Running head: OBJECT DRAWING

Visual Mental Representations Supporting Object Drawing: How Naming a Novel Object with a Novel Count Noun Impacts on Young Children's Object Drawing

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Abstract

Object drawing can be supported by a number of cognitive resources, each making available visual information about the object being drawn. These resources include perceptual input, short-term visual memory, and long-term visual memory. Each of these resources has the potential to make available distinct forms of visual representation, including viewpoint-specific and viewpoint-independent representations, object-specific and category representations, and separate representations of object colour. We review neuropsychological and developmental evidence supporting these claims, including evidence that the same drawing can reflect the influence of multiple forms of visual representation. Seven experiments are then reported, investigating object drawing by 4- to 6-year-old children, to confirm the support for drawing provided by different forms of visual representation. Young children are selected for investigation because their drawing is relatively unconstrained by culturally-determined norms which, in our culture, dictate that objects should be drawn just as they appear from the vantage point of the drawer. To distinguish the support provided by object and category representations, the experiments exploit the privileged links between count nouns as object labels, and representations of object categories. In addition, pre-established representations, visual or otherwise, are precluded from influencing drawing by asking the children to draw novel objects, and by creating novel count nouns with which to label the objects. The results reveal how viewpoint-specific perceptual representations, object-specific representations of shape and of colour, and category representations of shape, can each impact on object drawing, and in some circumstances on the same drawing. It appears that simple drawing tasks have the potential to reveal some of the distinct types of representation able to support visual cognition.

Visual Mental Representations Supporting Object Drawing: How Naming a Novel Object with a Novel Count Noun Impacts on Young Children's Object Drawing

The constellation of representational and production processes underpinning object drawing presents a complex situation to understand. Nevertheless, object drawings are a rich source of information about our visual knowledge of objects, and about how this knowledge is represented mentally. Where interest centres on the representational bases for object drawing, these can be most clearly revealed when the production demands of drawing are minimised, as when simple objects are drawn, and when qualitative aspects of the drawings are assessed.

Object drawing is supported by a number of cognitive resources, each of which has the potential to make available several forms of visual representation (e.g., visual representations of object colour and object shape). As a result, object drawings provide a rich source of data with which to explore the different types of visual representation able to support cognition. In addition, because they are multifaceted, object drawings can reflect the combined impact of different representational forms, and can reveal the executive processes responsible for co-ordinating their contributions. Furthermore, because object drawings can be relatively uncontrained, they have the potential to reveal individual differences in the representational support for visual cognition, such as when a degenerative disease leads to the disintegration of object knowledge (e.g., Bozeat et al. 2003).

In the first section of this paper, we consider some of the cognitive resources that support object drawing by providing visual information about the object being drawn. An elaboration of the framework proposed by Farah (1984) is adopted for this purpose. We then review neuropsychological evidence regarding the different forms of visual representation made available by these resources, including evidence that the same drawing can reflect the combined influence of several forms of visual representation. In the second section, we review a selection of experimental studies of young children's object drawing, and argue that various aspects of their drawings, especially whether they portray an object's hidden features, confirm the influence of distinct forms of visual representation. In the final section of the paper, we report seven experiments in which young children's object drawings reveal the support provided by different forms of representation. Young children are selected for investigation because they are relatively unconstrained by culturally-determined drawing conventions, and because their drawings are susceptible to a range of variables. Contributions from object and category representations are distinguished by exploiting the privileged links between count nouns as object labels and visual representations of object categories. In addition, any influence from pre-established representations is precluded by asking the children to draw novel objects, and by creating novel count nouns with which to label them. The results reveal how viewpoint-specific perceptual input, object-specific representations of shape and of colour, and category representations of shape, all support drawing, and how on occasions they can impact on different aspects of the same drawing.

Cognitive resources supporting object drawing, and distinct types of visual representation

It has been claimed that the visual representations on which object drawings are most directly based are themselves provided by several cognitive resources, including current perceptual input, short-term visual memory, long-term visual memory, and a visual buffer. For example, Farah (1984) proposes that visual representations generated from long-term memory (i.e., visual images), and visual representations based on current/recent perceptual input, can be registered in the same visual buffer. A range of cognitive operations can then be applied to the contents of this buffer, including drawing. Thus, the buffer can support live drawing of a model (i.e., copying a picture, or drawing a visible object), drawing from short-term visual memory, and drawing on request from long-term memory (see Figure 1).

Figure 1 about here

It is tempting to think that copying and live drawing, much like tracing, can be based directly on perceptual input, without the need for mediation by an internal visual representation. However, as Phillips, Hobbs, and Pratt (1978) point out, because drawers need to look away from a model in order to draw, a visual representation is needed to compensate for the loss of visual input, and to bridge the time interval required to redirect attention (i.e., strictly speaking, all perceptual input supporting drawing qualifies as recent, rather than current input). Several studies have confirmed that copying and live drawing are normally mediated by internal representations (e.g., Coltheart, Inglis, Cupples, Michie, Bates, & Budd, 1998; Phillips, Hobbs, & Pratt, 1978; Thaiss & De Blesser, 1992; Wapner, Judd, & Gardner, 1978). For example, Phillips et al. asked children to copy simple line drawings of a cube, and equivalent 2-D arrangements of lines. When a 3-D interpretation of the figure was possible, the children's drawings changed. They were likely, for example, to distort the spatial arrangement of the lines in their drawings in order to depict the sides of the cube as squares. Wapner et al. (1978) report a somewhat complementary situation, in which a visual agnosic patient's ability to recognize the object in a picture protected him from making copying errors. Thus, he found it easier to differentiate features that were significant for object recognition from features that were not. He also found it easier to differentiate details belonging to the depicted object from those belonging to the background against which the object appeared. When he failed to recognize an object, he also failed to appreciate that his copy of a drawing was spatially disorganized, compared with his copies of objects he could recognize. Coltheart et al. (1998) also illustrate, with a single case study, how copying a drawing is disrupted when the depicted object is not recognized. In each of these three studies, therefore, we see copying being influenced by the presence or absence of particular types of mental representation. For the children in the Phillips et al. study, the perception of a 3-D object induced errors in drawing, whereas in the Wapner et al. and Coltheart et al. studies it was the unavailability of representations mediating object recognition that induced drawing errors. Finally, Thaiss and De Blesser (1992) report a case of presenile dementia that included visual agnosia. Their patient found it difficult to derive visual representations that captured the global shapes of objects in pictures. Thus, whereas she could name the local letters in a compound stimulus, she struggled to name the global letter. Her difficultes were reflected in her copies of drawings which, because they were deficient in their potrayal of the global characteristics of the depicted objects, provided converging evidence that copying utilises internal representations.

The involvement of internal visual representations in object drawing is, of course, less open to dispute in the context of drawing from long-term memory. In agreement with Farah's (1984) model, researchers in neuropsychology have often observed drawing from long-term memory to be mediated by visual imagery (e.g., Behrmann, Winocur, & Moscovitch, 1992; De Vreese, 1991; Goldenberg, 1992; Jankowiak, Kinsbourne, Shalev, & Bachman, 1992; Magnie, Ferreira, Giusiano, & Poncet, 1999; Stangalino, Semenza, & Mondini, 1995). Indeed, drawing has been exploited to confirm that the ability to generate images from long-term memory can be selectively compromised by brain damage (e.g., Botez, Olivier, Vezina, Botez, & Kaufman, 1985; Goldenberg, 1992; Grossi, Orsini, & Modafferi, 1986; Riddoch, 1990; Stangalino et al., 1995).

Neuropsychological evidence confirming that object drawing can be mediated by distinct types of object representation

Each cognitive resource providing visual information to support drawing (i.e., perceptual input, short-term visual memory, and long-term visual memory), is presumed to have the potential to make available a number of different types of representation. These might include representations of the material from which an object is formed (embracing representations of surface colour and surface texture), viewpoint-specific and viewpoint-independent representations of object shape, and visual representations of specific objects, and of object categories. The impact of different types of representation on object drawing has been confirmed in neuropsychological research, with object drawing tasks helping to identify which representations have been compromised by brain damage, and which have not.

In several studies of visual agnosia, the drawings of patients have confirmed that, despite their agnosia, their representations of objects in long-term visual memory have been preserved, and can support the generation of visual images and drawings (e.g., Bartolomeo, Bachoud-Levi, De Gelder, Denes, Dalla Barba, Brugieres, & Degos, 1998; Berhmann et al., 1992, and Jankowiak et al., 1992). Behrmann et al., for example, report a visual agnosic who could draw objects to dictation (and, therefore, could draw objects he could not recognize), and could perform normally on a range of tests requiring visual images of objects to be generated from long-term memory. Lhermitte and Beauvois (1973) studied a case of visual-speech disconnection, using his ability to copy drawings of objects, and to draw objects from memory, to confirm that his visual representations of objects were preserved. The difficulties he experienced when trying to name pictured objects were attributed to a deficiency in the process whereby visual representations activate their corresponding verbal representations.

In other studies, however, drawing has confirmed that visual representations in long-term memory have been compromised (Coltheart et al., 1998; Miceli, Fouch, Capasso, Shelton, Tomaiuolo, & Caramazza, 2001). For example, Coltheart et al. (1998) used a patient's inability to produce identifiable drawings of objects to dictation, to confirm that his long-term memory for the visual attributes of objects was impaired (see also, Miceli et al., 2001).

In other cases, object drawings have confirmed the deterioration in a person's conceptual knowledge (e.g., Bozeat et al., 2003; Funnel & Sheridan, 1992; Magnie et al., 1999). Although object drawings are not based directly on such knowledge, which is non-perceptual in nature (cf. Coltheart et al., 1998), they require such knowledge to be accessed when drawings are being produced from an object name. That is, representations of object names access stored visual knowledge of objects only indirectly, via conceptual knowledge. Hence, the quality of object drawings produced from an object name, and the manner in which they are inaccurate, correlates with patients' performance on other tasks requiring access to conceptual knowledge (e.g., picture naming, and knowledge elicitation) (Funnel & Sheridan, 1992; Bozeat et al., 2003). When the same patients are able to base their drawings on either direct perceptual input (i.e., they are asked to draw an object, or copy a picture, that remains in view) or short-term visual memory (i.e., they are asked to copy a picture shortly after it has been removed from view), their drawings display normal levels of accuracy

(Bozeat, et al., 2003; Magnie et al., 1999).

The distinct forms of visual object representation able to support drawing are unlikely to be mutually exclusive. It has to be considered, therefore, that drawing will often reflect their combined influence. Certainly, there is evidence from non-drawing situations that multiple forms of visual representation can co-exist, and can impact simultaneously on visual cognition (e.g., Burgund & Marsolek, 2000; Cooper, Schacter, Ballesteros, & Moore, 1992; Marsolek, 1995, 1999; Stankiewicz, Hummel, & Cooper, 1998). For example, Burgund and Marsolek (2000) provide evidence that both viewpoint-specific and viewpoint-independent representations can be established from a visual encounter with an object, and can remain available to influence behaviour subsequently. Marsolek (1995, 1999) provides similar evidence confirming the simultaneous availability of object-specific and category representations. Carlson-Radvansky and Irwin (1994), Hinton and Parsons (1988), and McMullen and Jolicoeur (1990), have all demonstrated how representations mapping onto different frames of reference (e.g., viewer-based and object-based) can impact concurrently on visual cognition.

In light of such evidence, it is not surprising that an object drawing can be informed by multiple forms of visual representation (e.g., Berhmann & Plaut, 2001; de Vreese, 1991; Gainotti, Messerli, & Tissot, 1972; Halligan, Fink, Marshall, & Vallar, 2003; Marshall & Halligan, 1993; Miceli, et al., 2001; Robertson & Lamb, 1991). In the context of visual neglect, for example, one aspect of a drawing might confirm a patient's neglect, while a different aspect of the same drawing might not. This is observed when a drawing of a clock includes a complete circle to depict the overall shape of its face, but also includes the digits from the right side of the face only (e.g., Marshall & Halligan, 1993). In addition, when copying a picture depicting an arrangement of several objects, neglect patients have revealed a mix of viewer-based and object-based neglect, as if their drawings were supported by a mix of viewpoint-specific and viewpoint-independent representations (Gainotti, Messerli, & Tissot, 1972). Behrmann and Plaut (2001) provide a detailed, computational characterisation of the way in which viewer-based and object-based representations can combine to support drawing in visual neglect.

Drawings from memory of the Rey Osterreith Complex Figure[1] also can utilise different types of representation, depending which cerebral hemisphere is engaged by the task. Robertson and Lamb (1991) compared drawings of the figure produced by groups of patients with left hemisphere damage, against drawings produced by patients with equivalent damage to the right hemisphere. Whereas drawings produced by the former group tended to depict the outer, global contour of the figure, and omit its internal details, drawings produced by the latter group depicted only its internal details, and then in a rather disorganized manner. Robertson and Lamb observed comparable behaviour when the patients were asked to draw a compound stimulus from memory (e.g., a large letter constructed from small letters). The patients with damage to the left hemisphere produced just the global forms, whereas the patients with damage to the right hemisphere produced just the smaller forms. Confirming the representational basis of these effects, similar biases were evident in a forced-choice recognition test of memory for compound stimuli. One

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[1] The Rey-Osterreith Complex Figure is a complex geometrical line drawing used to assess perceptual organization and visual memory in people with brain injury. It is now used to assess a variety of cognitive processes supporting drawing, including organizational and planning processes, as well as perceptual and memory processes.

implication of these observations is that, under normal circumstances, a complete drawing of a figure from memory reflects the influence of at least two types of visual representation, one concerned with global form, the other with internal elements.

There is also evidence that object-specific and category representations can combine to support drawing from long-term memory. In a study of a person (LW) who had suffered from herpes simplex encephalitis, Walker (2005) noted that her ability to draw objects from long-term memory varied considerably from one object to the next. There were many objects she could not begin to draw, and the quality of the drawings she did produce varied from being *very poor* to *very good*. LW was asked to comment on the extent to which each of her drawings was based on memory for a particular object she remembered seeing (e.g., her father's wheelbarrow) or on her knowledge of that type of object in general. Her responses to this question were reliable, being correlated significantly with other aspects of her behaviour (e.g., the probability with which she had encountered such an object in her everyday life since her illness). The point to be made here, however, is that in addition to claiming that some of her drawings were based entirely on one or other kind of representation, she also claimed that many of her drawings were based on a mix of both kinds of representation. Walker also obtained data from a group of healthy adults, and these confirmed that drawings from long-term memory vary in the degree to which they are based on object-specific and category representations. For these participants, the balance of influence was correlated with the semantic category of the object being drawn, with drawings of non-living entities being more likely to be based on object representations than on category representations, and vice versa.

When patients suffering from semantic dementia are asked to copy a picture of an object shortly after it has been removed from view, their drawings reveal the combined support from viewpoint-specific object representations and category representations (Bozeat et al., 2003). While the former representations guarantee good levels of accuracy in drawing, approaching the levels observed in direct copying, the influence of the latter is revealed in the distortions that reflect the manner in which their conceptual knowledge has become degraded. When the same patients draw from short-term memory without influence from conceptual knowledge (i.e., they are asked to reproduce geometric patterns after they have been removed from view), their drawings are protected from the distorting influence of impoverished conceptual knowledge and the patients produce drawings displaying normal levels of accuracy.

Finally, the shapes and colours of familiar objects appear to be represented separately in long-term visual memory. Thus, in a number of neuropsychological cases, long-term visual memory for the colours of familiar objects has been selectively compromised. Though able to produce acceptable drawings of the shapes of objects from long-term memory, these patients were unable to colour their drawings appropriately, and were unable to select the appropriately coloured drawing from a set of inappropriately coloured drawings (e.g., de Vreese, 1991; Miceli, et al., 2001). Despite the separate representation of object shape and object colour in long-term visual memory, drawers are normally inclined to depict both aspects in their drawings of familiar objects, confirming the combined influence of distinct forms of representation. Additional evidence that object drawings can reflect the combined impact of distinct forms of representation has emerged from studies of children’s drawing.

The representational basis of children's object drawing

In his review of drawing behaviour from a neuropsychological perspective, van Sommers (1989) explains how the different forms of representation identified by Marr (1982), which include viewpoint-specific and viewpoint-independent representations of object shape, might support drawing. Phillips et al. (1978) had earlier revealed how children's drawings of objects can incorporate a mix of viewpoint-specific and viewpoint-independent (i.e., object-based) elements. For example, whereas their drawings of a cube often incorporated just those sides that were visible from their vantage point, appropriately arranged on the page, the sides were drawn as squares. Similarly, Ingram (1985) and Light (1985) both illustrate how different aspects of a child's drawing of an arrangement of two objects can reflect the influence of viewer-based and array-based representations. Indeed, in Ingram's study, three distinct types of visual representation were observed to impact on a drawing (i.e., viewer-specific, array-specific, and object-based representations). Barrett and Light (1976) also demonstrate how different aspects of young children's drawings of a model house can reveal the combined influence of an object-specific representation, that is also viewpoint-specific, and a category representation. Whereas the children's drawings included many elements reflecting their current view of that particular house, they also included a door, even though it was pointed out to them that the house did not have one.

Hidden part portrayal and young children's object drawing.

An especially marked and theoretically significant feature of children's object drawings is whether or not they portray object parts that are currently hidden from view. In our Western culture at least, older children and adults are inclined to portray an object just as it appears from their vantage point, and so will not portray any object parts that are currently hidden from view. However, children below 7 - 8 years of age will often draw object parts that are hidden from view (e.g., Bremner & Moore, 1984; Freeman & Janikoun, 1972). When speculating about the basis of this age-related effect, some researchers have assumed that the characteristics of a drawing reflect the nature of the mental representation(s) on which it is based, and have argued that the child's developmental status influences the choice of representation(s) on which to base a drawing (see Krascum, Tregenza, & Whitehead, 1996, for a brief review). That the representational basis of children's drawings can reflect a matter of choice, rather than a resource limitation, is indicated by the fact that young children are capable of drawing an object as it appears from their vantage point (Bremner & Moore, 1984; Krascum, Tregenza, & Whitehead, 1996; Taylor & Bacharach, 1982), and will do so when circumstances encourage this (Davis, 1984, 1985; Lewis, Russell, & Berridge, 1993; Light, 1985; Light & Simmons, 1983). They do so, for example, when explicitly instructed to produce a viewpoint-specific drawing (Beale & Arnold, 1990; Lewis et al., 1993), or when the significance of such a drawing is implied by the context in which an object is viewed (Davis, 1983; Light, 1985). It seems, therefore, that with respect to hidden part exclusion, young children have at least some of the cognitive resources to produce the same types of object drawing produced by older children and adults. Furthermore, given that under some circumstances older children will depict hidden parts in their drawings of objects (e.g., Krascum, Tregenza, & Whitehead, 1996), the cognitive resources responsible for hidden part portrayal in young children's drawings appear not to be a casualty of development.

How might hidden part portrayed reveal the representational basis for a drawing? This will depend on a number of factors, including the nature of the drawer's experience of the object, and whether the object comes from a familiar category. Drawings in which an object is depicted just as it appears from the drawer's vantage point are likely to reflect the support provided by representations based on current perceptual input. However, where the object being drawn has only been seen from its current vantage point, it will be difficult to dissociate this support from the support provided by an object-specific memory representation, since the latter might also be restricted to preserving information gleaned from the same, single vantage point. Where an object has been seen from many viewpoints, however, then the support from these two forms of representation can be more easily dissociated. Under these circumstances, a drawing that depicts the object just as it appears from the drawer's vantage point is more likely to reflect current perceptual input, than the information accumulated in an object representation in memory.

Drawings in which hidden parts are depicted must reflect the drawer's knowledge of an object, and a broad distinction has been made in the developmental literature between knowledge of the individual object, and knowledge of the category to which the object belongs (e.g., Barrett & Light, 1976; Bremner & Moore, 1984; Freeman & Janikoun, 1972). Barrett and Light (1976) label the impact of these two sources of knowledge as *intellectual realism* and *symbolism*, respectively. Intellectual realism refers to the depiction of what is known from first hand experience of the object being drawn, without reference to knowledge of the category to which it belongs. Symbolism, on the other hand, refers to the depiction of what is known about the category to which the object belongs. In different terminology, intellectual realism reflects the impact of object-specific representations, whereas symbolism reflects the impact of category representations.

Both types of representation can be registered in, and later made available by, short-term and long-term memory, although category representations are most likely to be registered in the latter. For example, in the case of an individual object that is familiar to the drawer, such as her own drinking cup, all of its parts will be known, regardless of whether they are seen during the drawing exercise. That is, a complete object-specific representation will be available in long-term visual memory, and will be able to support the portrayal of any object parts currently hidden from view. In the case of an individual object that has not been encountered before, an object-specific representation incorporating all its parts will require that these are seen during the drawing exercise. A complete, object-specific representation would then be available in short-term memory to support drawing. Where an individual object belongs to a familiar category, a category representation will be available in long-term memory to provide information about all its category-relevant parts, and to support the portrayal of these, regardless of whether they have previously been seen by the drawer. The category representation will not, however, be able to specify any idiosyncracies in the nature of these hidden parts - direct experience of the object is required for this. The fact that the probability of part depiction varies according to the category relevance of the part (see, Barrett & Light, 1976; Freeman & Janikoun, 1972; Krascum, Tregenza, & Whitehead, 1996), may be taken as evidence that category representations can dictate at least some of the characteristics of a child's drawing of an object.

Bremner and Moore (1984) provide two demonstrations of the impact that object-specific representations can have on hidden part portrayal. In the first of these, they asked young children to draw a cup placed before them with its handle hidden from view. In one condition, the children were allowed to explore the cup, visually and manually, before it was placed in position to be drawn. As a result, they were more inclined to portray its handle. Because the children did not need to see the handle in order to identify the object as a cup, Bremner and Moore proposed that they based their drawing, at least in part, on a representation of the individual cup, built up as the cup was explored, rather than on a categorical representation. They went on to provide a second, more direct demonstration of intellectual realism by showing that, under similar circumstances, young children will include a hidden part in their drawings of a novel object (a cube with a cone protruding from one face). Because novel objects do not belong to established categories, the portrayal of a hidden part in this case could not have reflected the influence of a category representation.

There are several demonstrations that young children's knowledge of an object's category also can impact on their portrayal of its hidden parts (e.g., Barrett & Light, 1976; Freeman & Janikoun, 1972; Lewis et al., 1993). For example, as has been noted already, Barrett and Light found that 5- to 7-year-olds are strongly inclined to include a category-defining object part, even when this is missing from the particular object they are drawing. That is, they will include a handle in their drawings of a cup that has lost its handle, and will include a door on a house that lacks one. To give another example, Freeman and Janikoun presented children with a cup oriented so that a flower motif on its exterior surface was in direct view, while its handle was out of view. Prior to the cup being placed in position to be drawn, it was given to the children to examine. Children under 8 years included a handle in their drawing of the cup, and were disinclined to draw the motif. Older children were not inclined to portray a handle, and drew the motif instead. Given that the handle of a cup is category relevant, whereas a motif is not, the selective portrayal of the handle confirms the impact of the object's categorical status. It also suggests that young children are inclined to draw objects in ways that ensure their categorical status is portrayed. Finally, Lewis et al. presented 5-year-olds with a transparent glass mug oriented in depth so that its handle pointed away from them. Without a handle, the object was most appropriately classified as a "glass" rather than as a "mug". Therefore, with the handle only partially visible through the glass, there was some uncertainty about its categorical status. How the object was named by the experimenter emerged as a factor determining whether a handle was incorporated in the drawings. More specifically, when the object was named as a “mug” the children tended to portray a handle. When it was named as a “glass”, they were less likely to portray a handle. By resolving the uncertainty about the object’s categorical status, naming allowed representations of the named category to become dominant in determining if a handle was included in the children’s drawings.

Bremner and Moore (1984) demonstrated that naming an object can induce hidden part portrayal even when there is no uncertainty about the object’s category. They placed a cup in front of young children with its handle hidden from view. Even without seeing its handle, the children were able to identify the object as a cup. When asked to draw the object in front of them, without it being named, the young children tended not to include a handle in their drawings. However, they did include the handle when they named the object themselves prior to drawing. One possible explanation for this effect is that the request to name the object encouraged the children to believe they were expected to ensure that the categorical status of the object was portrayed in their drawings, and so elected to base their drawings on a category representation of the object. It is worth noting that almost invariably in studies of children’s hidden part portrayal, the object to be drawn has been named. One exception is the study by Taylor and Bacharach (1982), where hidden part portrayal was observed only infrequently.

It is not easy to distinguish the contributions of object and category representations when the object being drawn is from a familiar category. Whenever such an object is encountered, a category representation will be available to influence behaviour, in addition to a representation of the individual object. Therefore, when an object part that is hidden from view has previously been seen by the drawer, steps need to be taken to determine if its depiction in the drawing is a reflection of the actual part that was seen (i.e., the drawing is based on an object representation), or a reflection of an established categorical representation of the object and its parts.

Inevitably, there is more certainty about the representational basis for drawings of novel objects, since these will not have pre-established category representations (see, for example, the comments on Bremner & Moore, 1984, above). If a means could be found to easily induce the formation of category representations for novel objects, then there would be much to recommend its use. Fortunately, research on the development of object categorisation and object naming has shown that hearing a novel object named with a novel count noun can induce infants and young children to create a shape-based category representation for the object (Baldwin, 1989; Hall, 1993; Hall & Moore, 1997; Hall, Quantz, & Persoage, 2000; Hall & Waxman, 1993; Landau, 1994; Landau, Smith, & Jones, 1988; 1992; Smith, Jones, & Landau, 1992; Waxman, 1999a; Waxman & Booth, 2001; Waxman & Hall, 1993; Waxman, Philippe, & Branning, 1999; Waxman, Senghas, & Benveniste, 1997). For example, when the presentation of a novel object is accompanied by the statement “This is a dax”, young children extend the label (“Is this a dax?”) to other objects that are similar in shape, even if these objects are made from different material and are different in size. When a novel object is not named, or is labelled with a mass noun or an adjective, young children group the object with other objects on a different basis, paying more attention to the material from which the object is formed (Baldwin, 1989; Dickinson, 1988, 1992; Hall & Moore, 1997; Hall et al., 2000; Landau, 1994; Landau et al., 1988; Smith et al., 1992; Subrahmanyam, Landau, & Gelman, 1999; Waxman, 1999b; Waxman & Booth, 2001). These findings suggest a research strategy for distinguishing the impact of object and category representations on young children’s drawings. Specifically, drawings of a novel object could be elicited, sometimes with and sometimes without the object being named in a way that leads to the formation of a category representation.

The Experiments

Drawings are a rich source of information about the representations supporting visual cognition. Because they are relatively uncontrained, they can reveal the combined influence from multiple forms of representations, and the within- and between-individual variation in the weighted contributions from these representations. For example, they can reveal the changing influence of different types of representation as development progresses. They can also reveal the manner in which object knowledge deteriorates as a result of degenerative disease (e.g., Bozeat et al. 2003).

In seven experiments, young children's drawings of novel objects are examined to reveal the impact of different types of visual representation. The types of representation considered include viewpoint-specific representations based on perceptual input, and object-specific and category representations in memory. Although the main focus of attention is on children's portrayal of object parts that are hidden from view at the time of drawing, additional aspects of their drawings are considered. These include whether the correct colour has been chosen for the drawing (i.e., the colour matching the object's colour), and whether the object in the drawing is shaded-in. These two additional aspects are taken as indicators of children's inclination to portray the material properties of the object.

With the exception of a small number of 4-year-olds in Experiment 1, all the children participating in the experiments were 5 or 6 years old. It is known that the probability of hidden part portrayal in the drawings from this age group is sensitive to the context in which the object is presented for drawing (see Bremner & Moore, 1984).

Although even younger children would be expected to display higher rates of hidden part portrayal, this would be so high as to become relatively insensitive to context (see, for example, Krascum et al., 1996). Older children were not sampled, because they are more influenced by cultural norms and so show little inclination to portray hidden parts. Because of this, they do not offer the same opportunity to explore the impact of different forms of representation on hidden part portrayal.

In all of the experiments, the children were allowed to inspect every facet of a novel object before it was placed in position to be drawn with one of its parts hidden from view. In all but one of the experiments, the object was similar to the novel object employed successfully by Bremner and Moore (1984) (i.e., a cube with a cone protruding from one face). Because the object was novel, it was possible to have a baseline condition in which the object was not named. A category representation would not then be available to impact on drawing. Instead, drawing would have to be based either on current perceptual input or on the object-specific visual knowledge accrued during inspection. In the former case, the children would not be expected to portray the cone. In the latter case, they would be expected to portray the cone, given that it had been seen and was a prominent part of the object.

In some conditions, the experimenter named the novel object with a novel count noun as the children were inspecting it from a range of angles. Based on previous research (cf. above), demonstrating that count noun labelling induces infants and young children to create a shape-based category representation for an object, it was expected that naming the novel object with a count noun would induce hidden part portrayal. Of course, this expectation assumes the children will judge the hidden part to be category-relevant. This assumption is tested and confirmed in Experiment 5.

In other conditions, word forms that are not associated with shape-based object category representations are used to label the novel objects. This was intended to provide a check that the count noun status of a label is critical in inducing hidden part portrayal. In turn, this was intended to confirm that category representations were responsible for the additional instances of hidden part portrayal observed when objects are labelled with a count noun. Novel words functioning as mass noun and as adjectives were used for this purpose. Previous research on the development of object language has revealed that these two word forms do not induce infants and young children to create a category representation based on object shape, but instead direct their attention to the object's material properties (Baldwin, 1989; Dickinson, 1988; Hall, 1993; Hall & Moore, 1997; Hall et al., 2000; Hall & Waxman, 1993; Landau, 1994; Landau et al., 1988, 1992; Smith et al., 1992; Subrahmanyam, Landau, & Gelman, 1999; Waxman, 1999a,b; Waxman & Booth, 2001; Waxman & Hall, 1993; Waxman et al., 1997, 1999). Although labelling with a mass noun and an adjective would not be expected to induce hidden part portrayal, it was considered possible that they would induce children to portray the object's material properties. Perhaps they would be more inclined to select the correct colour for their drawing, and more likely to shade-in the object in their drawing. This possibility was examined in Experiments 1, 2, and 4.

Experiments 3 - 4 and 6 - 7 were designed to distinguish more effectively the support for drawing provided by object-specific and category representations. The children were presented with two, differently coloured versions of the *cube+cone* object, each of which they were required to draw. The children inspected every aspect of the first object before it was placed in position to be drawn, with its cone hidden from view. However, at no point were they allowed to see the second object's cone before it was placed in position to be drawn, again with its cone hidden from view. By restricting the children's exposure to the second object, the depiction of a cone in their drawings of this object could be attributed to a category representation based on their more comprehensive exposure to the first object. In this way, the impact of object naming and object categorisation on drawing could be explored, separately from any contribution from object representations. Specifically, it was determined if labelling the second object with the same count noun used to label the first object would induce the children to portray its hidden cone, even though they had not seen it. Confirmation of this would provide evidence that naming the first object created a category representation which later served as the category representation for both objects.

Experiments 6 and 7 examine when labelling a novel object with a count noun is most likely to lead to the creation of a category representation. More specifically, it is asked if hidden part portrayal is more likely to be induced if object naming occurs while the object and its parts are still available for inspection. Alternatively, it might be just as likely to be induced if naming occurs subsequently, as part of the instruction to draw. If the latter were to be the case, then naming could simply be encouraging the children to believe they were required to depict the object's category. If the former were to be the case, there would be support for the idea that naming induces the formation of a category representation.

In all of the experiments, children were assigned randomly to different conditions, with the restriction that the sub-groups were matched for mean age and the proportion of males and females. No child participated in more than one experiment. The drawings from a small number of children could not be used for various reasons (e.g., they elected to draw a familiar object, rather than the novel object placed before them). It is also useful to note here that the drawings from each experiment were coded independently by at least two judges who were ignorant of the condition under which individual drawings had been produced.

For some experiments, the judges were in complete agreement. For other experiments, the disagreement concerning how a small number of drawings should be coded was resolved through discussion among the judges.

Experiment 1

Infants and young children are inclined to form a category representation for a novel object when this is labelled with a count noun. Furthermore, they are likely to focus on shape as the source of category-defining features, rather than on material properties. Because of this, naming a novel object with a novel count noun should provide the opportunity for a category representation to impact on their drawings of the object. In turn, therefore, to the extent that young children are inclined to depict the category to which an object belongs, naming with a count noun should induce the portrayal of any hidden parts judged to be category relevant. Experiment 1 was designed to determine if naming a novel object with a novel count noun induces hidden part portrayal, relative to labelling with a different word form.

After visually inspecting each aspect of a novel item from a range of angles, children were asked to draw the item from a position where a prominent part was hidden from view. For one group of children, the item was introduced with a label in the form of a count noun (e.g., "This is a jox"). For the other children, the item was introduced with a label in the form of a mass noun (e.g., "This is some jox"). On the basis of previous results (Bremner & Moore, 1984), it was expected that some children would include the hidden part regardless of how the item was named. However, it was predicted that more children would do so when the item was named with a count noun, as opposed to a mass noun, confirming the impact of a category representation. Children who do not portray the hidden part would be assumed to be basing their drawing on viewpoint-specific representations reflecting current perceptual input.

The children were free to draw the object in a range of colours, only one of which matched the object's colour. Given the association between mass nouns and the material properties of items (e.g., Dickinson, 1988; Subrahmanyam, Landau, & Gelman, 1999), it was of interest to determine if labelling with a mass noun, though not inducing hidden part portrayal, would induce the children to more accurately depict the material properties of the item by, for example, selecting the correct colour for their drawing, and by shading-in the object in their drawing. To facilitate an effect from mass noun labelling, the material and form of the novel items were such as to allow them to be readily perceived either as objects (i.e., artefacts) or as portions of substance. They were formed from non-rigid material and were moderately irregular in shape, giving the impression that they had not been carefully manufactured. Subrahmanyam et al. (1999) discuss and illustrate the theoretical significance of items whose status is made to be ambiguous in this way.

Method

Participants

Seventy seven 4- to 6-year-olds (mean age 5 yr 5 month; range 4 yr 3 month to 6 yr 3 month) participated in the study, with a small minority being 4 years old (n = 15). Thirty-eight children were assigned to the *count noun* condition (mean age 5 yr 6 month; range 4 yr 2 month to 6 yr 3 month), and thirty-nine were assigned to the *mass noun* condition (mean age 5 yr 5 month; range 4 yr 2 month to 6 yr 3 month).

Materials

Two items were created, one from light red compacted wool, the other from light blue sponge. The red item comprised a larger sphere (6 cm diameter), with a smaller sphere (3 cm diameter) attached to it. The blue item comprised a larger block (10 x 6 x 4 cm), with a smaller block (5 x 2 x 1 cm) attached to the centre of one of its smallest surfaces. In both cases, the appended part was small enough to be completely hidden from view when the item was placed at eye level in front of the child. Eight coloured pencils were made available for drawing, and these were placed neatly in a flat dish so that they were simultaneously visible and equally accessible. There was a light and dark version of each of four colours (i.e., blue, red, orange, and grey). The light red and light blue pencils were good matches for the wool and sponge from which the items were formed.

Design and procedure

Each child was asked to draw one of the items. The experimenter presented the item following a carefully rehearsed routine. This gave the child the opportunity to visually examine every aspect of the object. More specifically, the item was initially presented at eye level, with the protruding part facing away from the child. The experimenter then slowly rotated the item through 360 deg in the horizontal plane, taking care to minimise the extent to which her hands obstructed the child's view of the item The red item was introduced with the label "jox", and the blue item was introduced with the label "brak". The item was then positioned at eye level on a box 1 m in front of the child, with the protruding part hidden from view. The child was then asked to draw the object. The two experimental conditions differed according to how the object was introduced verbally to the child.

Count noun. As the item was presented for the child to inspect, the experimenter said "This is a jox/brak". When it was in position to be drawn, the experimenter continued with "Ok, this is a jox/brak. Can you draw it for me, please?"

Mass noun. As the item was presented for the child to inspect, the experimenter said "This is some jox/brak". When the item was in position to be drawn, the experimenter continued with "Ok, this is some jox/brak. Can you draw it for me, please?"

Each of the two items was equally likely to be introduced with a count noun or a mass noun.

Table 1 about here

Results

The results are presented in Table 1.

Hidden part portrayal

As predicted, more children portrayed the hidden part in the *count noun* condition than in the *mass noun* condition (Fisher's exact $p = .03$, $\phi = .25$).

Colour selection and shading-in

Contrary to expectations, the number of children electing to draw the item in the correct colour was not influenced by the form class of the verbal label (Fisher's exact $p > .05$). Similarly, the form class of the verbal label did not impact on the likelihood that a child would shade in their drawing (Fisher's exact $p > .05$). In addition, there was no association between shading-in and hidden part portrayal (Fisher's exact $p = .31$), indicating that these were not mutually exclusive features of a drawing. It was not the case, for example, that the hidden part would normally be depicted in the centre of the large base part, but that this was precluded whenever a child elected to shade-in their drawing.

Experiment 2

Labelling an object with an adjective (e.g., "This is a daxy one") seems to have much the same effect as labelling it with a mass noun. When an object is labelled with an adjective, the shape bias in name extension is much less apparent than with count noun labelling, and can be replaced completely by a bias to respond on the basis of the material properties of the object, such as its colour and surface texture (Landau, 1994; Landau et al., 1992; Hall & Moore, 1997; Hall et al., 2000; Smith et al., 1992; Waxman, 1999b; Waxman & Booth, 2001).

Experiment 2 contrasted the impact on drawing of labelling an object with a count noun and labelling it with an adjective. An additional baseline condition was included in which the object was not labelled. It was expected that labelling with an adjective, like labelling with a mass noun (cf. Experiment 1), would not induce hidden part portrayal, and so it was anticipated that hidden part portrayal would be equivalent in the *adjective* and *unnamed* conditions. It was also expected that the impact of labelling on the portrayal of an object's hidden part would be more evident in the *count noun* condition than in the other two conditions. Based on previous research, it might be expected that labelling with an adjective would encourage the children to portray the material out of which an object was formed (i.e., they would take care to select the correct colour and shade-in their drawings), mimicking the shift towards a material bias that has been observed in other tasks. However, given that mass nouns more obviously refer to the material properties of items than do adjectives, the absence of an effect of mass noun labelling in Experiment 1 suggests that no effects on colour choice and shading-in should be observed.

The children inspected all aspects of a novel object, and as they did so the experimenter introduced it verbally in one of three ways. For some children, the experimenter named the object as “a dax”, whereas for other children it was referred to as “a daxy one”. In a baseline condition, the object was simply referred to as “this”. The object was then placed in position to be drawn, with one of its parts hidden from view. The children were asked to draw the object just as it appeared to them. By specifying that they should draw it “just as it appears to you now”, it was intended to discourage the children from making a conscious decision to depict what they knew about the object and its category-relevant features. If they could be induced to depict the object’s hidden part nevertheless, then the impact of verbal labelling would be especially compelling.

Method

Participants

Sixty one 5-year-olds (mean age 5 yr 3 month; range 5 yr 0 month to 5 yr 11 month) participated in the study. Twenty two children were assigned to the *count noun* condition (mean age 5 yr 2 month; range 5 yr 0 month to 5 yr 11 month), twenty to the *adjective* condition (mean age 5 yr 3 month; range 5 yr 1 month to 5 yr 10 month), and twenty to the *unnamed* condition (mean age 5 yr 3 month; range 5 yr 0 month to 5 yr 11 month).

Materials

Two versions of a novel object, one red and one blue, were used as models for drawing. Each model took the form of a 12 cm wooden cube with a wooden cone protruding from the centre of one face. The cone had a base radius of 3 cm, and a height of 8 cm. All surfaces of the objects were smoothed and finished in gloss paint.

Six crayons were made available to the children. There was a light and dark version of each of three colours (i.e., blue, red, and grey), and the dark blue and dark red provided good matches to the colour of the objects.

Design and procedure

Each child was asked to draw one of the objects under one of three experimental conditions which were distinguished according to how the object was introduced verbally. The experimenter presented the object following a carefully rehearsed routine, providing the child with an opportunity to visually examine each facet of the object from a range of angles. More specifically, the object was initially presented with the cone pointing upwards. The experimenter then slowly rotated the object, taking care to minimise the extent to which her hands obstructed the child's view of the object. The object was first rotated 630 deg around the x-axis (in a direction that meant the cone ended up pointing away from the child), and then 720 deg around the y-axis. In this way the child was exposed to each facet of the object. The object was then positioned at eye level on a table 1 m in front of the child and with the cone out of view. From this position, only the front face of the cube was visible. The child was asked to draw the object. How the object was verbally introduced to the children varied across the three experimental conditions.

Count noun. In this condition, as the object was presented for the child to inspect, the experimenter said "Look at this, this is a dax". When it was in position to be drawn, the experimenter continued with "Look at it carefully, as it appears to you now. Can you draw this for me as it appears to you on the table in front of you?"

Adjective. In this condition, as the object was presented for the child to inspect, the experimenter said "Look at this, this is a daxy one". When it was in position to be drawn, the experimenter again continued with "Look at it carefully, as it appears to you now. Can you draw this for me as it appears to you on the table in front of you?"

Unnamed. In this condition, as the object was presented for the child to inspect, the experimenter simply referred to it as "this", saying "Look at this." When it was in position to be drawn, the experimenter again continued with "Look at it carefully, as it appears to you now. Can you draw this for me as it appears to you on the table in front of you?"

Each object was equally likely to serve as the model in each condition.

Table 2 about here

Results

The results are presented in Table 2.

Hidden part portrayal

The number of children including the hidden part in their drawings varied significantly across the three conditions [$\chi^2(2, N = 62) = 9.84$, $p < .01$]. Inspection of the results indicates that, as predicted, the incidence of hidden part portrayal was not significantly higher in the *adjective* condition than in the *unnamed* condition (Fisher's exact $p = .52$, $\phi = .15$). When these two conditions were together compared against the *count noun* condition, the incidence of hidden part portrayal was, as predicted, significantly higher in the *count noun* condition (Fisher's exact $p = .003$, $\phi = .38$).

Colour selection and shading-in

In agreement with the results from Experiment 1, neither correct colour selection, nor shading-in, was sensitive to the verbal context in which the object was introduced [$\chi^2(2, N = 62) < 1$, in both cases].

Discussion of Experiments 1 and 2

The new finding from Experiments 1 and 2 is that naming a novel object with a novel count noun increases the incidence of hidden part portrayal in young children's drawings. This is consistent with other evidence, reviewed above, indicating that naming a novel object with a count noun induces young children to establish a category representation for the object, with shape providing the category-defining features. In the context of young children's object drawing, creating a category representation allows it to support drawing and, in turn, increases the portrayal of category relevant parts, even if these are currently hidden from view. Because count noun labelling induced the children in Experiment 2 to portray the hidden part, even though they were explicitly requested to draw the object just as it appeared to them during drawing, the impact of a category representation would seem not to require the children to make a conscious decision to communicate an object's category. Once established, a category representation appears to impact on drawing automatically.

It may be noted that the impact of a category representation on drawing need not be restricted to the additional instances of hidden part portrayal occuring when the first object was named with a count noun, compared with when it was labelled with a different word form or was not named. Although an object representation would have been responsible for all instances of hidden part portrayal in the absence of count noun labelling, it might not have been responsible for any instances of hidden part portrayal in the other conditions.

The mass noun and adjective labels provided two control conditions to confirm that the count noun status of a verbal label was critical in inducing hidden part portrayal. Consistent with previous research indicating that these two word forms do not increase the salience and category relevance of shape, they did not themselves induce hidden part portrayal. However, neither did they induce the portrayal of an object's material properties, through correct colour selection and shading in. It would seem, therefore, that previous findings highlighting the association between these two word forms and the material properties of objects may not extend to the object drawing task.

Not all children depicted the object's hidden part, even though we might assume they knew it was there. It seems that the drawings produced by these children were dominated by viewpoint-specific representations based on perceptual input, rather than by object representations in memory (i.e., what they knew about the object based on their direct experience of it).

Experiment 3

Experiment 3 examined the impact of different forms of representation on young children's drawings of two successively presented novel objects. The objects were those used in the preceding experiment, and so were identical in shape but different in colour. As before, the children were allowed to inspect every facet of the first object before it was placed in position to be drawn, with its cone hidden from view. However, at no point were the children allowed to see the second object's cone before it was placed in position to be drawn with its cone hidden from view. Consequently, portrayal of the second object's cone was contingent on the children presuming the object was an exemplar from the same category as the first object. In this way, the impact of object naming and object categorisation on drawing could be distinguished from the impact of object representations.

For some children, the experimenter named the first object with a count noun (i.e., as "a dax"), whereas for other children the object was not named (i.e., it was simply referred to as "this"). For some children, the second object was again named by the experimenter as "a dax", while for others it was simply referred to as "this". Naming the second object as "a dax" was intended to signal that it belonged to the same category as the first object. Because of this, it was expected that the category representation for the first object would also serve as the category representation for the second object, thereby facilitating the portrayal of the second object's cone. This expectation was assessed by comparing the incidence of hidden part portrayal in drawings of the second object when this object was unnamed versus when it was given the same name as the first object, to signal that both objects belonged to the same category. In other words, it was predicted that only in the condition where both objects were named with the same count noun would hidden part portrayal be induced. When only the first object was named, it was not expected that hidden part portrayal in drawings of the second object would be induced. Instead, the incidence of hidden part portrayal in these drawings was expected to be no different from that observed when neither object was named.

Method

Participants

One hundred eight 5- and 6-year-olds (mean age 5 yr 11 month; range 5 yr 1 month to 6 yr 10 month) participated in the study. Thirty-six children were assigned to each of three experimental conditions distinguished according to how the objects were introduced verbally. For the *named-named* condition, the mean age was 6 yr 0 month, and the age range was 5 yr 2 month to 6 yr 9 month. For the *named-unnamed* condition, the mean age was 5 yr 11 month, and the age range was 5 yr 1 month to 6 yr 10 month. For the *unnamed-unnamed* condition, the mean age was 5 yr 11 month, and the age range was 5 yr 1 month to 6 yr 9 month.

Materials

The two objects employed in Experiment 2 were used here. A black pencil was provided for drawing.

Design and procedure

Each child produced two drawings, one of each object, under one of three experimental conditions. The experimenter first presented one of the objects following the routine used in Experiment 2. The object was then positioned at eye level on a table 1 m in front of the child with its cone out of view, and the child was asked to draw the object. After the drawing was completed, both it and the object were removed from view, and the second object was presented in the same place on the table and in the same orientation, again with the request that the child draw it. Care was taken to ensure that at no time did the child glimpse the second object's cone. How the two objects were verbally introduced varied across the three experimental conditions.

Named - Named. In this condition, both objects were labelled with the same count noun. As the first object was presented for the child to inspect, the experimenter said "Look at this, this is a dax". Once it was in position to be drawn, the experimenter continued with "Can you draw this dax for me?" Nothing was said about the second object until it was in position to be drawn, whereupon the experimenter said "Can you draw this dax for me?"

Named - Unnamed. In this condition, exactly the same procedure was followed with the first object. Again nothing was said about the second object until it was in position to be drawn, but now the experimenter refrained from naming it, saying "Can you draw this for me?"

Unnamed - Unnamed. In this condition, neither object was named by the experimenter. As the first object was presented for the child to inspect, the experimenter said "Look at this", and when it was in position to be drawn, she continued with "Can you draw this for me?" Nothing was said about the second object until it was in position to be drawn, at which point the experimenter said "Can you draw this for me?"

Within each condition, the two objects served equally often as the first and second object to be drawn.

Table 3 about here

Results

Table 3 shows the number of children in each condition who included the hidden part in each of their drawings.

Naming and hidden part portrayal in drawings of the first object. The number of children including the hidden part in their first drawing varied significantly across the three conditions [$\chi^2(2, N = 108) = 6.11$, $p < .05$]. Inspection of the results suggests that, as predicted, the incidence of hidden part portrayal was higher in the *named-named* and *named-unnamed* conditions than in the *unnamed-unnamed* condition. As was expected, given that participants in the two naming conditions were treated in an identical manner as far as the first object was concerned, equivalent levels of hidden part portrayal were observed (Fisher's exact $p = 1.0$). When the combined results from these two conditions were compared against the results from the condition in which the first object was unnamed, the difference in hidden part portrayal proved to be significant (Fisher's exact $p = .01$, $\phi = .24$).

Naming and hidden part portrayal in drawings of the second object. In all three conditions, hidden part portrayal was less prevalent in the children's second drawing than in their first. With each child acting as their own control, application of McNemar's χ^2 confirmed the significance of this change in frequency for each condition [$\chi^2(1, N = 36) =$ 20.0, 26.0, and 19.0, for the *named-named*, *named-unnamed*, and *unnamed-unnamed* conditions, respectively, $p < .001$ in every case]. The number of children including the hidden part in their second drawings varied significantly across the three conditions [$\chi^2(2, N = 108) = 8.57$, p < .025]. The incidence of hidden part portrayal in the second drawing was higher in the *named-named* condition, where the second object was named in the same way as the first object, than in the *named-unnamed* and *unnamed-unnamed* conditions, where it was not named in the same way as the first object. As predicted, identical and very low levels of hidden part portrayal were obtained in the latter two conditions, despite participants' differing experiences with regard to the first object. Comparing the combined results from these two conditions against the results from the *named-named* condition, revealed a significant effect of naming the second object in the same way as the first object (Fisher's exact $p = .01$, $\phi = .28$).

Figure 2 about here

Discussion

By demonstrating that count noun labelling induces hidden part portrayal, children's drawings of the first object confirm the findings of Experiments 1 and 2. Again, it was also the case that some of the children did not depict the hidden part, even though we might assume they knew it was there. Their drawings appear to have been informed by viewpoint-specific representations based on perceptual input, rather than by object representations in memory (i.e., what they knew about the object based on their direct experience of it).

There was no opportunity for the children to inspect the different facets of the second object before it was drawn from a position where its cone was hidden from view. Neither current perceptual input, nor recent perceptual input as preserved in short-term memory, could inform them about the presence of the cone, and so it was expected that this would not be portrayed in their drawings. With the exception of just four children, the results from the two conditions in which the second object was not named confirmed this expectation.

The differential rate of hidden part portrayal across the two drawings is most easily interpreted in relation to the condition where neither object was named. In this condition, an object-specific memory representation for the first object will have incorporated information about every aspect of the object. In contrast, because the second object was only ever encountered from a single viewpoint, its object-specific representation would preserve no more information than was provided by current perceptual input, with both sources of information being restricted to a single viewpoint. Hence, drawings of the second unnamed object would not be expected to portray the hidden part, whether they were mediated by current perceptual input or by an object-specific representation.

Finally, naming the second object with the same count noun as the first object signalled its membership of the same object category and, therefore, its possession of the same category relevant parts. This encouraged some of the children to believe the second object had a cone that was currently out of view, and this belief was reflected in their drawings. We see in this experiment, therefore, the impact on drawing of a category representation at the very earliest moments in its formation.

Experiment 4

It was decided to examine again the impact of labelling two objects with the same count noun, while including a control condition in which a different word form was used to label the objects. Specifically, naming with a count noun and labelling with an adjective were compared to confirm that the count noun status of the label was critical in inducing hidden part portrayal in Experiment 3.

In most respects, Experiment 4 replicated Experiment 3. The main innovation involved whether the object label was a count noun or an adjective. The first object to be drawn was labelled with either a count noun or an adjective, or it remained unlabelled. For all children, the second object was referred to in the same way as the first object so that, for example, where the first object had been referred to as “a dax”, the second object also was referred to as “a dax”. Based on findings from studies of language development, along with the results from Experiment 2, it was expected that labelling with an adjective would not induce hidden part portrayal relative to the *unnamed* condition. Based on the results from Experiment 2, it was expected that labelling with an adjective would not increase the incidence of correct colour selection and shading-in. Based on Experiment 3, it was expected that labelling both objects with the same count noun would encourage the portrayal of a cone in drawings of the second object.

The colour in which the children chose to draw the objects was monitored, because this had the potential to reveal if drawings of the second object were based on a mix of representational forms. More specifically, it was of interest to know if drawings of the second object, when they were being influenced by categorical representations derived from the first object, would also be influenced by object-specific representations. Specifically, when drawings of the second object portrayed a hidden cone, confirming the influence of a categorical representation based on the first object, would they also depict the second object in its own colour?

Method

Participants

One hundred thirty eight 5- and 6-year-olds (mean age 5 yr 11 month; range 5 yr 0 month to 6 yr 11 month) participated in the study. Forty six children were assigned to each of three experimental conditions. For the *count noun* condition, the mean age was 5 yr 11 month, and the age range was 5 yr 0 month to 6 yr 11 month. For the *adjective* condition, the mean age was 6 yr 0 month, and the age range was 5 yr 0 month to 6 yr 11 month. For the *unnamed* condition, the mean age was 6 yr 0 month, and the age range was 5 yr 0 month to 6 yr 11 month.

Materials

The two novel objects used in Experiments 2 and 3 were used again. Six crayons were provided, comprising a dark and a light version of each of three colours (i.e., red, blue, and grey). The dark red and dark blue crayons were good matches for the actual colours of the objects.

Design and procedure

The procedure was essentially the same as the one followed in Experiments 3, with each child producing two drawings under one of three experimental conditions that differed according to how the two objects were verbally introduced.

Count noun. In this condition, as the first object was presented for the child to inspect, the experimenter said "Look at this, this is a dax". When it was in position to be drawn, the experimenter continued with "Can you draw this dax for me?" Nothing was said about the second object until it was in position to be drawn, whereupon the experimenter said "Can you draw this dax for me?"

Adjective. In this condition, as the first object was presented for the child to inspect, the experimenter said “Look at this, this is a daxy one”. When it was in position to be drawn, the experimenter continued with “Can you draw this daxy one for me?” Nothing was said about the second object until it was in position to be drawn, whereupon the experimenter said “Can you draw this daxy one for me?”

Unnamed. In this condition, as the first object was presented for the child to inspect, the experimenter simply referred to it as “this”, saying “Look at this.” When it was in position to be drawn, the experimenter still referred to it as “this”, saying “Can you draw this for me?” As in the other two conditions, nothing was said about the second object until it was in position to be drawn, whereupon the experimenter said “Can you draw this for me?”

For each condition, the blue object served as the first object to be drawn on 24 occasions, and the red object served as the first object to be drawn on 22 occasions.

Table 4 about here

Results

The results are presented in Table 4.

Hidden part portrayal

Effects of verbal labelling on hidden part portrayal in drawings of the first object. The incidence of hidden part portrayal in drawings of the first object was relatively high in all three conditions, suppressing the variation that was expected. Nevertheless, as predicted, and in line with the results from Experiment 2, hidden part portrayal was more frequent in the *count noun* condition than in the *adjective* and *unnamed* conditions, and was at similar levels in the latter two conditions. However, across all three conditions the variation in hidden part portrayal was not significant [$\chi^2(2, N = 138) = 3.59, p > .10$].

Effects of verbal labelling on hidden part portrayal in drawings of the second object. As observed in Experiment 3, hidden part portrayal was less prevalent in children's drawings of the second object than in their drawings of the first object. For each condition, application of McNemar's χ^2 confirmed the significance of this change in frequency [$\chi^2(1, N=46) = 11.1$, 19.4, and 24.1, for the *count noun*, *adjective*, and *unnamed* conditions, respectively, $p < .01$ in every case]. Across all three conditions, the variation in hidden part portrayal was significant [$\chi^2(2, N = 138) = 23.3$, $p < .01$]. It is clear from Table 4, that the incidence of hidden part portrayal was higher in the *count noun* condition than in the *adjective* and *unnamed* conditions. When the results from the latter two conditions were compared, the effect of labelling with an adjective was not significant (Fisher's exact $p = .15$). In contrast, when the results from the *count noun* condition were compared against the combined results from the *adjective* and *unnamed* conditions, a significant effect of count noun labelling was confirmed (Fisher's exact $p < .01$, $\phi = 0.4$).

Colour selection

The children showed a pronounced tendency to select the colour that most closely matched the colour of the object in front of them (i.e., the dark red and dark blue), as appropriate. The correct colour was chosen for 70% of the first drawings, and for 75% of the second drawings. This confirms that when children produced their second drawing they paid close attention to the object in front of them, selecting the correct shade of colour, even though their experience of the first object induced them to portray a cone. Indeed, in relation to the 47 children across all three conditions who portrayed a cone in their drawings of the second object, 40 (85%) chose the crayon that matched the colour of this object. For the 91 children who did not portray a cone, 65 (71%) chose the crayon that matched the colour of the second object. Focusing specifically on the results from the condition where the second object was named as “a dax”, of the 28 children who portrayed it with a cone, 27 (96%) chose the crayon that matched the colour of this object. For the 18 children who did not portray a cone, 14 (78%) chose the correct crayon. It is clear from these results that children who were being influenced by their experience of the first object when drawing the second object (i.e., they included a cone), were not simply reproducing their first drawing without regard for the second object’s features (especially its colour). Thus, despite including a cone, they were more likely to choose the crayon that matched the colour of the second object than any other colour. Indeed, this crayon was more likely to be selected when the cone was portrayed than when it was not.

Effects of verbal labelling on colour selection. Verbal labelling did not have a significant impact on children’s colour selection for their first drawing [$\chi^2(2, N = 138) < 1$]. This replicates the results from Experiments 1 and 2. Although verbal labelling did impact on their choice of colour for the second drawing [$\chi^2(2, N = 138) = 8.51, p < .025$], it was the count noun condition, rather than the adjective condition, where correct colour selection was most likely.

Shading in

The drawings could be unambiguously classified according to whether the children had attempted to represent the object’s surfaces by shading them in. Although children in the *adjective* condition were more likely than children in the other two conditions to shade in their drawings, the incidence of shading-in did not vary significantly across conditions [$\chi^2(2, N = 138) = 3.50, p > .10$ and $\chi^2(2, N = 138) = 3.62, p > .12$, for the first and second object drawings, respectively]. When the association between shading in and hidden part portrayal was explored in the *adjective* condition, it emerged that these two aspects of the drawings were not mutually exclusive. Thus, for the thirty two drawings that were shaded in, 18 (56%) portrayed the cone, whereas for the sixty drawings that were not shaded in, 30 (50%) portrayed the cone.

Discussion

Naming the first object with a novel count noun again increased the incidence of hidden part portrayal, consistent with it having induced the creation of a category representation during encoding, which was then able to impact on drawing. The same did not happen when the object was labelled with an adjective, confirming the importance of the count noun status of an object label.

Once again, it can be assumed that the drawings of children who did not portray the first object's hidden part, even though the children had seen it previously, were dominated by current perceptual input, rather than by any object representations in short-term memory.

With regard to drawings of the second object, the results confirm that the label assigned to the two objects had to be a count noun in order for children to form a categorical representation of the first object. Only then could their representation of the first object provide the basis for the categorical representation of both objects, and thereby impact on their drawings of the second object. When both objects were labelled with an adjective, the incidence of hidden part portrayal in both drawings was no higher than when neither object was labelled.

In general, children elected to draw using the crayon that matched the colour of the object they were being asked to draw. In doing so, they chose the corresponding shade of colour (i.e., a visual match), and not just the correct category of colour (i.e., they selected the dark red and dark blue, over the light red and light blue). It also seems that when the children were drawing the second object, they did not simply reproduce their first drawing using the same crayon. Indeed, a closer look at their drawings of the second object revealed that, in those conditions where their experience of the first object induced them to portray a cone, they were more likely to choose the colour that matched the second object, than any other colour. Furthermore, they were more likely to choose the correct colour when the cone was portrayed than when it was not portrayed. The absence of any mutual exclusivity between hidden part portrayal and correct colour selection is an important result, suggesting two things. First, that a young child's drawing of an object can be simultaneously influenced by a visual colour representation for the object, and by a category representation of the object's shape. In the present context, the former influenced the choice of colour for the drawing, whereas the latter informed their decision to portray a cone. Second, this result confirms that the categorical representations established for objects when they are labelled with count nouns are more concerned with the shapes of the objects (i.e., with object parts), than with their material properties (i.e., object colour).

Experiment 5

The account being offered about how naming an object with a count noun induces hidden part portrayal assumes the children judged the cone to be category relevant. Given the prominence of the cone, this is a reasonable assumption to make. However, to evaluate this assumption, the perceived category relevance of the (hidden) cone was manipulated in Experiment 5, to see if this would influence the extent to which count noun labelling induced its portrayal.

Young children were presented with two novel objects. One of these was the red object used in Experiments 2 - 4. The other object did not have a cone, but was otherwise identical to the first. Both objects were shown to the children, from a full range of angles, so that it became clear to them how the objects differed in shape. The two objects were presented in counterbalanced order across participants. The children were then asked to draw each object in turn, in the order in which they had been introduced, from a position where the cone was hidden from view so that the objects looked identical. In one condition, the experimenter named both objects using the same count noun, as either “a dax” or “a rif”. In a second condition, the experimenter used a different count noun to label each object, naming one “a dax”, and one “a rif”. It was presumed that assigning the same name to the objects would signal that they belonged to the same category, in which case the cone would become category irrelevant. Assigning the objects different names would signal that they belonged to different categories, in which case the only feature distinguishing them (i.e., the cone), would be category relevant. It was predicted that when the cone was indicated as being category relevant, the young children would be more inclined to portray it, even though it was hidden from view when the object was in position to be drawn.

Method

Participants

Seventy six 5- and 6-year-olds (mean age 5 yr 9 month; range 5 yr 0 month to 6 yr 11 month) participated in the study. Thirty eight children were assigned to each of the two conditions. For the *same name* condition, the mean age was 5 yr 9 month, and the age range was 5 yr 1 month to 6 yr 10 month. For the *different name* condition, the mean age was 5 yr 9 month, and the age range was 5 yr 0 month to 6 yr 11 month.

Design and procedure

Each child produced two drawings, one of each object, under one of two conditions. In both conditions, the experimenter presented the objects following a routine that ensured that each child saw every facet of both objects. The two objects were then placed in position to be drawn, side-by-side and face on, with the cone hidden from view. From this position, the two objects looked identical. The child was then asked to draw each object in turn, on separate pieces of paper, with the experimenter touching the object that needed to be drawn next as she gave the instruction to draw. Using a black pencil, the child drew the two objects in the order in which they had been presented, and in each condition the object with a cone was equally likely to be introduced and drawn first or second. The two conditions of the experiment differed according to the way in which the objects were verbally introduced.

Same name. In this condition, both objects were given the same name by the experimenter, which was equally likely to be "a dax" or "a rif". During initial presentation, the experimenter introduced each object by saying "Look at this dax/rif". Then, in the drawing phase, she invited the child to draw each object in turn by saying "Look at this dax/rif. Can you draw this dax/rif for me?"

Different name. This condition was like the preceding condition, except the two objects were given different names by the experimenter, with each name being equally likely to be assigned to the object with a cone.

Table 5 about here

Results

No drawings of the object without a cone portrayed a cone. Table 5 shows the number of children in each condition who portrayed a cone in their drawing of the object that possessed one. Whether this object was introduced and drawn first or second is preserved in the table.

Across both drawing, the incidence of hidden part portrayal was higher when the two objects were given different names, than when they were given the same name (Fisher's exact $p = .03$, $\phi = .34$). However, whereas this effect of naming was significant for the second drawings (Fisher's exact $p = .02$, $\phi = .26$), it was not significant for the first drawings (Fisher's exact $p = .32$, $\phi = .08$).

Discussion

The results of this experiment confirm that category representations can support drawing, and that naming a novel object with a count noun facilitates the creation and impact of such representations. When naming an object with a count noun signalled that an object part was category relevant, rather than category irrelevant, the young children were more likely to portray the part, even though it was hidden from view. By labelling the two objects in the current experiment with either the same count noun or different count nouns, the implied category relevance of the cone was varied. When the objects were given different names, it was implied that the cone was category relevant, because this was the only feature differentiating the objects. When the objects were given the same name, it was implied that the cone was category irrelevant. This was so because only one of the objects possessed a cone, and yet they were both being given the same category label. The young children were more inclined to portray the hidden cone when the verbal context in which the object was presented implied that the cone was category relevant.

It is interesting that the impact of signalling that the cone was category irrelevant was most pronounced when the corresponding object was drawn second. This suggests that young children find it difficult to establish, or revise, a category representation retrospectively. To elaborate, when the object with a cone was presented and named first, there was nothing at the time to indicate that the cone was category irrelevant. Indeed, it has been argued already, in accounting for the results from previous experiments, that the children would have judged the cone to be category relevant. Hence, the category representation associated with the count noun label would incorporate the cone. Only subsequently, when the second object was presented and named in the same way, would the cone be signalled as being category irrelevant, requiring the children to revise their category representation of the first object in order to exclude the cone. Judging from their inclination to portray the hidden cone, they appear to have found it difficult to revise their category representations of the first object. Of course, there was no need to revise their category representation associated with the count noun when the object without a cone was presented first, since their category representation of this object did not include a the cone. When the object with a cone was presented afterwards, and assigned the same name, the category representation would not need revising because the category irrelevance of the cone would simply be being confirmed. It would be interesting to see if and how the inflexibility in categorisation noted here, and in Experiment 2, would dissipate with developmental status.

Experiment 6

When the first novel object was named in Experiments 3 and 4, it was named at each of two phases in the sequence of events on a trial, that is, when the object was presented for inspection and again when it was in position to be drawn. It is possible that naming had its impact at either one or both of these phases. For example, by signalling that the object belonged to a category, naming could have influenced how children perceived the task demands. More specifically, naming could have encouraged them to believe they were expected to produce a drawing from which the categorical status of the object could be identified, which in turn would have induced them to portray all of the object's significant parts, whether occluded or not. In this case, when naming occurred should not be critical, although it might be argued that naming would be most influential when the request to draw was made. Alternatively, if establishing a new categorical representation for a novel object during inspection is not automatic, naming might increase the likelihood that such a representation is established. In this case, hearing the object named as the experimenter presents it for inspection might be more influential than hearing it named subsequently. This would be expected if alternative forms of representation are more likely to be established during object encoding than retrospectively, as the performance of adults in a primed object decision task suggests (see, for example, Cooper & Schacter, 1992; Schacter & Cooper, 1993).

Experiment 6 examined if naming is more likely to lead to the formation of a category representation, which can then impact on drawing, when it occurs while a novel object is being inspected, rather than at the point of drawing. As an alternative, it was considered that naming might influence children's drawing regardless of when it occurs, as would be expected if it served simply to encourage the children to believe they were required to portray the object in a way that allowed its categorical status to be identified. Expecting temporal contiguity to be unnecessary has some precedence. Research on object-label learning in 19- to 24-month-olds, indicates that an object need not be labelled while it is still available for visual inspection in order for such learning to occur (Akhtar & Tomasello, 1996; Baldwin, 1993; Tomasello & Barton, 1994).

In most respects, Experiment 6 replicated Experiment 3. The main innovation involved just when in the sequence of events the children heard the experimenter name the first novel object. For some children, the experimenter named the object as "a dax" while it was being inspected, and then again when it was in position to be drawn. For other children, the object was simply referred to as "this" during inspection, but as "a dax" when it was in position to be drawn. For a third group of children, the object was only ever referred to as "this".

As in Experiment 3, the children were also asked to draw the second novel object, which was placed in position to be drawn without its cone having been seen. For all children, the second object was referred to as "a dax" when it was in position to be drawn. It was predicted that those children who also heard the first object named as "a dax", provided this was at a time that induced hidden part portrayal, would adopt their category representation of the first object as the category representation for both objects, with the effect that they would include a cone in their drawings of the second object. In other words, hidden part portrayal with regard to the second object would provide an additional and strong test of just when an object (in this case the first object) should be named in order for a categorical representation to be established and to impact on drawing.

Method

Participants

One hundred eight 5- and 6-year-olds (mean age 6 yr 0 month; range 5 yr 0 month to 6 yr 11 month) participated in the study. Thirty six children were assigned to each of three experimental conditions. For the *named at inspection* condition, the mean age was 6 yr 0 month, and the age range was 5 yr 2 month to 6 yr 9 month. For the *named in position* condition, the mean age was 6 yr 0 month, and the age range was 5 yr 1 month to 6 yr 10 month. For the *unnamed* condition, the mean age was 6 yr 0 month, and the age range was 5 yr 0 month to 6 yr 11 month.

Materials

The objects used in Experiments 3 - 4 were used again, and a black pencil was provided for drawing.

Design and procedure

Each child drew both objects under one of three experimental conditions, that differed according to how the first object was verbally introduced to the children.

Named at inspection. In this condition, as the first object was presented for the child to inspect, the experimenter said “Look at this, this is a dax”. Once it was in position to be drawn, the experimenter continued with “Can you draw this dax for me?”

Named in position. In this condition, as the first object was presented for the child to inspect, the experimenter simply referred to it as “this”, saying “Look at this.” Once it was in position to be drawn, the experimenter then named the object, saying “This is a dax. Can you draw this dax for me?”

Unnamed. In this condition, as the first object was presented for the child to inspect, the experimenter simply referred to it as “this”, saying “Look at this.” Once it was in position to be drawn, the experimenter still referred to it as “this”, saying “Can you draw this for me?”

In all three conditions, nothing was said about the second object until it was in position to be drawn, whereupon the experimenter said “Can you draw this dax for me?”

Table 6 about here

Results

Table 6 shows the number of children in each condition who included the cone in each of their drawings.

Naming and hidden part portrayal in drawings of the first object. The incidence of hidden part portrayal in the first drawing was higher in the *named at inspection* condition than in the *named in position* and *unnamed* conditions. However, the incidence of hidden part portrayal did not vary significantly across the three conditions [$\chi^2(2, N = 108) = 3.89, p > .10$]. Exploration of the differences between conditions, using two orthogonal contrasts, gave some indication that naming at inspection did most to encourage hidden part portrayal. When the results from the *named in position* and *unnamed* conditions were compared, the difference in hidden part portrayal was not significant (Fisher's exact $p = .5$). When the results from the *named at inspection* condition were compared against the combined results from the *named in position* and *unnamed* conditions, a significant effect of naming at inspection was suggested (Fisher's exact $p = .04$, $\phi = 0.19$). However, because the overall χ^2 analysis was not significant, and because the selection of these comparisons was not determined a priori, the outcome of this last contrast must be treated cautiously. Nevertheless, the outcome indicates the trend to be expected with regard to drawings of the second object.

Naming and hidden part portrayal in drawings of the second object. It is clear from Table 6 that, in all three conditions, hidden part portrayal was less prevalent in the children's second drawing than in their first. With each child acting as their own control, application of McNemar's χ^2 confirmed the significance of this change in frequency for each condition [$\chi^2(1, N{=}36) = 13.1$, 19.1, and 14.1, for the *named at inspection*, *named in position*, and *unnamed* conditions, respectively, $p < .01$ in every case]. The variation in hidden part portrayal across the three conditions was highly significant [$\chi^2(2, N = 108) = 11.66, p < .01$]. Much of this variation was attributable to the higher incidence of hidden part portrayal in the *named at inspection* condition than in the *named in position* and *unnamed* conditions. In line with the trends observed in relation to the first object, comparing the latter two conditions failed to reveal a significant effect of naming in position (Fisher's exact $p = .15$). In contrast, comparing the results from the *named at inspection* condition against the combined results for the *named in position* and *unnamed* conditions, revealed a significant effect of naming at inspection (Fisher's exact $p < .01$, $\phi = 0.31$).

Discussion

With regard to the first object, the drawings of some young children were again dominated by viewpoint-specific representations reflecting perceptual input, as evidenced by their portrayal of the object just as it appeared from their vantage point, without its hidden part being portrayed. They did not portray the cone, despite having seen the object from all angles, and despite having had the opportunity to establish a complete object representation that would support portrayal of the hidden part.

As in Experiments 3 and 4, the children more frequently depicted the hidden part in their drawings of the first object, than in their drawings of the second object. This result is again most easily interpreted in relation to the condition where neither object was named. Whereas a complete object representation of the first object was available in short-term memory to support drawing, the object representation established for the second object was restricted to those features that were visible from the single view from which the object was currently being perceived. Portrayal of the first object's hidden part was not significantly influenced by count noun labelling of the object. Instead, the incidence of hidden part portrayal was relatively high in all conditions. There was a suggestion, however, that naming at inspection was most likely to induce hidden part portrayal. Fortunately, drawings of the second object provided a better test of when object naming is most likely to induce hidden part portrayal.

Although only a subset of the children heard the first object named, all of the children heard the second object named as “a dax”. Children hearing the first object named as “a dax” while it was being inspected, were more inclined than other children to portray the second object with a cone. Children who heard the first object named as “a dax” only when it was in position to be drawn, showed little inclination to portray the second object with a cone. In this way, drawings of the second object confirm that count noun labelling of the first object was most likely to induce hidden part portrayal when it occurred while there was still the opportunity for it to be inspected from a range of angles. When the first object was named only when it was in position to be drawn, the incidence of hidden part portrayal in drawings of the second object was not significantly higher than when the first object was not named. These observations are consistent with the idea that naming influenced children’s drawing by facilitating the derivation of a categorical representation of the first object. Once derived, this representation could be extended to the second object, and then increase the incidence of hidden part portrayal in drawings of that object. The fact that naming the first object only when it was in position to be drawn had no impact on drawing, contradicts the idea that naming had its effect by influencing how children perceived the task demands. In particular, it does not appear that a categorical representation of the first object was always available, and that naming induced hidden part portrayal simply by encouraging the children to believe that the experimenter was requiring them to draw the objects in a way that ensured their categorical status could be identified. This conclusion is also consistent with the results of Experiment 2. In that experiment, count noun labelling induced hidden part portrayal even though the children were given explicit instruction to draw the object "as it appears to you now", and so were discouraged from drawing what they knew of the object. It also seems that a category representation that includes all of an object's parts, whether hidden or not, is difficult to establish retrospectively (i.e., at the time the object is fixed in position to be drawn). Other evidence that young children are limited in what they can achieve in retrospect was obtained from Experiment 5. In that experiment, young children found it difficult to revise their category representation of an object in light of their experience of how a second object was to be categorised.

Experiment 7

When the first object was named at inspection in Experiment 6, it was also named later, when it was in position to be drawn. Therefore, the impact of naming at inspection was confounded with the fact that the object was named twice. The results from Experiment 2 indicate that this confound is unlikely to have been responsible for the differential rates of hidden part portrayal. In that experiment, children of the same age were asked to draw the same object. However, when the object was named with a count noun, it was named only at inspection. It was not named when once it was placed in position to be drawn. Despite this, the incidence of hidden part portrayal in Experiment 2 (82%) was almost identical to that observed in Experiment 6 (83%).

In Experiment 7, the potential significance of naming the object while it was in position to be drawn, as well as during inspection, was assessed directly. Essentially, Experiment 6 was repeated with a group of children of comparable age. There were two labelling conditions. In one condition, the first object was named only at inspection. In the second condition, it was named both at inspection and when it was in position to be drawn. If the confound present in Experiment 6 explains the main finding of that experiment, then only the *named both at inspection and in position* condition should induce the same rate of hidden part portrayal as was observed in the *named at inspection* condition of Experiment 6. The rate of hidden part portrayal in the *named at inspection only* condition should be less than that observed in the *named both at inspection and in position* condition, and less than that observed in the *named at inspection* condition of Experiment 6.

Method

Participants

Eighty two 5- and 6-year-olds (mean age 5 yr 11 month; range 5 yr 2 month to 6 yr 9 month) participated in the study. Forty children were assigned to the *named at inspection only* condition (mean age 5 yr 10 month; range 5 yr 3 month to 6 yr 6 month), and forty two to the *named both at inspection and in position* condition (mean age 5 yr 11 month; range 5 yr 2 month to 6 yr 9 month).

Materials

The materials used in Experiment 6 were used here.

Design and procedure

Each child drew both objects under one of two experimental conditions that differed according to when the first object was labelled with a count noun.

Named at inspection only. In this condition, as the first object was presented for the child to inspect, the experimenter said "Look at this, this is a dax". Once it was in position to be drawn, the experimenter continued with "Can you draw this for me?"

Named both at inspection and in position. In this condition, as the first object was presented for the child to inspect, the experimenter said “Look at this, this is a dax”. Once it was in position to be drawn, the experimenter named the object again, saying “Can you draw this dax for me?”

In both conditions, nothing was said about the second object until it was in position to be drawn, whereupon the experimenter said “Can you draw this dax for me?”

Results

Table 6 shows the number of children in each condition who included the cone in each of their drawings.

Naming and hidden part portrayal in drawings of the first object. The incidence of hidden part portrayal in the first drawings was equally high in both conditions (Fisher’s exact $p = 1$). It will be noted that the frequency of hidden part portrayal in the *named at inspection only* and *named both at inspection and in position* conditions (85% and 83%, respectively), is comparable to that observed in the *named at inspection* condition of Experiment 6 (83%).

Naming and hidden part portrayal in drawings of the second object. In both conditions, hidden part portrayal was less prevalent in the children’s second drawing than in their first. With each child acting as their own control, application of McNemar’s χ^2 confirmed the significance of this change in frequency for each condition [$\chi^2(1, N=40) = 8.63$, and $\chi^2(1, N=42) = 5.71$, for the *named at inspection only* and *named both at inspection and in position* conditions, respectively ($p < .001$ in each case)]. Table 6 also shows that the incidence of hidden part portrayal was higher, rather than lower, in the *named at inspection only* condition than in the *named both at inspection and in position* condition, though the difference was not significant (Fisher’s exact $p = .27$, $\phi = 0.14$).

Comparison with Experiment 6. When the values for the incidence of hidden part portrayal in the *named at inspection only* condition were compared against those observed in the *named in position* condition of Experiment 6, a significant difference was confirmed for both objects (Fisher's exact $p = .05$, $\phi = 0.22$, and $p < .001$, $\phi = 0.50$, for the first and second object, respectively).

Discussion

The results from this experiment confirm that labelling an object with a count noun as it is being inspected, increases the incidence of hidden part portrayal. They also confirm that labelling the object again, with the same count noun, when it is in position to be drawn, does not further increase hidden part portrayal, even though there is the potential for it to do so (i.e., performance is below ceiling). In light of this result, and given the close correspondence in the frequency of hidden part portrayal in the *named at inspection* conditions of Experiments 6 and 7, it seems that the confound present in Experiment 6 did not explain the high level of hidden part portrayal observed in the *named at inspection* condition of that experiment. It seems, therefore, that hidden part portrayal is more likely to be induced if an object is named as it is being inspected from different viewpoints, than if it is named subsequently, when it is fixed in position to be drawn.

General Discussion

The experiments reported here have revealed how different representational forms can impact on object drawing.

In all of the experiments, young children were allowed to inspect every aspect of a novel object before it was placed in position to be drawn with a prominent part hidden from view. In the absence of naming, two forms of representation were available to support drawing. The first is a viewpoint-specific representation based on current perceptual input which, because it represents the object as seen from the drawer's current vantage point, did not support the portrayal of the object's hidden part. The second form of representation is an object representation preserved in short-term memory that incorporates all the information about the object that was acquired during its inspection. Because it incorporates information about more object parts than can be seen from a single vantage point, this object representation can be regarded as a viewpoint-independent representation. In the present context, an object representation encouraged portrayal of the novel object's hidden part, despite this being hidden from view at the time of drawing. The impact of this object representation accounts for the higher incidence of hidden part portrayal when the novel object was seen from all angles, than when it was seen only from the angle from which it was to be drawn (i.e., the first and second objects in Experiments 3, 4, 6, & 7).

When a novel object was named with a novel count noun, signalling its membership of a category of objects, its hidden part was more likely to be portrayed. This is attributed to the establishment and impact of a category representation for the object, and the assumption that the children would perceive the hidden part to be category relevant was confirmed in Experiment 5. Converging evidence that the impact of count noun labelling was mediated by a category representation came from the observation that labelling with a novel mass noun or a novel adjective did not have the same effect. In these cases, hidden part portrayal was no more likely than when the object was not labelled.

The importance of the word form of the object label, and in particular the significance of the count noun status of the label, is consistent with evidence concerning linguistic and conceptual development. Thus, whereas labelling an object with a count noun is likely to induce infants and young children to create a shape-based category representation, labelling it with either a mass noun or an adjective is not (Baldwin, 1989; Dickinson, 1988; Hall, 1993; Hall & Moore, 1997; Hall et al., 2000; Hall & Waxman, 1993; Landau, 1994; Landau et al., 1988, 1992; Smith et al., 1992; Subrahmanyam, Landau, & Gelman, 1999; Waxman, 1999a,b; Waxman & Booth, 2001; Waxman & Hall, 1993; Waxman et al., 1997, 1999). Indeed, Waxman (1999a) has proposed that naming an object with a count noun is itself an act of object categorisation. Furthermore, links between object naming and object categorisation are especially apparent for certain types, or levels, of categorisation (e.g., Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Several studies have shown that when infants and young children hear objects labelled with a count noun, they are most likely to establish a category representation at an intermediate taxonomic level (Hall, 1993; Hall & Waxman, 1993; Waxman, 1999a; Waxman & Hall, 1993; Xu, Carey, & Welch, 1999), possibly corresponding to the basic level of categorisation (see Rosch et al., 1976). Linking count nouns with basic-level categories would be particularly important because these categories are especially useful (see Rosch et al., 1976). They are also some of the first categories to be established and named as young children develop, and typically have simple count nouns assigned to them (for reviews, see Rosch et al., 1976, and Waxman, 1999a). According to some researchers, an object's shape, defined as its major parts in configuration, is a much more salient feature for categorisation at the basic level than are its material properties (see, for example, Biederman, 1987; Landau, 1994; Rosch et al., 1976; Tversky & Hemenway, 1984). These general claims for a privileged link between count noun labelling and basic-level categorisation are consistent with the fact that in the present study labelling an object with a count noun impacted on young children's portrayal of its shape (i.e., its parts), but not on their portrayal of its surface properties (i.e., colour).

Because mass nouns and adjectives as object labels are often associated with the material properties of objects (cf. above), it was considered if labelling a novel object with these word forms would induce the young children to portray its material properties. Evidence for this was sought in Experiments 2 and 4, by monitoring children's choice of colour with which to draw the object, and whether they elected to shade-in the object in their drawing. There was no evidence that labelling with these alternative word forms induced the children to depict the object's material properties, though there was a non-significant tendency for labelling with an adjective to induce the children to shade-in their drawings.

The most compelling evidence that category representations can impact on object drawing, came from children's drawings of a second object (Experiments 3 - 7). Because this *cube+cone* object was only seen after being placed in position to be drawn, an object representation, like the current perceptual representation, would not incorporate any information pertaining to the hidden cone. As a result, drawings based on either of these two forms of representation would not portray the hidden cone. Labelling the second object with the same count noun used to label the first object signalled that both objects belonged to the same object category. Because the children's exposure to the second object was less extensive than their exposure to the first object, it added nothing to the category representation. In effect, therefore, the category representation established for the first object served as the category representation for both objects. Because this category representation incorporated both a cube and a cone, drawings based on it would include a cone. Hence the impact of count noun labelling on drawings of the second object. By showing that labelling both objects with the same novel adjective did not induce hidden part protrayal in drawings of the second object, Experiment 5 confirmed the significance of the count noun status of the object label. In so doing, it provided additional converging evidence for the significance of a category representation based on the children's experiences of the first object.

When, in Experiment 4, the children were given a choice of different coloured crayons to draw with, they were most likely to select the colour that matched the colour of the object they were drawing. With regard to their drawings of the second object, this tendency to select the correct colour was unaffected by their portrayal of a cone. The fact that these two aspects of their drawings of the second object showed no signs of being incompatible with each other, indicates that two forms of representation were impacting simultaneously on the production of these drawings. Whereas the category representation for the second object was influencing their decision to portray a cone, the visual representation of the object's colour was influencing their choice of colour. Barrett and Light (1976) also provide evidence for the presence of intellectual realism and symbolism in the same drawing, implying simultaneous contributions from object and category representations. It is, of course, very unlikely that a drawer, when asked to draw an object placed before them, would ignore the details of the object entirely, and simply represent its category, as if they were drawing solely in response to being given the object's category label. It is not surprising, therefore, that whenever a contribution from a category representation is evident in a drawing, there is also evidence for a contribution from an object-specific representation.

This account of the impact on drawing of different types of representation, and of the moderating influence of naming, assumes that young children do not always form a category representation automatically, but sometimes have to be induced to do so. The results from Experiments 6 and 7 indicate that, in being induced to form a category representation, young children are sensitive to when, in the sequence of events, they hear the object named. Thus, naming was more likely to lead to the portrayal of the hidden cone when it occurred while the different facets of the novel object were being inspected. It did not have this effect retrospectively. This observation was regarded as confirmation that naming had its impact on hidden part portrayal by inducing the creation of a category representation, and not just by encouraging the children to believe their drawings had to depict the object's categorical status. That the latter was not the case was also suggested by the results of Experiment 2, where count noun labelling induced hidden part portrayal even though the children were specifically instructed to draw the object just as it appeared to them from their drawing position.

The issue of when an object needs to be labelled with a count noun in order for a category representation to be created, resonates with another issue, concerning just when an object has to be labelled in order for young children to learn the object-label association. In several studies, it has been demonstrated that 19- to 24-month-olds do not have to hear an object labelled while they are looking at it in order for the object-label association to be learned. Indeed, they can sometimes learn this association just as easily when the label is presented before (Baldwin, 1993; Tomasello & Barton, 1994) or after (Akhtar & Tomasello, 1996) the object is available for visual inspection. This demonstration appears to stand in sharp contrast to the present results, which emphasise the importance of hearing an object named as it is being inspected. Although it remains unclear how this apparent discrepancy might be resolved, the results of the present study suggest that research on object-label learning will benefit from acknowledging the potential significance of the grammatical form of the label, and the different types of representation to which a label might become associated. That object-label learning can exploit privileged links between count nouns and certain types of object representation is suggested by Walker, Dixon, and

Smith (2000). These researchers demonstrated that when adults hear an object depicted in a line drawing named with a novel count noun (e.g., "This is a dax"), they learn the object-label association more easily when the picture depicts a structurally possible object, than when it depicts a structurally impossible object. Walker et al. infer from this that object names have privileged links with certain types of representation, and specifically with the descriptions of global, 3D shape that can be derived for structurally possible objects, but not for structurally impossible objects.

The present study has focussed on shape (defined as parts in configuration) as the most salient, category relevant feature, and on the implications of count noun labelling for the representation and depiction of shape. It is conceded, however, that count nouns can be used to label categories for which shape is neither the sole, nor the most salient defining feature (e.g., Booth and Waxman, 2002a, 2003; Kemler Nelson, Russell, Duke, and Jones, 2000). For example, when Booth and Waxman (2002a) presented novel objects to 3-year-olds in the context of a vignette which described them as having conceptual properties typical of animals, the labels were extended on the basis of both shape and surface texture. In addition, Kemler Nelson et al. demonstrated that 2-year-olds will sometimes extend the count noun assigned to a novel object to other objects that can fulfil the same function, even when these are less similar in overall shape than objects that fulfil different functions. Where categories appear to be established on the basis of attributes other than shape, it might be expected that count noun labelling will impact on drawing in a different way than was observed in the present study. Young children might be less likely to portray an object's hidden parts, and more likely to depict its other, category relevant attributes. For example, where the demonstrated function of a novel object is contingent on the material from which it is formed (see, for example, Landau, Smith, & Jones, 1998), labelling the object with a count noun might induce young children to depict its material properties (e.g., through colouring and shading in) rather than its shape.

The account of how naming induced hidden part portrayal assumes the children judged the hidden part to be category relevant. Given the prominence of the part, this is a reasonable assumption to make. The importance of the perceived category relevance of the hidden part was confirmed in Experiment 5. The category relevance of the cone for the *cone+cube* object was manipulated by presenting the object alongside another object that did not have a cone, but which was otherwise identical. When both objects were named with the same novel count noun, the cone was signalled as being category irrelevant. When the two objects were assigned different names, the cone was signalled as being category relevant. Portrayal of the hidden cone was significantly more likely in the latter condition. The presence of an order effect was interpreted as confirming that young children find it difficult to establish and/or revise category representations retrospectively.

There are other ways in which the category relevance of an object part could be communicated to a drawer. One possibility would be to demonstrate that the part is essential for the function the object is intended to serve. Krascum et al. (1996) have provided evidence already that this can influence hidden part inclusion in children's drawings, though this was only the case for the group of 8-year-olds in their study; it did not apply to the group of 4-year-olds. Thus, although 8-year-olds are not normally inclined to depict a hidden part of an object, many of them (75%) did so when it was explained to have an important functional role. By contrast, a substantial number of the 4-year-olds (66%) were inclined to depict the hidden part, and were insensitive to whether its functional role was explained to them.

The account of how naming impacted on drawing in the present study also assumes that category representations are distinct from object representation; they are not just object representations tagged with a category identifier. Whereas object representations incorporate all of an object's parts, category representations incorporate only category-relevant parts. Hence, when object representations alone are supporting drawing, it will be the parts the drawer has experienced directly that will be portrayed, regardless of their category relevance. When category representations alone are supporting drawing, only the parts the drawer understands to be category relevant will be portrayed. The results from Experiment 5 go some way towards confirming this.

Distinguishing the contributions from object and category representations would be made easier if the representations were considered to map on to the corresponding forms of representation revealed in studies of adult object recognition. For example, it would be reasonable to identify the object shape representations referred to here with the sets of multiple views that Tarr (1995) has argued support individual object recognition. Similarly, it would be reasonable to identify the category shape representations referred to here with the geon structural descriptions that Biederman (1987) has argued underlie object recognition at the basic level of categorisation. As a set of multiple views, an object representation would only preserve images corresponding to the subset of views from which an object has been encountered. As a geon structural description, a category representation would not be restricted by viewpoint in this way, since such a description is itself largely viewpoint independent. Hence, experiments in which objects are encountered from a restricted set of viewpoints might serve to confirm that drawing can be supported by distinct object and category representations. If the current proposal is correct, then when an object is not named (i.e., not categorised) children's drawings should be based on a set of multiple views of the object, and should depict the object from one or more of the viewpoints from which it was encountered. In contrast, when an object is named, children's drawings might also be based on a geon structural description which, because it is largely viewpoint-independent, would allow the children to depict the object from a viewpoint from which it has not been encountered.

In summary, the experiments have taken advantage of object drawings as a rich source of information about the representational support for visual cognition. The relatively unconstrained nature of object drawing allows the contributions from multiple forms of representation to be confirmed, as both within-individual and between-individual variation, providing clarification of some theoretically important issues concerning children's drawing. The different types of visual representation observed to impact on young children's object drawings included viewpoint-specific representations based on current perceptual input, object-specific representations of shape and of colour, and category representations of shape. The key observations confirming the contributions from these are as follows:

Viewpoint-specific perceptual representations. Some children drew an object just as it appeared from their vantage point, even though they had been exposed to all facets of the object and knew, therefore, that the object had a part that was currently hidden from view (all experiments).

Object-specific representations of shape. Some children portrayed a hidden part after seeing all aspects of a novel object that had not been named (Experiments 2 - 7). Hidden part portrayal was much more likely in this case, than when the object had been seen only from the angle from which it was to be drawn (i.e., the first and second objects in Experiments 3, 4, 6, & 7).

Object-specific representations of colour. When colouring their drawings, the children closely matched the colour of the object being drawn, and did not just select a categorical colour match (Experiment 4). They did this even when aspects of shape in their drawing of the second object (i.e., hidden part portrayal), was being dictated by a categorical representation based on their experience of the first novel object (Experiment 4).

Category representations of shape. The frequency of hidden part portrayal was enhanced by labelling a novel object with a novel count noun, but not by labelling it with a novel mass noun or a novel adjective (all experiments). A cone was portrayed in drawings of the second novel object when this was assigned the same count noun label as the first object, even though the second object's cone was never seen (Experiments 3, 4, 6, & 7). The frequency of hidden part portrayal was increased when the count noun labelling of two contrasting novel objects implied that the part was category relevant, rather than category irrelevant (Experiment 5).

Although direct evidence for a combined contribution from multiple representational forms was confined to the demonstration that an object-specific colour representation and a category shape representation can both impact on the same drawing, it is presumed that in many circumstances object drawings will reflect combined contributions from multiple representational forms. Evidence supporting this claim was reviewed in the earlier sections of this paper.

We began this paper by commenting on the different cognitive resources able to provide different types of information about the visual nature of objects. In particular, attention was drawn to perceptual input, short-term visual memory, and long-term visual memory, all of which were presumed capable of providing visual information to be registered in a visual buffer, and to be experienced as a visual image. The present experiments did not attempt to determine if the object and category representations supporting drawing were originating from short-term or long-term visual memory (assuming that such a distinction is valid). Thus, although pre-established representations in long-term memory were precluded from impacting on drawing, by using novel objects and novel object labels, no control was exercised over whether the representations established in the experimental task itself were registered in short-term and/or long-term memory. Clarification of this particular issue requires further research. Studies in which drawing is delayed after exposure to the object to be drawn, and in which varying numbers of other objects are presented during this interval, are being planned. One expectation is that with increasing delay to drawing, the impact of perceptual and object-specific representations will diminish, and the impact of long-term categorical representations will increase. A consequence of this will be a shift towards performance becoming more dependent on category representations. In their classic study of the formation of prototypical category representations, Posner and Keele (1968; 1970) observed just such a shift. It was noted in an earlier section that Bozeat et al. (2003) also observed this when they compared immediate and delayed object drawing in patients suffering from semantic dementia.

References

Akhtar, N. & Tomasello, M. (1996). Two-year-olds learn words for absent objects and actions. *British Journal of Developmental Psychology, 14,* 79-93.

Baddeley, A. D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology: General, 129,* 126-145.

Baldwin, D. A. (1989). Priorities in children's expectations about object label reference: Form over colour. *Child Development, 60,* 1291-1306.

Baldwin, D. A. (1993). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology, 29,* 832-843.

Barrett, M. D., & Light, P. H. (1976). Symbolism and intellectual realism in children's drawings. *British Journal of Educational Psychology, 46,* 198-202.

Bartolomeo, P. (2002). The relationship between visual perception and visual mental imagery: A reappraisal of the neuropsychological evidence. *Cortex, 38,* 357-378.

Bartolomeo, P., Bachoud-Levi, A.C., De Gelder, B., Denes, G., Dalla Barba, G., Brugieres, P., & Degos, J.D. (1998). Multi-domain dissociation between impaired visual perception and preserved mental imagery in a patient with bilateral extrastriate lesions. *Neuropsychologia, 36,* 239-249.

Beale, C. R., & Arnold, D. S. (1990). The effect of instructions on view-specificity in young children's drawing and picture selection. *British Journal of Developmental Psychology, 8,* 393-400.

Behrmann, M., & Plaut, D. C. (2001). The interaction of spatial reference frames and hierarchical object representations: Evidence from figure copying in hemispatial neglect. *Cognitive, Affective, and Behavioral Neuroscience, 1,* 307-329.

Behrmann, M., Winocur, G., & Moscovitch, M. (1992). Dissociation between mental imagery and object recognition in a brain-damaged patient. *Nature, 359,* 636-637.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review, 94,* 115-147.

Booth, A. E., & Waxman, S. R. (2002a). Word learning is 'smart': Evidence that conceptual information affects preschoolers' extension of novel words. *Cognition, 84,* B11-B22.

Booth, A. E., & Waxman, S. R. (2002b). Object names and object functions serve as cues to categories for infants. *Developmental Psychology, 38,* 948-957.

Booth, A. E., & Waxman, S. R. (2003). Mapping words to the world in infancy: Infants' expectations for count nouns and adjectives. *Journal of Cognition and Development, 4,* 357-381.

Botez, A., Olivier, M., Vezina, J.L., Botez, T., & Kaufman, B. (1985). Defective revisualisation: Dissociation between cognitive and imagistic thought: Case report and short review of the literature. *Cortex, 21,* 375-389.

Bozeat, S., Lambon Ralph, M. A., Graham, K. S., Patterson, K., Wilkin, H., Rowland, J., Rogers, T. T., & Hodges, J. R. (2003). A duck with four legs: Investigating the structure of conceptual knowledge using picture drawing in semantic dementia. *Cognitive Neuropsychology, 20,* 27-47.

Bremner, J. G., & Moore, S. (1984). Prior visual inspection and object naming: Two factors that enhance hidden feature inclusion in young children's drawings. *British Journal of Developmental Psychology, 2,* 371-376.

Burgund, E.D. & Marsolek, C.J. (2000). Viewpoint-invariant and viewpoint-dependent object recognition in dissociable neural subsystems. *Psychonomic Bulletin and Review, 7,* 480-489.

Carlson-Radvansky, L.A., & Irwin, D.E. (1994). Reference frame activation during spatial term assignment. *Journal of Memory and Language, 33,* 646-671.

Coltheart, M., Inglis, L., Cupples, L., Michie, P., Bates, A., & Budd, B. (1998). A semantic subsystem of visual attributes. *Neurocase, 4,* 353-370.

Cooper, L. A., & Schacter, D. L. (1992). Dissociations between structural and episodic representations of visual objects. *Current Directions in Psychological Science, 1,* 141-146.

Cooper, L.A., Schacter, D.L., Ballesteros, S., & Moore, C. (1992). Priming and recognition of transformed three-dimensional objects: Effects of size and reflection. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18,* 43-57.

Davis, A. M. (1983). Contextual sensitivity in young children's drawings. *Journal of Experimental Child Psychology, 35,* 478-486.

Davis, A. M. (1984). Noncanonical orientation without occlusion: Children's drawings of transparent objects. *Journal of Experimental Child Psychology, 37,* 451-462.

Davis, A. M. (1985). The canonical bias: Young children's drawings of familiar objects. In N.H. Freeman & M.V. Cox (Eds.), *Visual order: The nature and development of pictorial representation.* (pp. 202-213). Cambridge: Cambridge University Press.

de Vreese, L.P. (1991). Two systems for colour-naming defects: Verbal disconnection vs colour imagery disorder. *Neuropsychologia, 29,* 1-18.

Dickinson, D.K. (1988). Learning names for materials: Factors constraining and limiting hypotheses about word meaning. *Cognitive Development, 3,* 15-35.

Ellis, R. & Allport, D.A. (1986). Multiple levels of representation for visual objects: A behavioural study. In A. G. Cohn & J. R. Thomas (Eds., *Artificial intelligence and its applications.* Chichester: John Wiley.

Ellis, R., Allport, D.A., Humphreys, G.W., & Collis, J. (1989). Varieties of object constancy. *Quarterly Journal of Experimental Psychology, 41,* 775-796.

Farah, (1984). The neurological basis of mental imagery: A componential analysis. *Cognition, 18,* 245-272.

Freeman, N. H., & Janikoun, R. (1972). Intellectual realism in children's drawings of a familiar object with distinctive features. *Child Development, 43,* 1116-1121.

Funnel, E., & Sheridan, J. (1992). Categories of knowledge? Unfamiliar aspects of living and nonliving things. *Cognitive Neuropsychology, 9,* 135-153.

Gainotti, G., Messerli, P., & Tissot, R. (1972). Qualitative analysis of unilateral spatial neglect in relation to laterality of cerebral lesions. *Journal of Neurology, Neurosurgery and Psychiatry, 35,* 545-550.

Goldenberg, G. (1992). Loss of visual imagery and loss of visual knowledge - A case study. *Neuropsychologia, 30,* 1081-1099.

Grossi, D., Orsini, A., & Modafferi, A. (1986). Visuoimaginal constructional apraxia: On a case of selective deficit of imagery. *Brain and Cognition, 5,* 255-267.

Hall, D. G. (1993). Basic-level individuals. *Cognition, 48,* 199-221.

Hall, D. G. & Moore, C. E. (1997). Red Bluebirds and Black Greenflies: Preschoolers' understanding of the semantics of adjectives and count nouns. *Journal of Experimental Child Psychology, 67,* 236-267.

Hall, D. G., Quantz, D. H., & Persoage, K. A. (2000). Preschoolers' use of form class cues in word learning. *Developmental Psychology, 36,* 449-462.

Hall, D. G. & Waxman, S. R. (1993). Assumptions about word meaning: Individuation and basic-level kinds. *Child Development, 64,* 1550-1570.

Halligan, P.W., Fink, G.R., Marshall, J.C., & Vallar, G. (2003). Spatial cognition: Evidence from visual neglect. *Trends in Cognitive Sciences, 7,* 125-133.

Hinton, G.E., & Parsons, L.M. (1988). Scene-based and viewer-centred representations for comparing shapes. *Cognition, 30,* 1-35.

Ingram, N. (1985). Three into two won't go: Symbolic and spatial coding processes in young children's drawings. In N.H. Freeman & M.V. Cox (Eds.), *Visual order: The nature and development of pictorial representation* (pp. 231-247). London: Cambridge University Press.

Jankowiak, J., Kinsbourne, M., Shalev, R.S., & Bachman, D.L. (1992). Preserved visual imagery and categorization in a case of associative visual agnosia. *Journal of Cognitive Neuroscience, 4,* 119-131.

Kemler Nelson, D. G., Russell, R., Duke, N., and Jones, K. (2000). Two-year-olds will name artifacts by their functions. *Child Development, 71,* 1271-1288.

Krascum, R., Tregenza, C., & Whitehead, P. (1996). Hidden-feature inclusions in children's drawings: The effects of age and model familiarity. *British Journal of Developmental Psychology, 14,* 441-455.

Landau, B. (1994). Object shape, object name, and object kind: Representation and development. *The Psychology of Learning and Motivation, 31,* 253-304.

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3,* 299-321.

Landau, B., Smith, L. B., & Jones, S. S. (1992). Syntactic context and the shape bias in children's and adults' lexical learning. *Journal of Memory and Language, 31,* 807-825.

Landau, B., Smith, L. B., & Jones, S. S. (1998). Object shape, object function, and object name. *Journal of Memory and Language, 38,* 1-27.

Lawson, R. & Humphreys, G. W. (1996). View specificity in object processing: Evidence from picture matching. *Journal of Experimental Psychology: Human Perception and*

Performance, 22, 395-416.

Lewis, C., Russell, C., & Berridge, D. (1993). When is a mug not a mug? Effects of content, naming, and instructions on children's drawings. *Journal of Experimental Child Psychology, 56,* 291-302.

Lhermitte, F., & Beauvois, M.F. (1973). A visual-speech disconnexion syndrome. *Brain, 96,* 695-714.

Light, P. (1985). The development of view-specific representation considered from a socio-cognitive standpoint. In N. H. Freeman & M. V. Cox (Eds) *Visual order: The nature and development of pictorial representation.* Cambridge University Press: Cambridge, UK.

Light, P., & Simmons, (1983). The effect of a communication task upon the representation of depth relationships in young children's drawings. *Journal of Experimental Child Psychology, 35,* 81-92.

Magnie, M-N., Ferreira, C.T., Giusiano, B., & Poncet, M. (1999). Category specificity in object agnosia: preservation of sensorimotor experiences related to objects. *Neuropsychologia, 37,* 67-47.

Marr, D. (1982). *Vision.* New York: Freeman.

Marshall, J.C., & Hallligan, P.W. (1993). Imagine only the half of it. *Nature, 364,* 193-194.

Marsolek, C.J. (1995). Abstract visual-form representations in the left cerebral hemisphere. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 375-386.

Marsolek, C. J. (1999). Dissociable neural subsystems underlie abstract and specific object recognition. *Psychological Science, 10,* 111-118.

McMullen, P. A., & Jolicoeur, P. (1990). The spatial frame of reference in object naming and discrimination of left-right reflections. *Memory & Cognition, 18,* 99-115.

Miceli, G., Fouch, E., Capasso, R., Shelton, J.R., Tomaiuolo, F., & Caramazza, A. (2001). The dissociation of color from form and function knowledge. *Nature Neuroscience, 4,* 662-667.

Phillips, W.A., Hobbs, S.B., & Pratt, F.R. (1978). Intellectual realism in children's drawings of cubes. *Cognition, 6,* 15-33.

Posner, M. I., & Keele, S. W. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology, 77,* 353-363.

Posner, M. I., & Keele, S. W. (1970). Retention of abstract ideas. *Journal of Experimental Psychology, 83,* 304-308.

Riddoch, M.J. (1990). Loss of visual imagery: A generation deficit. *Cognitive Neuropsychology, 7,* 249-273.

Robertson, L.C., & Lamb, M.R. (1991). Neuropsychological contributions to theories of part/whole organization. *Cognitive Psychology, 23,* 299-330.

Rosch, E., Mervis, C.B., Gray, W.D., Johnson, D.M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology, 8,* 382-439.

Schacter, D. L., & Cooper, L. A. (1993). Implicit and explicit memory for novel visual objects: Structure and function. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 995-1009.

Smith, L. B., Jones, S. S., & Landau, B. (1992). Count nouns, adjectives, and perceptual properties in children's novel word interpretations. *Developmental Psychology, 28,* 273-286.

Stangalino, C., Semenza, C., & Mondini, S. (1995). Generating visual mental images: Deficit after brain damage. *Neuropsychologia, 11,* 1473-1483.

Stankiewicz, B.J., Hummel, J.E., & Cooper, E.E. (1998). The role of attention in priming left-right reflections of object images: Evidence for a dual representation of object shape. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 732-744.

Subrahmanyam, K., Landau, B., & Gelman, R. (1999). Shape, material, and syntax: Interacting forces in children's learning of novel words for objects and substances. *Language and Cognitive Processes, 14,* 249-281.

Tarr (1995). Rotating objects to recognize them: A case study on the role of viewpoint dependency in the recognition of three-dimensional objects. *Psychonomic Bulletin and Review, 2,* 55-82.

Taylor, M., & Bacharach, V. R. (1982). Constraints on the visual accuracy of drawings produced by young children. *Journal of Experimental Child Psychology, 34,* 311-329.

Thaiss, L., & Bleser, R.D. (1992). Visual agnosia: A case of reduced attentional "spotlight"? *Cortex, 28,* 601-621.

Tomasello, M. & Barton, M. (1994). Learning words in nonostensive contexts. *Developmental Psychology, 30,* 639-650.

Tversky, B. & Hemenway, K. (1984). Objects, parts, and categories. *Journal of Experimental Psychology: General, 113,* 169-197.

van Sommers, P. (1989). A system for drawing and drawing-related neuropsychology. *Cognitive Neuropsychology, 6,* 117-164.

Walker, P. (2005). Lost in a world where ducks have four legs, and giraffes masquerade as kangaroos: Changes in object knowledge after *herpes simplex encephalitis.* Submitted.

Walker, P., Dixon, S. & Smith, D. (2000). Associating object names with descriptions of shape that distinguish possible from impossible objects. *Visual Cognition, 7,* 597-627.

Wapner, W., Judd, T., & Gardner, J. (1978). Visual agnosia in an artist. *Cortex, 14,* 343-364.

Waxman, S. R. (1999a). The dubbing ceremony revisited: Object naming and categorization in infancy and early childhood. In D. L. Medin & S. Atran (Eds.), *Folkbiology* (pp. 233-284). Cambridge, MA: Bradford.

Waxman, S. R. (1999b). Specifying the scope of 13-month-olds' expectations for novel words. *Cognition, 70,* B35-B50.

Waxman, S. R. & Booth, A. E. (2001) Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. *Cognitive Psychology, 43,* 217-242.

Waxman, S. R. & Hall, D. G. (1993). The development of a linkage between count nouns and object categories: Evidence from 15- to 21-month-old infants. *Child Development, 64,* 1224-1241.

Waxman, S.R., Philippe, M., & Branning, A. (1999). A matter of time: novel nouns mark object categories when delays are imposed. *Developmental Science, 2,* 59-66.

Waxman, S. R., Senghas, A., & Benveniste, S. (1997). A cross-linguistic examination of the noun-category bias: Its existence and specificity in French- and Spanish-speaking preschool-aged children. *Cognitive Psychology, 32,* 183-218.

Xu, F., Carey, S., & Welch, J. (1999). Infants' ability to use object kind information for object individuation. *Cognition, 70,* 137-166.

Table 1

Experiment 1: The Number of Children in Each Condition Whose Drawings Displayed the Hidden Part, the Correct Colour, and Shading-In.

Condition	Drawing feature		
	Hidden part	Colour	Shading
Count noun (n = 39)	14	11	18
Mass noun (n = 38)	6	12	17

Table 2

Experiment 2: The Number of Children in Each Condition Whose Drawings Displayed the Hidden Part, the Correct Colour, and Shading.

Condition	Drawing feature		
	Hidden part	Colour	Shading
Count noun (n = 22)	18	12	4
Adjective (n = 20)	7	13	4
Unnamed (n = 20)	10	10	6

Table 3

Experiment 3: The Number of Children in Each Condition Including the Cone in Their Two Drawings.

Condition	Drawing	
	First	Second
Named - Named	31	9
Named - Unnamed	30	2
Unnamed - Unnamed	23	2

Note. n = 36 in each condition.

Table 4

Experiment 4: The Number of Children in Each Condition Whose Two Drawings Displayed the Hidden Cone, the Correct Colour, and Shading-In.

Condition	Drawing	
	First	Second
Hidden Cone		
Named with a count noun	41	28
Named with an adjective	36	12
Unnamed	34	7
Correct Colour		
Named with a count noun	34	41
Named with an adjective	33	29
Unnamed	30	34
Shading-In		
Named with a count noun	8	10
Named with an adjective	15	17
Unnamed	9	10

Note. n = 46 in each condition.

Table 5

Experiment 5: The Number of Children in Each Condition Including the Cone in Their Drawing of the Object Possessing a Cone, According to Whether This Object was Drawn First or Second.

Condition	Drawing	
	First	Second
Same name	13	7
Different name	16	16

Note. n = 38 in each condition, with 19 children in each condition drawing the object possessing a cone either first or second.

Table 6

Experiments 6 & 7: The Number of Children in Each Condition Including the Cone in Their Two Drawings.

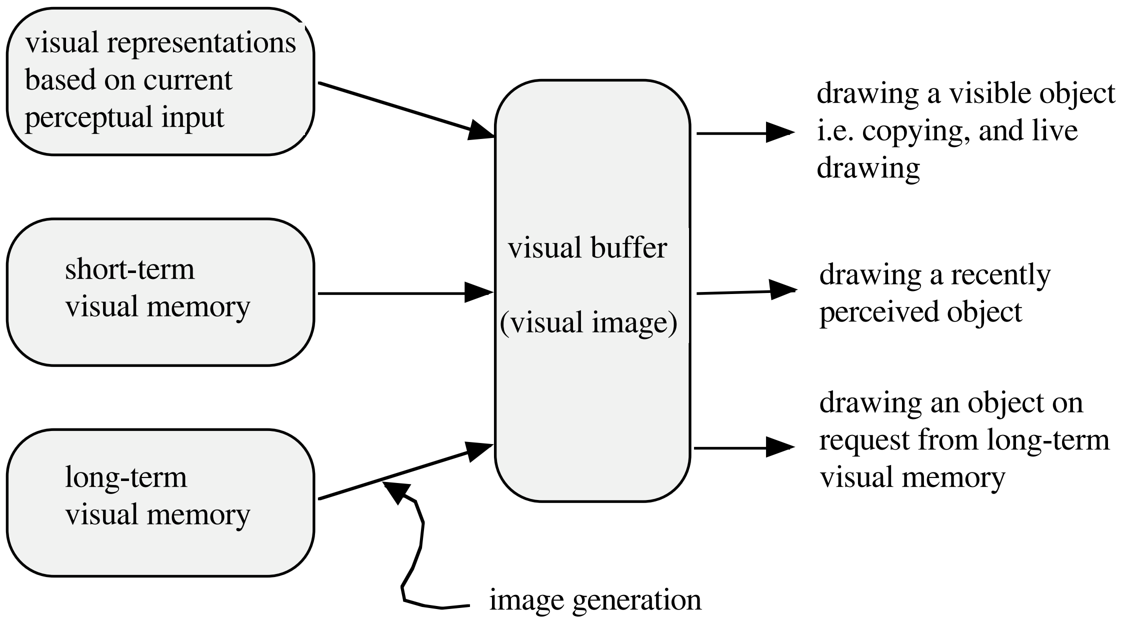
Condition	Drawing	
	First	Second[a]
Experiment 6		
Named at inspection (n = 36)	30	15
Named in position (n = 36)	24	3
Unnamed (n = 36)	23	7
Experiment 7		
Named at inspection only (n = 40)	34	22
Named both at inspection and in position (n = 42)	35	17

[a] Note. In all conditions the second object was named as “a dax” when it was in position to be drawn.

Figure legends

Figure 1. Some of the cognitive resources providing visual information about an object being drawn. Farah's (1984) scheme, in which a visual buffer plays a key role in perception and imagery, supporting a range of processes that include mental transformation and drawing, is extended by adding short-term visual memory. It is acknowledged, however, that the proposed distinction between short-term visual memory and the visual buffer is still under debate, as is the distinction between short-term and long-term visual memory. For example, Baddeley and Andrade (2000) provide evidence that factors impinging on the quality of the information in short-term visual memory (or the visuo-spatial sketchpad in the terminology of the working memory framework), also determine the vividness of a visual image generated from long-term visual memory. It might be argued from this that the visual buffer and short-term visual memory are one and the same thing.

Figure 2. Scanned images of drawings of the first object (left column) and second object (right column) provided by each of six children in Experiment 3. The first two children (rows) participated in the *Named-Named* condition, the next two children participated in the *Named-Unnamed* condition, and the final two children participated in the *Unnamed-Unnamed* condition.


visual representations based on current perceptual input
short-term visual memory
long-term visual memory
visual buffer
(visual image)
drawing a visible object i.e. copying, and live drawing
drawing a recently perceived object
drawing an object on request from long-term visual memory
image generation