in the 10–0 task, the green (right-hand) location in the 0–10 task, and the most probable (left-hand) location in the 9–1 task.

We isolate our investigations to the 61 children who passed the eye gaze measure and then either passed or failed the explicit measure in the false belief task. We were curious whether certainty would increase or potentially even decrease as children came to pass the explicit measure. We might expect a decrease in certainty because knowledge transitions are often marked by pauses, self-repetitions, and other markers of uncertainty (see the General Discussion).

**Younger versus older children.** We assumed that younger children would, by and large, be further from fully understanding false belief than older children. Of the 61 children who passed the eye gaze measure, we first split them into failers (of the explicit measure) and passers. Then, in each of these groups we split the children into the younger half and the older half. This left four groups. There were 18 younger failers, 17 older failers, 13 younger passers, and 13 older passers. In general, the younger failers (mean: 3.40 years) were younger than the younger passers (mean: 3.59 years), $t(29) = 1.78$, $p < .05$, one-tailed, and the older failers (mean: 4.09 years) were younger than the older passers (mean: 4.46 years),

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tr>
<td>Amount of Time (in Seconds) Spent Looking at the Correct and Incorrect Locations in the True and False Belief Tasks of Experiment 1</td>
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<tr>
<td>False belief task</td>
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<tr>
<td>Correct (left) location</td>
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<tr>
<td>Fail false belief explicit, fail eye gaze ($n = 11$)</td>
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<tr>
<td>Fail false belief explicit, pass eye gaze ($n = 35$)</td>
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<tr>
<td>Pass false belief explicit, fail eye gaze ($n = 4$)</td>
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<tr>
<td>Pass false belief explicit, pass eye gaze ($n = 26$)</td>
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</table>

*Note. All children passed the explicit measure of the true belief task.*
Table 2 shows how children in the four groups bet. Figure 2 summarizes this information, showing the percentage of children who demonstrated complete certainty on a task by betting all counters on the dominant location versus the percentage who showed some uncertainty by betting at least some counters on the nondominant location. There are two clear trends. First, certainty tends to be lower in all groups in the 9–1 task. Most important, this is true in the young failers. Fifteen out of 18 (83%) young failers bet at least some counters on the non-

Note. For the Ambiguous condition there was a reduced sample of 28 children and the dominant location is deemed to be the left-hand location.
dominant location in the 9–1 task, whereas only one child (6%) did so in the true belief, false belief, 10–0, and 0–10 tasks. Second, certainty on the false belief task tends to drop steadily to a low amongst the younger passers and then recovers somewhat in the older passers.

We analyzed these data using Wilcoxon Sign tests to determine whether children bet with less certainty (fewer counters on the dominant location) in the 9–1 task relative to the other tasks. Table 3 shows the results of these analyses. Children in all four groups were consistently less certain in the 9–1 task relative

![FIG. 2. Percentage of children betting all counters on the dominant location in Experiment 1.](image)

**TABLE 3**

<table>
<thead>
<tr>
<th></th>
<th>10–0</th>
<th>0–10</th>
<th>9–1</th>
<th>False belief</th>
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<tbody>
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<td>10–0</td>
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<td>0–10</td>
<td>n.s.</td>
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<tr>
<td>9–1</td>
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<tr>
<td>False belief</td>
<td>n.s.</td>
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<td>n.s.</td>
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<tr>
<td>True belief</td>
<td>n.s.</td>
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<td>n.s.</td>
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*Note. YF, young failers; OF, older failers; YP, young passers; OP, older passers. Comparisons are made using Wilcoxon Sign Tests. They compare each group separately, for whether children bet a different number of counters on the dominant location in the different tasks.*

*p < .05.

**p < .01.

***p < .001.
to the 10–0, 0–10, and true belief tasks, showing that the betting measure was sensitive to small changes in certainty. In contrast, betting in the false belief task relative to the other tasks differed in the four groups. The younger failers were as certain on the false belief task as they were on the 10–0, 0–10, and true belief tasks, and they were more certain than they were on the 9–1 task. The older failers showed a mixed pattern of certainty on the false belief task. They were less certain than in the 10–0 and 0–10 tasks, yet they were more certain than on the 9–1 task and there was no difference in certainty between the true and false belief tasks. The younger passers were particularly uncertain on the false belief task. They were less certain than in the 10–0, 0–10 and true belief tasks, and they were not more certain on the false belief task than on the 9–1 task. Certainty in the older passers recovered somewhat on the false belief task. Their betting was no different than on the 10–0, 0–10, and true belief tasks, and they were more certain than on the 9–1 task.

Our finding that the younger failers were more certain on the false belief task than on the 9–1 task is consistent with the idea that despite looking to the left-hand location, such children are not conscious that the story character might return there. In this group, 17 out of 18 children (94%) bet all counters on the right-hand location (where they said the character would go) despite looking to the left-hand location. In contrast, only 10 of 17 older failers (59%) bet all counters on the right-hand location. The remaining older failers may be in a transitional phase in that they explicitly claim the character will go to the right-hand location, but their betting indicates some explicit awareness that the character might go to the left-hand location.

The younger passers also seemed to be in a transitional phase in that, overall, they thought the character would go to the left-hand location, but they were not terribly confident because less than half of this group (46%) bet all counters on that location. We consider this outcome in depth in the General Discussion. Finally, the older passers seemed relatively confident in their answer to the explicit false belief question in comparison to the other tasks. They did not evidence full confidence because only 62% of this group bet all counters on the left-hand location. Yet that lack of confidence was also present in some of the other tasks and there were no significant differences in betting in the false belief task relative to the 10–0, 0–10 and true belief tasks.

Next, we compared confidence in the four groups on each task separately. There were significant differences in the four groups’ betting on the false belief task, Kruskal-Wallis Test Statistic = 11.03, p < .05, but not on any other tasks. Pair-wise comparisons of betting in the false belief task indicated that there were significant differences between the younger failers and: (a) the older failers, Mann-Whitney Test Statistic = 209.50, p < .05; (b), the younger passers, Mann-Whitney Test Statistic = 177.00, p < .01; and (c) the older passers, Mann-Whitney Test Statistic = 158.00, p < .05. There were no other differences in betting in individual tasks. These data are particularly striking in that they reveal differences in certainty on the false belief task between the younger and the older
failers, despite the fact that these groups would be characterized as having the same level of understanding using the standard explicit question.

Agreement between betting and standard explicit answers. There was no necessarily correct answer to the betting question although one would expect children’s betting to be consistent with their explicit answer unless they lacked confidence in their explicit answer. If they lacked confidence, then inconsistency (e.g., betting more counters on the left-hand location but naming the right-hand location when asked the explicit question) might be expected. This pattern would reinforce the idea that betting some counters on the nondominant location does not mean that children necessarily believe the object will go there, just that they recognize the possibility.

On the 10–0, 0–10, and true belief tasks there was near perfect agreement between betting and explicit answers. Respectively, there were 2, 2, and 4 children (out of 61 eye gaze passers) giving inconsistent answers. Likewise, Table 4 reveals that for the false belief task in the young failers and older failers there were, respectively, 0 and 1 child who switched answers, again indicating good confidence in their answers in this condition. In contrast, the passers were relatively unconfident in their answer to the explicit question in the false belief task, with 54% of the younger passers switching answers. Children in this group were significantly more likely to be inconsistent than either the younger failers, $\chi^2(1, n = 31) = 12.52, p < .01$, or the older failers, $\chi^2(1, n = 30) = 8.67, p < .01$.

One can also compare the extent to which children were uncertain in the 9–1 task relative to the false belief task. In general, children were quite uncertain on the 9–1 task because they frequently switched answers to the explicit and betting questions. The younger failers switched answers significantly more often in the 9–1 task relative to the false belief task (binomial test: $k = 6, n = 6, p < .01$), as did the older failers (binomial test: $k = 5, n = 6, p < .05$). In contrast, the (non-significant) trend was for the younger passers to switch more often in the false belief task, and there was no difference in the amount the older passers switched in the two conditions. These results are consistent in indicating, first, that the failers, particularly the younger ones, switched answers in the 9–1 task as a way of indicating uncertainty, but they were very certain on the false belief task. Second, the passers, particularly the younger ones, were very uncertain in the answer they gave in the false belief task.

**TABLE 4**

<table>
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<tr>
<th>Number and Percentage Disagreement between Betting Question and Standard Explicit Question in Experiment 1</th>
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<tr>
<td><strong>False belief task</strong></td>
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<tr>
<td>Younger failers: Passed eye gaze but failed explicit ($n = 18$)</td>
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<tr>
<td>Older failers: Passed eye gaze but failed explicit ($n = 17$)</td>
</tr>
<tr>
<td>Younger passers: Passed eye gaze and explicit ($n = 13$)</td>
</tr>
<tr>
<td>Older passers: Passed eye gaze and explicit ($n = 13$)</td>
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In sum, whereas children in all four groups tended to give inconsistent answers to the standard explicit and betting questions at about the same levels of frequency in the 9–1 task with no significant differences between groups, there was a substantial difference in certainty in the false belief task. The data are consistent with the idea that the younger failers have no insight into the knowledge conveyed by their eye gaze and that the transition to explicit knowledge is marked by a striking lack of confidence.

Other issues. One reason for lacking certainty in the false belief task is a general feeling that story details have not been understood correctly. This might show up in failures on the memory questions such that memory question performance would be the worst in the younger passers (i.e., the children who were least certain). However, there were no differences in memory question performance in the four groups, Kruskal-Wallis Test Statistic = 2.48, n.s. Younger failers were correct on 82% of memory questions, older failers on 84%, younger passers on 85%, and older passers on 90% of memory questions.

Another issue is whether the failers showed correct eye gaze at levels above chance. For the younger failers we calculated observed looking in the false belief task so that positive numbers would indicate correct looking (left-hand looking minus right-hand looking). We then compared observed looking to random looking (0). The mean observed looking time was 1.36 s, significantly different from random performance, \( t(17) = 6.77, p < .001 \). An analogous analysis was then carried out for the true belief task (right-hand looking minus left-hand looking). The mean observed looking time was 2.09 s, again significantly different from random performance, \( t(17) = 7.93, p < .001 \). We then conducted the same analyses for the older failers. For the false belief task the mean observed looking time was 1.48 s, significantly different from random performance, \( t(16) = 5.67, p < .001 \). Likewise, for the true belief task the mean observed looking time was 1.76 s, again significantly different from random performance, \( t(16) = 5.60, p < .001 \). Thus, both the younger failers and the older failers tended to look to the left in the false belief task and to the right in the true belief task at levels well above chance.

A final issue concerns the 37 children who were given the ambiguous probability task. Nine children were eliminated from the analyses; four because they failed the true belief task, three because they failed both the eye gaze and the explicit measures, and two because they passed the explicit but not the eye gaze measure. Table 2 includes betting information for the remaining 28 children. We deemed the left-hand location to be the dominant location because this was the dominant location in the 9–1 task. There were no significant differences in betting in the ambiguous condition in the four groups of children, Kruskal-Wallis Test Statistic = 0.40, \( p = .94 \). For this reason we collapsed the data for the different age groups and compared betting in the ambiguous task to betting in the 10–0 and 0–10 tasks using Wilcoxon Sign tests. Children were significantly more likely to spread their counters at more than one location in the ambiguous task relative to the 10–0 and 0–10 tasks (both \( ps < .001 \)). Identical results were obtained when we reran the analyses counting the right-hand location as the dominant location in the ambiguous task.
These results are consistent with the idea that betting was not reflective of a mindless matching strategy based on what children had seen or imagined was in the box. If children had used such a strategy then they should have bet all counters on a particular location in the 10–0 and 0–10 tasks (which they did), but also in the ambiguous task (which they did not). A matching strategy would not have led children to place counters in relatively equal amounts at each location in the ambiguous task because there was only one counter in the bag. Children’s tendency to spread their counters in the ambiguous task and not spread them in the 10–0 and 0–10 tasks is consistent with the idea that their betting on all tasks is based on certainty about probabilities.

**Discussion**

The results of Experiment 1 are consistent with the idea that the eye gaze measure truly taps unconscious knowledge. Yet one somewhat surprising finding was the large drop in certainty in the 9–1 task relative to the 10–0 and 0–10 tasks. In Experiment 2 we examined certainty more closely to ensure that performance in the 9–1 task was not a misleading measure.

**EXPERIMENT 2**

To assess betting more closely children were given tasks that should tap a range of certainty. These included the following: 10–0, 9–1, 8–2, 0–10, 7–3, 6–4, and 5–5, where the first number refers to the number of red objects in the bag and the second number refers to the number of green objects. Our interest was in whether children would tend to spread their counters more evenly in the 5–5 task than in the 9–1 task and bet on a single location in the 9–1 task.

**Method**

*Participants*

Participants included 40 children (mean = 3.63 years; range = 3.01 to 5.04 years; 25 girls and 15 boys). There were 19 3-year-olds and 21 4- to 5-year-olds. Children were from middle-class nurseries and a primary school in a predominantly White area of a mid-sized city in the United Kingdom.

*Procedure*

Tasks were given in the order listed above. The tasks were given in a constantly descending order to maximize children’s awareness of how many of each type of object were in the bag. The exception was the 0–10 task, which was given in the middle of the other tasks. This was to ensure that children were still paying attention to the number of counters of each type in the bag and were not responding using some mindless, fixed strategy, where they placed progressively fewer counters on the left-hand location as trials ensued, regardless of the actual proportions of red and green objects present. The procedure was otherwise identical to that of Experiment 1.
Results

Children’s betting on the dominant location in the different tasks is shown in Table 5 and this information is summarized in Figure 3. For the 5–5 task betting on the left-hand location is shown because the dominant location was the left-hand location in all tasks except the 0–10 and 5–5 tasks. We think that

<table>
<thead>
<tr>
<th>Condition</th>
<th>10</th>
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<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>Mean</th>
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<td>—</td>
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<td>—</td>
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<td>—</td>
<td>2</td>
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<td>—</td>
<td>1</td>
<td>—</td>
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<td>—</td>
<td>—</td>
<td>1</td>
<td>9.05</td>
</tr>
<tr>
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<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>1</td>
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<td>3</td>
<td>5</td>
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<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>4.18</td>
</tr>
</tbody>
</table>

Note. In the 5–5 task, the dominant location was taken as the left-hand location to illustrate how children’s betting on the left-hand location (the dominant location in all tasks except the 0–10 and 5–5 tasks) changed.

FIG. 3. Percentage of children betting on different locations in Experiment 2.
children’s betting changed systematically because they wished to illustrate the possibility that as the probabilities became more uncertain there was a better chance that the object could come down the right-hand slide. Figure 3 shows a trend for betting on the dominant location to decrease steadily from the 10–0 to the 5–5 task and for counter splitting and betting on the nondominant location to increase. This is also shown by the means in Table 5.

Table 6 includes information about the number of children betting at least some counters by both locations in each task (showing uncertainty) and the number of children betting all counters on the dominant location minus the number of children betting all counters on the nondominant location (where high numbers equate to certainty). One would expect children to place some counters by both locations progressively more often as one goes from the 10–0 and 0–10 tasks to the 5–5 task, and this is just what happened. Indeed, the observed pattern differed significantly from what would be expected if children treated all tasks equally and bet in the same way as in the 5–5 task when there was complete objective uncertainty, $\chi^2(6, N = 40) = 45.79, p < .001$. Likewise, one would expect that children would bet all counters on the dominant location and none on the nondominant location in the 10–0 and 0–10 tasks and that this bias would decline as one goes to the 5–5 task. Again, this is just what happened. Children’s tendency to bet on the dominant location differed significantly from what would be expected if children treated all tasks equally and bet in the same way as in the 10–0 task when there was complete objective certainty, $\chi^2(6, N = 40) = 164.26, p < .001$.

Another way of considering these data is to compare betting on the dominant location in the 10–0 task to that on the 9–1 task. There were 20 children who bet 10 counters on the left-hand location in the 10–0 task but not in the 9–1 task, and no children who did the opposite, McNemar’s $\chi^2(1, n = 20) = 20.00, p < .001$. Likewise, there were 15 children who bet 10 counters on the left-hand location in the 9–1 task but not in the 5–5 task, and only 3 children who did the opposite, McNemar’s $\chi^2(1, n = 18) = 8.00, p < .01$.

### Table 6

<table>
<thead>
<tr>
<th>Number of children placing at least some counters by both dominant and nondominant location</th>
<th>Number of children betting all counters on dominant location minus number of children betting all counters on nondominant location</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–0</td>
<td>2</td>
</tr>
<tr>
<td>0–10</td>
<td>4</td>
</tr>
<tr>
<td>9–1</td>
<td>14</td>
</tr>
<tr>
<td>8–2</td>
<td>19</td>
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<td>7–3</td>
<td>14</td>
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<tr>
<td>6–4</td>
<td>19</td>
</tr>
<tr>
<td>5–5</td>
<td>22</td>
</tr>
</tbody>
</table>
Furthermore, one can consider the number of children who split their counters evenly (five on each location). There were four children who split their counters evenly in the 9–1 task but not the 10–0 task and one child who did the opposite, McNemar’s $\chi^2(1, n = 5) = 1.80$, n.s. The lack of a difference in these two conditions makes sense because children should not be completely uncertain in either condition. In contrast, children were more likely to be completely uncertain in the 5–5 task relative to the 9–1 task. There were 12 children who split their counters evenly in the 5–5 task but not in the 9–1 task, and only four who did the opposite, McNemar’s $\chi^2(1, n = 16) = 4.00, p < .05$. To check for internal consistency we then reran all analyses using the 0–10 task instead of the 10–0 task and obtained the same results.

Discussion

The data of Experiment 2 reveal clear and systematic patterns. Betting in the 10–0 and 0–10 tasks was categorically different than that in the 9–1 task in that in the former tasks children tended to bet all counters on the dominant location. Likewise, betting in the 9–1 task was different to that in the 5–5 task in that in the latter task children tended to split their counters evenly between the two locations. The clear impression from both experiments is that children place one or more counters on the nondominant location as a means of acknowledging the possibility that the object chosen might go to that location. Betting is sensitive to small variations in certainty and is a valid means of assessing certainty in the false belief task.

GENERAL DISCUSSION

In this study we replicated Clements and Perner’s (1994) finding that an earlier understanding of false belief is revealed by eye gaze in comparison to explicit answers. More important, our data shed light on both the development of false-belief understanding and the general issue of transition from implicit to explicit knowledge. Children’s early knowledge is often thought to be implicit, yet there has been little direct evidence for this except that performance on one task precedes that on another task argued to tap the same concept. In the present study we investigated implicit knowledge by examining whether children have meta-knowledge about their knowledge. That is, when children look correctly to the left-hand slide when anticipating the story character’s return, but give an incorrect verbal answer, do they have some low confidence conscious knowledge that the character might go to the left-hand slide or are they unaware of this possibility? Ours is the first study to provide clear evidence that early knowledge revealed by indirect measures such as eye gaze can be implicit in this sense. The younger children who showed appropriate anticipatory gaze but incorrect explicit answers were very certain of their explicit answer, and the advantage for eye gaze over betting can best be understood as due to the greater unconscious component in eye gaze. Furthermore, the advantage of eye gaze over betting could not be because betting is an insensitive measure of explicit knowledge. Children bet much less confidently in the 9–1 task than they did in the false belief task or in
any other task and bet less confidently in the 5–5 task relative to the 9–1 task. Our findings contradict claims by Zelazo, Frye, and Rapus (1996) who suggested that eye movements in the false belief task might index conscious knowledge.

A recent study by Garnham and Ruffman (2001) extends our findings. They used three locations instead of two, yet still found correct eye gaze in the false belief task in the absence of correct verbal performance. With two locations it is conceivable that performance is based on an understanding of ignorance. One might go to the wrong location not because one thinks the object is there, but because one did not see the transfer and children believe not seeing leads to doing the wrong thing (Ruffman, 1996). With two locations the wrong location happens to coincide with the correct “believed” location. With three locations there are two wrong locations but only one “believed” location (where the character put the object initially). Hence, a strategy based on “doing the wrong thing” would result in random looking at either of the two empty locations, whereas a strategy based on belief would result in looking only at the initial location. Consistent with the idea that eye gaze reflects genuine insight into false belief, Garnham and Ruffman found looking only at the initial location.

Transitional knowledge. Siegler (1996) argued that at any point in time children think in multiple ways about a problem and that these different ways coexist for some period of time. Siegler’s argument is that different ways of thinking are held with different degrees of confidence and this will determine the likelihood that they are retrieved. We take “thinking” to refer to conscious deliberation. For this reason, our data extend Siegler’s model by demonstrating the ways in which implicit knowledge (eye gaze) might contradict explicit knowledge (verbal performance and betting), rather than there simply being contradictions in conscious knowledge. In addition, our data are consistent with the notion of contradictions in conscious knowledge. In this sense, multiple ways of thinking in the case of false belief development seem to occur at the time of transition. Just prior to the time when children give the correct answer to the verbal question, they (older explicit failers) show the very beginnings of multiple ways of (conscious) thinking. Despite verbally claiming that the character would look in the right-hand container, older failers tended to bet with less certainty on this answer than did the younger failers. Thus, our findings are consistent with the idea that the mere presence of a dissociation cannot always be taken as evidence of implicit understanding. Correct eye gaze in this situation may sometimes be accompanied by explicit insight that the solution indexed verbally or through reaching may be wrong (i.e., by insight that another solution is possible).

Younger children who passed the verbal measure also seemed to be in transition. These children said the character would go to the left-hand container, yet bet many counters on the right-hand location as well. They were significantly less certain than in the true belief task. Thus, conscious awareness of false belief seems to coexist with lingering uncertainty that the character might still go to the right-hand location. In contrast, for older children who passed the verbal measure there was no difference between betting in the false and true belief tasks.
The data are consistent with the idea that confidence is not necessarily related to whether the child’s answer is correct, but to how many alternative possibilities the child is aware of and views as plausible. Younger failers are very confident of their incorrect verbal answer because they have no conscious insight into false belief; they recognize only true beliefs. If children are aware only of a single outcome as possible then there is no reason to lack confidence in that outcome. Younger passers lack confidence because they are aware of both their old idea (true belief) and their new insight (false belief). They have likely only recently gained conscious insight into false belief and this insight has not yet been reconciled with their previous conscious understanding. Confidence should be lower in this group than in the younger or older failers if the betting measure taps mainly conscious knowledge whereas eye gaze taps mainly unconscious knowledge. One could not expect confidence to wane until children have gained an explicit understanding of false belief.

These ideas fit well with the fact that the explicit failers were usually consistent in the answers they gave to the standard explicit and betting questions in the false belief task but not the 9–1 task and that the young passers often gave inconsistent answers in the false belief task. Over time children become more confident, perhaps because the basic insight into false belief becomes relatively well consolidated or perhaps because it is only later that children gain explicit insight into why the character will go to the left-hand container (Clements, Rustin, & McCallum, 2000).

These ideas strike us as very plausible given what is known about transitional phenomena. Children who are in the process of gaining a new insight tend to pause, make false starts and self repairs when speaking, make metacognitive comments about their knowledge, and delete nouns or verbs from their statements thereby compromising clarity (Perry & Lewis, 1999). Likewise, children’s explanations on the trial in which they discover a new addition insight and the trial immediately preceding the discovery tend to be characterized by false starts, long pauses, and slow counting (Siegler & Jenkins, 1989). Children also slow down when in transition to a new mode of analogical reasoning (Hosenfeld, van der Maas, & vanden Boom, 1997). Likewise, children who are initially vague in explaining their incorrect solutions when given mathematics problems are more likely to benefit from instruction and achieve a new solution than children who are initially explicit and incorrect (Graham & Perry, 1993). In sum, new insights tend to be accompanied by various phenomena that signal uncertainty.

It is striking that our data reveal differences in false-belief understanding amongst children who would be classified as objectively identical on standard verbal questions (i.e., younger failers versus older failers). The data reveal the importance of using eye gaze and other indirect measures both as a means of identifying a child’s level of current understanding and as a means of characterizing transitions in development.

**Graded representations.** Our results have something in common with the “graded representations” view of cognitive development in infancy (e.g., Haith
& Benson, 1998; Munakata, McClelland, Johnson, & Siegler, 1997). For instance, Munakata et al. argue that knowledge develops in a piecemeal fashion and, like a PDP network, in terms of connection strength (i.e., the strength of connectivity between neurons). It evolves with experience but at any point in time, one task might elicit the correct answer whereas another task might elicit an incorrect answer. This view explains mismatches between reaching and looking in object permanence tasks by claiming that looking requires weaker internal connections. It would presumably explain our findings by claiming again that looking requires weaker internal connections than responses to the explicit question.

One challenge for the graded representations view is to explain why looking requires weaker representations. Yet a more important issue might be that of consciousness. To the best of our knowledge the graded representations view makes no commitment to whether weak representations are conscious or unconscious. If the view holds that weak representations (e.g., eye gaze) could be conscious, then it is not consistent with our results. To do justice to our findings the graded representations view would have to import notions of conscious and unconscious, and then what it boils down to is simply a theory about how conscious and unconscious representations might be implemented in the brain.

Yet even in this respect the graded representations view might be lacking. Many theorists hold that increasing connection strength on its own does not result in the transition to explicit knowledge. Instead, other parts of the brain need access to the knowledge encoded in a particular network (Baars, 1986) or there must be a process in which the connectionist output becomes transformed to the form of symbols (Clark & Karmiloff-Smith, 1994). In Dennett’s (1994) view, language might be the symbolic medium that allows one to “skeletonize” the output of a connectionist network (i.e., extract the essential gist knowledge). For these reasons, we think that the implicit–explicit framework provides a better fit to many aspects of development.

In conclusion, we have shown that correct looking in the absence of correct verbal performance will often signify the presence of unconscious knowledge. Important questions for future research are whether dissociations between eye gaze and explicit answers are widespread and whether nonverbal measures reveal knowledge that may sometimes be more central to behavior than explicit measures (Goldin-Meadow, 2000; Ruffman, 2000).

APPENDIX

Verbatim Procedure

Training

We’re going to play a game. I am going to hide this marble under one of these cups. Show me where the marble is by putting some of your counters next to the cup the marble is under. If you put your counters next to the cup the marble is under you will win the same number of counters you put down. If you put your
counters next to the wrong cup you will lose your counters. If you do not know
where the marble is put counters next to both cups. You can put the same num-
ber next to both cups or a different number. Put your counters next to the cup that
the marble is under.

Belief Stories

This is Ed. Ed is playing on the slides. When Ed wants to look in the red box
he slides down the red slide. When he wants to look in the green box he slides
down the green slide. Look! Ed slides down the red slide to look in the red box.
He slides down the green slide to look in the green box.

[Pause tape and ask]
Which slide will Ed come down to look in this [the red] box?
Which slide will Ed come down to look in this [the green] box?

False belief. Ed is looking for his ball. Ed sees his ball on the ground. He picks
up his ball and plays with it. When Ed has finished playing with his ball he puts
it in the red box. Ed is tired now so he goes up the ladder and behind the box to
his bedroom and falls fast asleep. Ed is asleep now so he cannot see the boxes.
Along comes Katy. Katy is looking for something to play with. She looks in the
red box and takes out the ball. Katy plays with the ball. When Katy has finished
playing with the ball she puts it in the green box. Then Katy goes away again.
When Katy has gone away Ed wakes up. He says, “I will go down the slide and
get my ball now”.

True belief. Nick is looking for his sweet. Nick sees his sweet on the ground.
He picks up his sweet and eats some of it. When Nick has finished eating his
sweet he puts it in the red box. Along comes Sally. Sally is looking for some-
ting to eat. She looks in the red box and takes out the sweet. Sally eats some
of the sweet. When Sally has finished eating the sweet, Nick watches as Sally
puts it in the green box. Then Sally goes away again. Nick is tired now so he
goes up the ladder and behind the box to his bedroom and falls fast asleep.
Later on Nick wakes up. He says “I will go down the slide and get my sweet
now.”

False and true belief stories.

Eye Gaze Prompt: I wonder which slide Ed/Nick will come down.

[Pause the audio tape and ask]

Standard Explicit Question: Which slide will Ed/Nick come down?

Betting Explicit Question: Put your counters next to the slide where
Ed/Nick will come down. If you do not know where Ed/Nick will come down put
counters next to both slides. You can put the same number next to both slides or
a different number.

“Beginning” Memory Question: Where did Ed/Nick put his ball/sweet in
the beginning?

“Now” Memory Question: Where is the ball/sweet now?

“Watch” Memory Question: Did Ed/Nick watch Katy/Sally move the
ball/sweet?
Probabilities Tasks

Show me the ball. Show me the square. This is Nick. Nick is playing on the slides. Nick takes a shape out of here and puts it in the chute at the back of the box. If it is a red square it will come down the red slide. If it is a green ball it will come down the green slide. Look! The red square comes down the red slide and the green ball comes down the green slide.

[Pause the audio tape and ask]
Which slide would this one [the square] come down?
Which slide would this one [the ball] come down?

In the game Nick won’t tell you whether he has got a ball or a square. You have to guess what the shape is. Look in here (a bag). There are 9 squares and 1 ball. Nick takes a shape out of here. He says, “I will put the shape down the slide now”.

Eye Gaze Prompt: I wonder which slide the shape will come down.

[Pause tape and ask]
Standard Explicit Question: Which slide will the shape come down?
Betting Explicit Question: Put your counters next to the slide where the shape will come down. If you do not know where the shape will come down put counters next to both slides. You can put the same number next to both slides or a different number.

Note. The script for the true and false belief tasks and the probabilities tasks was audio-recorded and played to the child at the time of testing. The experimenter paused the tape to ask the child questions or state information at various times during testing.

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