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Where's the orange? Geometric and extra-geometric influences on English children's descriptions of spatial locations*

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ABSTRACT

The effect of both geometric and extra-geometric factors on children's production of *in* is reported (free-response paradigm). Eighty children across four age groups (means 4;1, 5;5, 6;1, and 7;1) were shown video scenes of puppets placing real objects in various positions with reference to a bowl and a plate. Located objects were placed at three heights on top of piles of other objects in the scene. The extra-geometric factor of location control of the located object was manipulated by comparing static scenes to dynamic scenes in which the located object was depicted as either moving independently of, or together with, the reference object. Additionally, the located object was placed on other objects that were either the same or different (e.g. an apple on apples or on oranges). The results indicate that even the youngest children altered the way they talked according to not only geometric but also extra-geometric factors.

INTRODUCTION

Describing the position of objects and people around us is fundamental to everyday communication. In English, spatial prepositions (e.g. *in*, *on*, *above*) are the primary means of expressing where one object is located in relation to a reference object. For example, *the coin is in the hand* expresses where the coin (located object) is positioned with reference to the hand

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(reference object). Such expressions are ubiquitous in the English language, and provide an important portion of language for children to acquire. It has been shown that there is a consistent order of acquisition of spatial prepositions, with *in* (the focus of this paper) and *on* typically emerging as the first prepositions comprehended/produced by pre-school children (e.g. Clark, 1973; Johnston & Slobin, 1979). Further prepositions are added to a child's spatial lexicon throughout the early school years and by the late primary school years children have acquired the majority of spatial prepositions (around 7;0: e.g. Durkin, 1980).

There is evidence from research into adult comprehension and production of spatial prepositions that the comprehension of *in* is influenced by both GEOMETRIC and EXTRA-GEOMETRIC relations present in the visual scenes being described (e.g. Coventry, Carmichael & Garrod, 1994; Coventry, 1998; Coventry & Garrod, in press). *In* not only suggests that there is some degree of (geometric) topological enclosure of the located object by the reference object, but also indicates that there is a physical/functional (extra-geometric) relationship of location control present such that the position of the located object is constrained over time by the reference object. Imagine an apple perched high on top of a pile of other fruit in a bowl. Imagine further that the bowl is moved, and the apple moves with the bowl such that the movement of the bowl continues to determine the location of the apple. In contrast, imagine the case where the apple is wobbling on top of the pile of fruit (although remaining in contact with the fruit), but the rest of the fruit and bowl remain stationary. In the first case, location control is seen to hold because the bowl is clearly controlling the location of the apple over time. However, in the second case the bowl is not seen to control the location of the apple because the apple is moving of its own accord. Coventry (1998) presented adults with videotaped images of real objects (various fruits, balls and containers) which directly manipulated these factors. The effects of the movement manipulations were striking. *In* was produced most (compared to other prepositions) in cases where location control was strongest (where the located and reference objects were moving together), and least when the located object was moving of its own accord while the bowl remained stationary.

Garrod, Ferrier & Campbell (1999) reported a series of studies in which location control was manipulated in static scenes by the presence or absence of a visible alternative means of location control (a wire hanging from above and attached to the located object). They argued that, should the bowl be moved, the alternative source of control would compromise the container's ability to constrain the location of the located object over time. Not only did they find that ratings for *in* were reduced as the height of the pile rose above the bowl's rim, but they also found that ratings for *in* were reduced in the presence of an alternative controller. Moreover, they reported a significant

correlation between ratings of *in* given by one group of participants and independent judgements from another group of the likelihood that the located object and reference object will remain in the same relative positions should the bowl be moved.

In addition to location control, other extra-geometric factors have also been shown to influence the production and comprehension of *in*. Coventry (1998) found that if the other objects in the bowl were the same as the located object (e.g. an apple on top of other apples in a bowl), *in* was rated higher and produced more than if the other objects in the bowl were different from the located object (e.g. an apple on top of oranges in a bowl), but only when the located object was positioned high above the rim of the container. Furthermore, the specific functions objects have (e.g. the use of a bowl vs. a jug as a container of solids), and the label given to the same reference object (e.g. whether the same object is labelled a *dish* or a *plate*) have all been found to influence the production and comprehension of *in* (Coventry *et al.*, 1994; Feist & Gentner, 1998). Moreover, these extra-geometric effects have been found for adults' comprehension and production of a wide range of other prepositions (e.g. Carlson-Radvansky & Radvansky, 1996; Coventry, Prat-Sala & Richards, 2001).

So there is much evidence that a range of extra-geometric constraints affects the comprehension and production of spatial prepositions. There is also evidence that dynamic relations such as location control may feature in the representation of spatial relations and events in prelinguistic infants' knowledge of the spatial world. For example, Mandler (1992) suggests that prelinguistic infants analyse and abstract spatial and dynamic/kinetic properties from perceptual displays to form simplified spatial representations. Such analyses from observable events include moving, interaction, causing-to-move, contacting a surface and containing, and are related to notions such as location control. This information, in the form of image-schemas, provides a facilitatory level of representation that is intermediate between perception and language and forms the beginning of a child's conceptual system onto which language is grounded. Indeed, using the preferential looking paradigm it has been demonstrated that infants as young as 0;2.14–0;3.14 look longer when they see an object lowered 'into' a container and the container is then moved away revealing the object behind it, than when they see an object lowered 'behind' the container and the container is then moved away revealing the object behind it (Hespos & Baillargeon, 2001). It appears, therefore, that even very young infants recognize that the movement of one object relative to that of another is an important aspect of a containment event (a core element of location control), although full conceptual understanding of containment events continues to develop until late into a child's second year (Caron, Caron & Antell, 1988). Vandeloise (in press) proposes that the complex primitive of containment,

embodying both geometric and location control components, is crucial to the development of *in*. He argues that the complex primitive of containment not only helps to anchor children's early comprehension and production of the preposition *in* (in English), but also allows them to expand this to go beyond any prototypical meaning.

Although there is considerable evidence that a child's prelinguistic spatial world involves understanding of extra-geometric relations, and that adult comprehension and production of *in* are also influenced by these factors, little is known about the influence of geometry and location control on the production of prepositions by children, and about how children construct spatial expressions to describe containment events. The main aim of the present study was to test the influence of both geometric and extra-geometric relations on children's descriptions of visual scenes involving containment relations. However, it is important to note that a spatial scene involving a containment relation can be described in a number of ways. For example, an orange positioned on top of a pile of apples in a container can be described with reference to the container (*the orange is in the bowl* or *the orange is near the bowl*), with reference to the apples (*the orange is on the apples*) or with reference to both a containment and a support relation (*the orange is on the apples in the bowl*).

There is some evidence that adults and children prioritize containment and support relations over other spatial relations in their descriptions of spatial scenes (Plumert, Carswell, De Vet & Ihrig, 1995*a*; Plumert, Ewert & Spear, 1995*b*; Plumert & Hawkins, 2001). For example, Plumert *et al.* (1995*b*) showed children aged 3;0 and 4;0 a troll figure that lived in a model room. Next, they familiarized the children with a miniature toy mouse and were told that they would be hiding the mouse when the troll was not looking. They would then be asked to tell the troll where the mouse was hiding. The room contained pairs of objects, for example, two buckets and two hats. One from each of the pairs (i.e. one hat, one bucket) was used as the primary reference object and the mouse was placed either in, under or behind it. In order to disambiguate these primary reference objects from the identical object in the pair, children needed to refer to a secondary reference object. Sometimes the secondary reference object supported the primary reference object (e.g. one of the hats was *on* a bed), whereas sometimes the primary reference object was proximal to it (e.g. one bucket was *by* the bed). Plumert *et al.* found that four-year-olds used more utterances with two prepositional phrases than three-year-olds in their locative descriptions, and therefore produced fewer ambiguous utterances. Additionally both groups of children mentioned the primary reference object as the first (or only) reference object in their utterances (e.g. *the mouse is on the hat on the bed*/*the mouse is on the hat*) thus highlighting the most prominent location of the mouse in the utterances they produced. Both groups of children also

showed a significant preference for mentioning two reference objects in a single utterance if the secondary reference object supported rather than was proximal to the primary reference object. Plumert *et al.* (1995*a*) have reported similar results for adults, and recently have found comparable results for the saliency of containment over proximity relations for children (Plumert & Hawkins, 2001).

More generally when sentences involve more than a single phrase (e.g. route directions, event descriptions or discussions about future plans), it has been shown that the phrase first mentioned serves to focus the listener's attention on an important factor or component in the scene being described (MacWhinney, 1977; Flores d'Arcais, 1987; Bock & Huitema, 1999). For example, Flores d'Arcais (1987) investigated how elements of a situation are conceptually organized and how this affects the word order adults produce when describing those events. Over a series of studies, he found an effect of first mention for many situations. These included the first mention of large objects and of objects that lead the way in dynamic scenes (e.g. when there is movement of a series of unconnected objects, the one that is leading is mentioned first).

The primacy of support and containment relations over proximal relations in adults' and children's descriptions of spatial relations that potentially involve more than one reference object suggests that some spatial relations are more salient than others, and this subsequently appears to influence the way people describe the location of objects with reference to other objects. Indeed it has been argued that support and containment relations are more salient than proximal relations because of the functionality that they directly afford and the suggestion that the two objects are causally linked (Plumert *et al.*, 1995*a*; Plumert & Hawkins, 2001). However, Plumert *et al.* have not tested the influence of location control on the production of *in* directly. Given the findings for location control with adults, we were interested in establishing how this (and other factors) influences the production of spatial expressions developmentally. More specifically, we were interested to find out which factors influence children's conceptualization of scenes of containment and how this is expressed in their language.

THE EXPERIMENT

This experiment was designed to explore the effects of geometric and extra-geometric factors on children's production of *in*; specifically height, location control and whether the located object was the same as or different from other objects in the scene, were manipulated in a similar fashion to the studies with adults described above (Coventry, 1998). In order to elicit natural language production, video scenes with puppets hiding real objects were shown to children. Each session involved a 'game' for the child to play

with puppets. The child's role was to watch video scenes on a computer and tell a blindfolded puppet where the puppet on the video had 'hidden' the located object (a free response paradigm). The dependent variable was the description given by the child. Generally, we expected that children's descriptions would show a developmental trend similar to that found in previous studies (e.g. Plumert *et al.*, 1995*b*) with older children producing more detailed utterances than younger children. However, we hypothesized that all children would prioritize the containment relation in their utterances by locating the located object *in the bowl* as the first or only prepositional phrase in their utterances when describing scenes that highlighted location control more than when describing scenes where non-location control information was present. Additionally, we hypothesized that children would be more likely to use *in the bowl* as first or only prepositional phrase when the scene involved strong rather than weaker topological enclosure.

METHOD

Design

A (4) age group × (3) height × (3) location control × (2) other objects same as or different from the located object partial within-groups design was used for the experiment. Age group was the between-groups variable. Height, location control and whether the located object was the same or different to other objects in the scene (labelled hereafter as *continuity* for the sake of brevity) were the within-group variables. The experiment consisted of 72 videotaped spatial scenes, plus an additional 56 distracter scenes, resulting in a total of 128 videotaped scenes. Examples of these scenes can be seen at the following web site: http://www.psychology.plymouth.ac.uk/research/slg

Four located objects and four transparent bowls were manipulated to examine how the height of the pile of objects in the bowl (degree of geometric topological enclosure), the level of location control provided by the bowl (an extra-geometric factor), and continuity (a second extra-geometric factor) affected children's production of locative expressions. The levels of these three variables were as follows (and examples of the scenes used are displayed in Figure 1).

Height of pile in bowl (*geometric manipulation*). Three levels of height were manipulated (see Figure 1(a)–(c), where the located object is indicated by a star). The located object was either touching the base of the bowl (Figure 1(a)), was positioned level with the rim of the bowl, approximately +13 cm from the base, in contact with other objects that were touching the base of the bowl (Figure 1(b)), or was positioned high above the rim of the

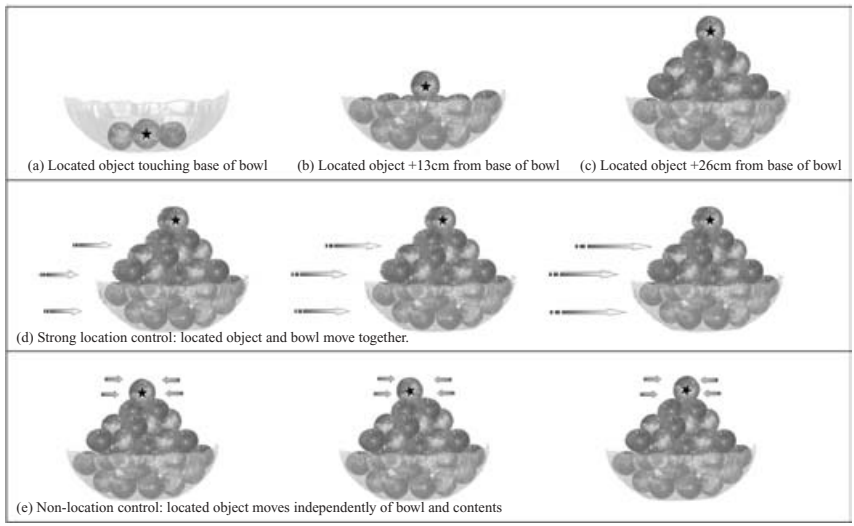

Fig. 1. Examples of the main bowl manipulations of height and location control.

bowl, approximately +26 cm above the base, in contact with other objects that were touching the base of the bowl (Figure 1(c)).

Location control of the bowl (*extra-geometric manipulation*). Three levels were manipulated: strong location control, non-location control and static. Strong location control depicted the located object moving together with the bowl and its contents from side-to-side (see Figure 1(d)). By contrast, the non-location control condition showed the located object moving from side-to-side, independently of the bowl and other objects inside the bowl, whilst at all times remaining in contact with the objects beneath it (see Figure 1(e)). The static condition involved no movement of located object or bowl (e.g. Figure 1(c)).

Continuity of the located object with other objects in the scene (*extra-geometric manipulation*). Either the located object was the same as the other objects in the bowl (e.g. an apple placed on top of other apples, as in the case of all examples in Figure 1) or they were different to the other objects in the bowl (e.g. an orange placed on top of apples).

A total of 72 scenes were filmed across the three main variables (4 located objects × 3 levels of height × 3 levels of location control × 2 levels of continuity).

In addition to the scenes for the main manipulations, fifty-six distracter scenes were also displayed and were interleaved with the scenes described above (see Figures 2 and 3 for examples). These scenes had the dual function of acting as distracter scenes for the main experiment while also

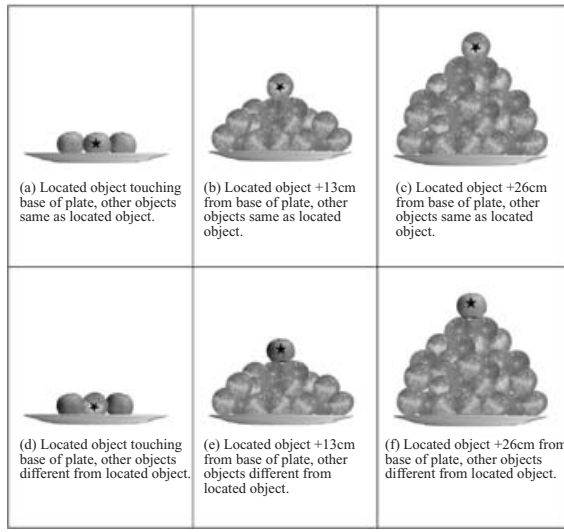

Fig. 2. Examples of distracter scenes involving a plate as reference object.

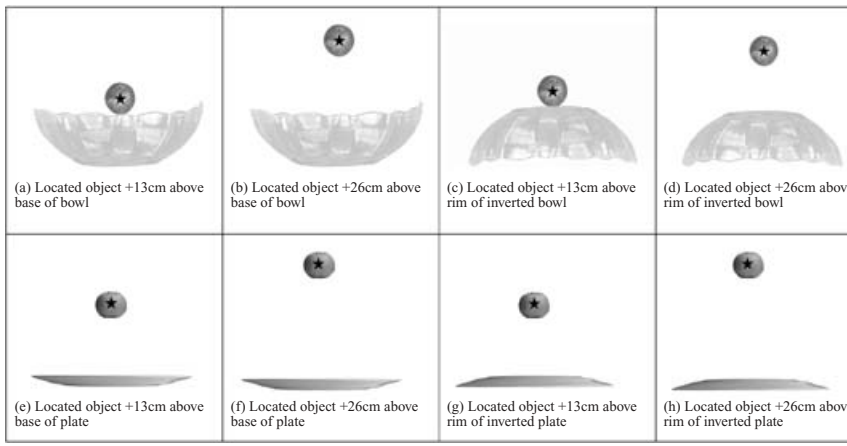

Fig. 3. Examples of distracter scenes with the located object positioned above a bowl and a plate.

affording a means of establishing the extent to which children drop into a pattern of saying *in* to describe every manipulation using a bowl (using what Clark, 1973 refers to as a 'mapping strategy' – if object A is a container, then object B belongs inside it). The fifty-six distracter scenes comprised twenty-four scenes that were similar in nature to the manipulations of

height and continuity for the main bowl scenes (as described above) but used a plate rather than a bowl as a potential reference object (24 scenes: 4 located objects × 3 levels of height × 2 levels of continuity; see Figure 2 for examples). The thirty-two remaining distracter scenes were designed to give the potential for a greater range of prepositional use. These involved either the bowl or the plate as the reference object with the located objects suspended above them (using invisible thread) approximately +13 cm above the lowest part of the bowl/plate (as in Figure 3(a), (c), (e) and (g)) or approximately +26 cm above the lowest part of the reference object (Figure 3(b), (d), (f) and (h)), with no other objects present in the scene. Additionally, for half these scenes, the bowl and plate were orientated in their canonical, upright position (Figure 3(a), (b), (e) and (f); 16 scenes – 4 located objects × 2 levels of height × 2 upright reference objects). However, for the other half of the scenes the plate and bowl were inverted (Figure 3(c), (d), (g) and (h), 16 scenes: 4 located objects × 2 levels of height × 2 inverted reference objects).

Participants

Eighty children from four age-groups participated. The youngest age group attended a small nursery school, and had a mean age of 4;1 ($n=20$, range 3;4 to 4;6). The older groups attended an infants' school in the same town. These groups had mean ages of 5;5 ($n=20$, range 4;8 to 5;7), 6;1 ($n=20$, range 5;8 to 6;8) and 7;1 ($n=20$, range 6;9 to 7;8). All participants were native English speakers with normal, or corrected to normal, eyesight and hearing. In a pretest, two children from the youngest group failed to display any comprehension or production of the prepositions *on*, *over*, or *above*, preferring to use *in* for all spatial locations. Additionally, one child from the second age group became unwell during testing. These participants were not used in the experiment.

Materials

Video scenes of each manipulation were filmed four times, once with each of the located objects. These were an apple, an orange, a ball and a child's building block and were identified by the prominent display of a visible star stuck to each object. Two hand puppets (a teddy bear and a lion) were depicted between spatial scenes to involve the children in a game. The reference objects used were transparent bowls (of similar dimensions to each other) and a white plate (for some of the distracter scenes). All spatial scenes were filmed using a Panasonic VHS camera against a plain background. The scenes involving the puppets were filmed in a natural setting (a child's playroom). These puppet scenes were then edited together and

alternated with the 128 individual spatial scenes across four separate video sessions. A narrator's voice was then dubbed over the scenes, describing the actions of the puppets and asking the questions.

The four video sessions were all of a similar structure. Although the order of the manipulations differed across sessions, they were arranged to minimize priming effects and to prevent children giving the same response throughout. Each session comprised one scene from each of the main manipulations (18 scenes) and fourteen distracter scenes, producing a total of 32 spatial scenes for each session. These were presented in four blocks of eight spatial scenes. Each block appeared thus:

- The four located objects were depicted in front of the two puppets.
- One puppet was blindfolded and then the other puppet moved a located object to a new location.
- The screen then faded to black for one second.
- Simultaneously the narrator's voice asked *where's the orange* [*apple/ball/block*]*?*
- The spatial scene (containing that object) was then revealed for 5 seconds to allow the child to respond.
- The video then returned to the scene depicting the remaining three located objects and the puppet then removed and relocated one of these objects.
- Once again, the screen faded to black for a second while the narrator asked the question before revealing the relocated object in a spatial scene, and so on.
- After all four objects had been hidden twice, the puppets changed roles.

Procedure

Each child was tested individually in the morning session at school on four separate occasions (once for each of the video sessions, with no more than 10 days between the first and last meeting). The videos were counterbalanced to ensure that no two children in one age group saw them in the same order.

For all sessions, the child sat at a table with the experimenter holding the puppets from the video to their right. Using the hand puppets, the first session began with a brief pretest of each child's comprehension and production for the prepositions *in*, *on*, *over*, and *under*. This also acted as an introduction to the puppets and the game they were to play. They were then shown a 15 inch screen and asked to watch a video of the located objects and puppets whilst the experimenter explained the game. The children were asked to name the located objects and their attention was drawn to the stars on the located objects for ease of identification. They were told that one of

the puppets would be hiding the objects and that it was their job to tell the other (blindfolded) puppet where the object had been placed. When the experimenter was sure the child knew what to do, the video session was displayed. For sessions 2–4 this was the only task required of the children.

During testing, when the child was requested to respond, if the child did not do so, the experimenter paused the video and repeated the narrator's question *where's the orange* [*apple/ball/block*]*?* If a response was given in the form of 'preposition-reference object', it was recorded and the game continued. If an inappropriate response was given, such as *there* [pointing], the child was reminded that the puppet could not see because it was blindfolded and that they had to tell the puppet where the object had been hidden. One further attempt was made to elicit a response before the next scene was shown. All responses for the experiment were recorded onto audiotape and were later transcribed verbatim.

RESULTS

An alpha level of 0·05 was used for all statistical tests. Tukey (H.S.D.) tests were used for all follow-up analyses unless age group was included in the analyses when Tukey (H.S.D.) tests for unequal *N*s were used. All the data, including children's descriptions of the distracter scenes, were transcribed verbatim and initially categorized. We begin by considering how errors and unusual utterances were categorized and how children used nouns when describing the bowl and plate, before going on to explore the length of utterances across age groups. We then present a brief analysis of the distracter scenes to check that children were using a variety of completions in the experiment overall, and to establish to what extent children were using *in* if the reference object was a bowl irrespective of the spatial relation present (i.e. the extent to which a mapping strategy was used; Clark, 1973). We then present the analyses of the utterances used for the main bowl manipulations.

General descriptions of the utterances

Errors, unusual and ambiguous responses. It was important that only the meaningful utterances were analysed. We therefore needed to exclude those utterances that contained factual errors, that did not involve the type of construction we were trying to elicit, or that were potentially ambiguous. Errors were defined as any utterance that referred to an object or objects not in the scene. For example, producing a preposition plus the noun phase *the apples*, when there were no other objects apart from the bowl or the plate present, was considered to be an error. However, simple naming mistakes (e.g. calling a *bowl* a *pot*) were not considered to be errors.

Unusual responses were defined as 'any prepositional phrase that used a reference object other than the objects in the scene' (again, excluding naming mistakes), such as *in the ceiling*, *up in the air*, and *in the sky*. The youngest children who did not yet produce the prepositions *over* or *above* mainly gave these descriptions for the distracter scenes where the located object was suspended above the reference object. Finally, ambiguous responses were defined as any utterance that contained a preposition without a reference object such as *in there*, *up there*, or simply *on*. In these cases it was impossible to establish whether the children were locating the object with reference to the container/support object or the other objects in the scene.

Errors, unusual or ambiguous responses comprised only 3% of all the data collected (328 utterances out of a total of 9856 utterances) and were mainly produced to describe the distracter scenes where the located object was suspended above the bowl or plate. The frequency of erroneous utterances reduced with age with 41% of them (133 utterances) being produced by age group 1 (4;1), 30% (97) produced by age group 2 (5;5), 18% (60) produced by age group 3 (6;1) and only 12% (38) produced by age group 4 children (7;1).

The production of nouns. Not all children used the noun *bowl* to describe the bowls or the noun *plate* to describe the plate. Some children named the bowl according to the located object used (e.g. *ball bowl*, *apple plate*, etc). This was more common with the group of children of mean age 6;1. It was interesting to note that the children only ever used these noun–noun compounds when they responded using single prepositional phrases. Related findings have been reported in previous studies where children coin new compound words for objects (and actions) where the second noun designates the kind of object being talked about, often with the head-noun used in several compounds to denote members of the same category (e.g. Clark, 1981).

Some children made errors in their naming of the reference objects. For example, the bowl was called a *pot*, *saucepan*, *dish* and occasionally *plate*. These were all relatively uncommon and not peculiar to any one age group. For ease of reporting, from this point forward in the text we will refer to the nouns used as *bowl* (for a bowl), *plate* (for a plate) and *orange* (for the oranges, apples, balls and blocks in the scene).

Length of utterances. The utterances (excluding erroneous responses) fell into one of two categories. The first category comprised single phrase utterances, minimally containing a preposition and a noun. The second category comprised utterances containing two single prepositional phrases combined together (see Table 1 for examples). Eleven children in each of the age groups 1–3 and seventeen of the children in age group four uttered these longer descriptions in addition to single prepositional phrase

TABLE 1. *Examples of the one and two prepositional phrases produced by participants*

One prepositional phrases	*Two prepositional phrases*
Over the plate	*On top of blue blocks in a glass bowl*
On the plastic bowl	*With the oranges in the bowl*
On top of the bowl	*On a plate on top of other blocks*
On top of the oranges	*In a bowl on top of apples*
In the block bowl	*Up above all the other oranges on a plate*
Above the plate	*In the other oranges in the bowl*

utterances. The production of two prepositional phrases increased with age; the mean percentage uses of two prepositional phrases were 10, 11, 15 and 29% for age groups 1–4 respectively, and the difference between age groups one and four was significant, $t_{0\cdot05}(36) = 2\cdot12$, $p < 0\cdot05$. A similar developmental difference in the length of utterances has also been found in other studies (e.g. Plumert *et al.*, 1995*b*).

Analyses of distracter scenes. Before examining whether the manipulations of geometry, location control and continuity influenced the spatial expressions produced to describe bowl scenes, it was important to check that the distracter scenes had been successful in eliciting a variety of responses from the children, and to examine the extent to which children in different age groups responded by using a mapping strategy (i.e. if there's a bowl in the scene then it's *in*; Clark, 1973).

We begin by examining whether the twenty-four (distracter) scenes with the plate depicting the located object at three heights and two levels of continuity (see Figure 2) were successful in eliciting different prepositions to the (matching) static main scenes manipulating height and continuity involving the bowl (Figure 1(a)–(c)). We examined all utterances mentioning the bowl or the plate for these scenes, and calculated the percentage use of *in* and *on* as prepositions appearing in the prepositional phrase attached to these nouns. For example, the two prepositional phrase descriptions *in the bowl on top of the apples*, *on top of the blocks on the bowl* and *on the apples in the plate* were all included in the analysis as were any single prepositional phrases that mentioned the bowl or plate. In contrast, the single prepositional phrases that did not use the bowl or plate as a reference object, for example *in the oranges*, were not included. When we did this, we found that 98% (3178) of prepositional phrases that described the position of the located object to the bowl used *in* with the reference object *bowl* whereas only 17% (222) of the responses to the plate scenes used *in* with the reference object *plate*. Conversely, only 4% (133) of prepositional phrases that described the bowl scenes used the preposition *on* with the reference

object *bowl* while 80% (1046) of the responses for the plate scenes used *on* with the reference object *plate*. Clearly participants were not using a strategy of completing all the scenes with an *in* response, and therefore we can be reassured that the distracter scenes were successful in eliciting a variety of utterances from participants.

Although it is clear that children did not stick to the same preposition throughout the task, it was important to establish the extent to which children were using a mapping strategy to describe the scenes (*cf*. Clark, 1973), such as 'if it's a bowl, then it's *in*'. We therefore compared the utterances given by children when they described the main bowl scenes when the located object was on top of a pile of other objects either +13 cm or +26 cm from the base of the bowl (e.g. Figure 1(b) and (c)), to the utterances they produced for the (matching) distracter scenes where the located object was suspended either +13 cm or +26 cm above the base of the bowl (e.g. Figure 3(a) and (b)). We examined all utterances mentioning the bowl for these scenes, and calculated the percentage use of *in* vs. other prepositions appearing in the prepositional phrase with the word *bowl*.

Comparing responses for the above scenes with those for the containment scenes we found that although *in-bowl* pairings were high overall, children did not produce the same preposition when the located object was on top of a pile as when it was suspended above the bowl (see Table 2). Indeed, children in all age groups, and at both heights, produced the preposition *in* when the located object was on top of a pile of objects in the bowl at least 80% of the time. The production of *in* for the scenes where the located object was above the bowl reduced to 28% of bowl references for the youngest age group (whom we might expect to show some degree of mapping strategy use), and to as low as 0 and 3% for age groups three and four respectively. As illustrated in Table 2, children also used the prepositions *on*, *on top of*, *above* and *over* to describe the position of the located object in the above scenes much more than when the located object was at the same height but was in contact with other objects in the bowl. Children of all ages produced different prepositions to describe the scenes where other objects were present than when they were absent. They also produced a wider range of prepositions for the scenes when the other objects were absent. This strongly suggests that the use of these scenes to prevent children from simply producing *in* for all scenes involving a bowl was successful.

Analysis of the main bowl manipulations. We wished to establish whether children's descriptions of the scenes altered according to the geometric and extra-geometric factors present in the scenes. The manipulations were height (three levels: touching the base of the bowl, +13 cm from the base and +26 cm from the base), location control (three levels: static, non-location control, strong location control) and continuity (two levels: located

TABLE 2. *Percentage (and number) of prepositions occurring with the reference object bowl for the main bowl manipulations where the located object was on top of a pile of objects vs. suspended above the bowl with no other objects present*

	In (413 utterances)				*On/on top of/above/over (542 utterances)*			
Age group:	*Group 1* Mean 4;1 (3;4–4;6)	*Group 2* Mean 5;5 (4;8–5;7)	*Group 3* Mean 6;1 (5;8–6;8)	*Group 4* Mean 7;1 (6;9–7;8)	*Group 1* Mean 4;1 (3;4–4;6)	*Group 2* Mean 5;5 (4;8–5;7)	*Group 3* Mean 6;1 (5;8–6;8)	*Group 4* Mean 7;1 (6;9–7;8)
Located object +13 cm from base on top of pile	81 (35)	93 (54)	80 (37)	84 (53)	19 (8)	7 (4)	20 (9)	16 (10)
Located object +13 cm above base, no pile	28 (20)	22 (16)	9 (7)	8 (6)	72 (51)	78 (57)	91 (72)	92 (73)
Located object +26 cm from base on top of pile	85 (33)	92 (48)	83 (30)	84 (48)	15 (6)	8 (4)	17 (6)	16 (9)
Located object +26 cm above base, no pile	28 (15)	14 (9)	0 (0)	3 (2)	72 (39)	86 (54)	100 (69)	97 (71)

object same or different to other objects in the bowl). When we examined the utterances we found that the most common response from children of all ages when describing the main bowl scenes was the single prepositional phrase *in the bowl* (with a total frequency of 2823 utterances; see Appendix A for a breakdown of the percentages of types of utterances for each age group). Of the remaining single prepositional phrases, *on top of the oranges* (933 utterances) and *on the oranges* (378 utterances) were also frequently produced. Of the two prepositional phrases, *on top of the oranges in the bowl* (303 utterances) and *in the bowl with the oranges* (313 utterances) occurred the most.

As we have seen in a previous section, more than half of the children in the three youngest groups produced two prepositional phrases at least some of the time, with the oldest group giving significantly more information in their descriptions than the youngest group. We were therefore interested in establishing whether children modified the way they described the spatial scenes as a function of the main manipulations. In order to do this, the method of coding that was adopted for the inferential analyses categorized the utterances on a first mention basis, following Plumert *et al.* (1995*b*) (see also Flores d'Arcais, 1987; Bock & Huitema, 1999; for more general discussion of first mention analyses).

The main analysis investigated whether the manipulations in this study affected children's conceptualization of the scenes in terms of when they described the location of the located object with reference to containment as first (or only) mention (e.g. *in the bowl*) compared to when they did not (e.g. *on the oranges*, *on/above the bowl*, etc.). The data were placed into three categories according to the first prepositional phrase uttered by the child when describing each scene. Category 1 (3144 utterances) comprised all single prepositional phrase utterances that used the preposition *in* with the bowl as a reference object. Additionally it also contained all of the two prepositional phrase utterances that used the preposition *in* with the bowl if it was the first prepositional phrase mentioned (e.g. *in the bowl on top of the apples* or *in the bowl with the blocks*). The remaining data that either used another preposition with the reference object bowl (e.g. *on* or *over the bowl*) or located the located object initially with respect to the oranges (e.g. *in the oranges*, *on top of the apples*, *on the blocks in the bowl*) were placed into Category 2 (2281 utterances). Both of these categories contained one and two prepositional phrase utterances (see Table 3 for examples). Finally, erroneous responses (as previously defined) were placed into Category 3 (119 utterances).

The ratio of Category 1 utterances was calculated against Category 2 utterances (ignoring Category 3) for each cell of the design and expressed as a percentage. A four-way, partial-within-group, analysis of variance was then performed on these data. The between-groups variable was age

TABLE 3. *Examples of utterances coded in each of the three categories for the main bowl manipulations*

Category 1 (*In*-bowl)	Category 2 (Other preposition-bowl, other reference objects)	Category 3 (Erroneous utterances)
In the apple bowl with all the apples	*On top of the blocks*	*Inside*
In the block bowl	*On the apples*	*In the other ones*
In a glass bowl on top of all the other oranges	*In the balls*	*On*
In the dish with the other pink blocks	*On the bowl*	*In there*
In the pan	*With the red blocks in the bowl*	*On top*
	On top of a tower of blocks in a moving glass bowl	*Outside*
	Above the bowl	*Don't know*
		Up there

TABLE 4. *Results of the analysis of variance for the main bowl (containment) manipulations*

Source	df and F value	MS (error)	Significance
AGE (A)	$F(3, 73) = 0{\cdot}58$	15 508·56	ns
HEIGHT (H)	$F(2, 146) = 136{\cdot}61$	2712·47	****
LOCATION CONTROL (L)	$F(2, 146) = 17{\cdot}92$	157·94	****
CONTINUITY (C)	$F(1, 73) = 16{\cdot}95$	246·72	****
A × H	$F(6, 146) = 2{\cdot}47$	2712·47	*
A × L	$F(6, 146) = 1{\cdot}05$	157·94	ns
A × C	$F(3, 73) = 2{\cdot}28$	246·72	ns
H × L	$F(4, 292) = 4{\cdot}59$	168·68	***
H × C	$F(2, 146) = 1{\cdot}49$	208·28	ns
L × C	$F(2, 146) = 4{\cdot}81$	118·04	**
A × H × L	$F(12, 292) = 1{\cdot}10$	168·68	ns
A × H × C	$F(6, 146) = 0{\cdot}25$	208·28	ns
A × L × C	$F(6, 146) = 1{\cdot}91$	118·04	ns
H × F × C	$F(4, 292) = 0{\cdot}60$	155·77	ns
A × H × L × C	$F(12, 292) = 0{\cdot}63$	155·77	ns

Note: * $p < 0{\cdot}05$, ** $p < 0{\cdot}01$, *** $p < 0{\cdot}001$, **** $p < 0{\cdot}0001$.

(4 groups: Mean ages 4;1, 5;5, 6;1 and 7;1). The within-group variables were height (3 levels: touching the base of the bowl, +13 cm from the base and +26 cm from the base), location control (3 levels: static, non-location control, strong location control) and continuity (2 levels: other objects either the same as or different from the located object).

The results from the ANOVA are displayed in Table 4. A significant main effect of height was found. Follow-up analysis revealed significant differences between all three levels; children produced *in the bowl* as the

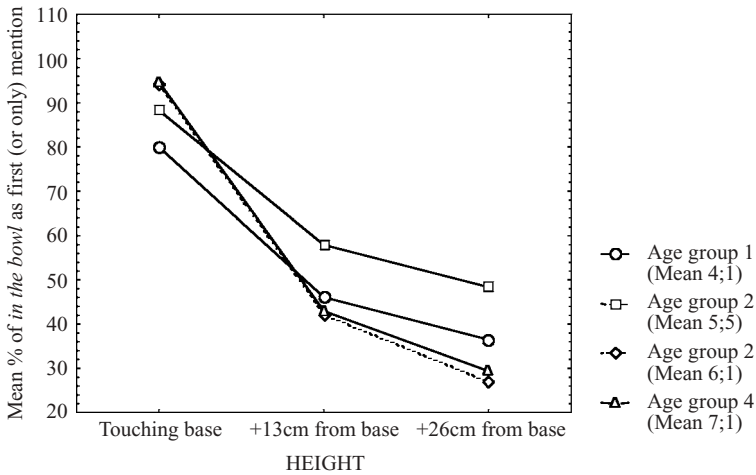

Fig. 4. Interaction between age group and height of pile for the main bowl manipulations.

first (or only) prepositional phrase most when the located object was touching the base of the bowl (mean 89%), and least when the located object was +26 cm above the base of the bowl (mean 35%). Additionally, the significant interaction between height and age (displayed in Figure 4) showed that although all age groups displayed this trend, these height differences became more considerable with increasing age.

A main effect of location control was found, and all three levels differed significantly from one another. However, the interaction between height and location control revealed differences only with higher piles (see Figure 5). When the located object was +13 cm from the base of the bowl children used *in the bowl* as the first (or only) prepositional phrase significantly more when describing scenes depicting strong location control compared to non-location control scenes and static scenes. When the located object was positioned +26 cm above the base of the bowl, they used *in the bowl* more when describing strong location control scenes compared to non-location control scenes. No differences between levels of location control were found when the located object was touching the base of the bowl.

There was also a main effect of continuity. Overall *in the bowl* was used as first (or only) mention more for scenes where the other objects in the scene were the same as rather than different from the located object. The interaction between continuity and location control was also significant (see Figure 6). When the other objects in the scene were the same as the located object, *in the bowl* as first (or only) prepositional phrase was

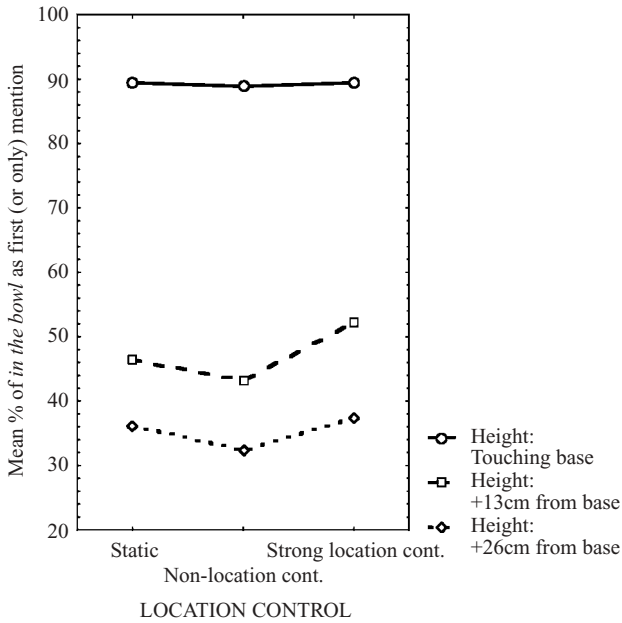

Fig. 5. Interaction between location control and height.

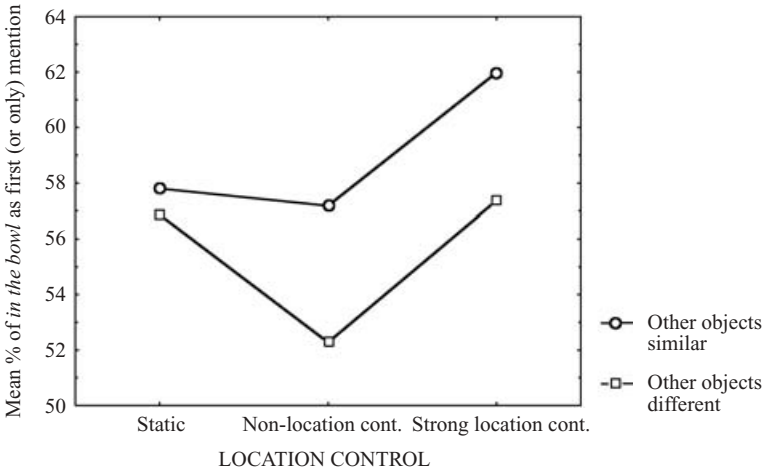

Fig. 6. Interaction between location control and continuity.

produced significantly more for strong location control scenes than for either static scenes or non-location control scenes. When the other objects were different from the located object, in the bowl as first (or only) mention

was produced significantly less for non-location control scenes than for strong location control or static scenes.

DISCUSSION

The results reported above demonstrate that young children are sensitive to both geometric and extra-geometric information when describing the relative positions of objects to containers. Some of the youngest children highlighted these factors by selecting the salient relationship between located and reference object(s) in the scene (e.g. containment, support) and expressing it by way of a single prepositional phrase (e.g. *in the bowl*). However, in a similar manner to previous studies (e.g. Plumert *et al.*, 1995*b*), over half of the youngest children and most of the older children produced richer utterances involving two prepositional phrases making reference to both possible reference objects (i.e. bowl/oranges or plate/oranges). When such utterances were used, the phrase mentioned first reflected the most salient relationship between located and reference object(s) present in the scene being described.

Mirroring results found with adults, the geometric factor of height of pile and the extra-geometric factors of location control and continuity (whether the located object was the same or different from other objects in the bowl) all affected children's production of spatial expressions. When the height of the pile of objects was high, children used the expression *in the bowl* as the first (or only) description less than when describing scenes where the located object was enclosed within the parameters of the bowl. Therefore, the containment relationship of located object and bowl was most salient when the object was below the rim of the bowl, which is consistent with effects found with adults (e.g. Garrod *et al.*, 1999). However, the manipulation of location control at higher heights affected the salience of the located object/bowl containment relation. At these heights, when the bowl demonstrated strong location control, children produced the description *in the bowl* as the first (or only) prepositional phrase significantly more than when they were describing static and non-location control scenes. Likewise, *in the bowl* was used significantly less as the first (or only) prepositional phrase for non-location control scenes than for static scenes. The factor of location control was moderated by continuity (whether or not the other objects in the bowl were the same as or different from the located object). Continuity only influenced the use of *in the bowl* as first (or only) mention when strong location control or non-location control were present. In both cases use of *in the bowl* as first (or only) mention decreased when the located object was different from the other objects in the pile vs. when the located object was the same as the other objects.

The interplay between location control and continuity is informative. With static scenes, there is no clear evidence that location control is likely to

hold or not, and continuity has no effect. However, when evidence for non-location control is present, if the located object is different from the other objects in the pile, this may serve to reinforce expectations of non-location control and use of *in the bowl* diminishes further. Conversely, for strong location control scenes, the expectation of location control is reinforced when the located object is the same as the other objects in the container, and use of *in the bowl* as first (or only) mention increases. One interpretation of these results is that a range of both geometric and extra-geometric variables is put together in a situation model, and the utterance produced relates to the output of the model (Coventry & Garrod, in press).

We can also consider in relation to the concepts of containment and support, whether one relationship is more important than the other. For the main scenes in this study there were two potential reference objects thus creating a conflict regarding the type of relation that can be highlighted in descriptions. The located object could be either 'contained by the bowl' or 'supported by the other objects' in the bowl. Generally, when the located object was fully enclosed by the bowl, children referred to it as being *in the bowl* as the first (or only) mention about 90% of the time. However, when the pile of (supporting) objects was higher than the rim, the frequency of this type of description was significantly reduced. Given that the vast majority of the other descriptions referred to a support relationship (e.g. *on the oranges*), we can see that the saliency of support over containment was high when the bowl did not fully enclose the located object. However, for scenes depicting the same heights, when the containment function of the bowl was highlighted by means of demonstrating location control, the production of *in the bowl* increased. Therefore this is preliminary evidence for the greater saliency of containment over support as the other objects supporting the located object continued to do so even when the bowl was moved. As noted in the introduction, previous studies have looked at these relationships separately and found a preference for both containment and support relations over proximal relations in memory and language (e.g. Plumert *et al.*, 1995*b*; Plumert & Hawkins, 2001). The present study has investigated, for the first time, containment and support in the same scenes using a production task, and the results indicate a possible hierarchy whereby containment relations are more salient than support relations.

Overall, the results reported here show that children's descriptions of spatial scenes involving objects positioned relative to containers are affected by both geometric and extra-geometric factors. However, we do not yet know whether all of these factors are noticed by children during their very early acquisition of spatial terms or whether some factors are more primary than others. Landau & Munnich (1998) suggested that geometry may be primary for the child, with extra-geometric relations influencing language

later in development, while Vandeloise (in press) has argued that extra-geometric relations are primary influences from the outset. In the present study the effects of location control were apparent across all age groups and the effect size was stable across age groups. However, the effect of height on children's utterances was more profound for children in the older age groups than for children in the younger age groups. The continued development of geometric distinctions suggests that mapping spatial terms onto geometric relations does not necessarily precede an ability to make extra-geometric distinctions, although comprehension studies are required to establish more precisely when sensitivity to geometric and extra-geometric constraints occur in development. Additionally, it is important to establish whether extra-geometric factors also play a role in the production of spatial expressions by children to describe spatial relations other than containment and support relations. Research with adults has found strong extra-geometric influences across a wide range of spatial relations (see Coventry & Garrod, in press) and it is therefore likely, given the present results, that extra-geometric constraints play an important role in understanding the acquisition of a range of prepositions throughout development.

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APPENDIX A

PERCENTAGE (AND NUMBER) OF UTTERANCES PRODUCED FOR EACH AGE GROUP FOR THE MAIN BOWL SCENES

Utterances	Total frequency	*Group 1* Mean 4;1 (3;4–4;6 $n=18$)	*Group 2* Mean 5;5 (4;8–5;7 $n=19$)	*Group 3* Mean 6;1 (5;8–6;8 $n=20$)	*Group 4* Mean 7;1 (6;9–7;8 $n=20$)
Inside the bowl	62	2% (21)	1% (18)	<1% (10)	1% (13)
In the bowl	2823	50% (652)	64% (882)	47% (673)	43% (616)
On the bowl	112	3% (36)	2% (27)	3% (44)	0% (5)
On top of the bowl	139	2% (21)	2% (30)	3% (36)	4% (52)
Above the bowl	40	0	<1% (2)	<1% (2)	3% (36)
Over the bowl	36	0	0	<1% (4)	2% (32)
In the oranges	34	<1% (12)	<1% (10)	<1% (11)	0% (1)
On the oranges	378	5% (64)	8% (105)	14% (201)	<1% (8)
On top of the oranges	933	25% (319)	9% (120)	16% (231)	18% (263)
In the bowl *with* the oranges	313	3% (42)	1% (19)	7% (97)	11% (155)
On the oranges *in* the bowl	49	0	2% (34)	<1% (7)	<1% (8)
On top of the oranges *in* the bowl	303	<1% (4)	3% (35)	5% (77)	13% (187)
With the oranges *in* the bowl	169	6% (77)	4% (51)	1% (14)	2% (27)
Other Utterances (<2% in single category)	97	1% (14)	1% (16)	2% (30)	3% (37)
Ambiguous/Errors/Non utterances	56	3% (34)	1% (18)	<1% (4)	0
Total:	5544	100% (1296)	100% (1368)	100% (1440)	100% (1440)