‘Ghost’ experiments and the dissection of social learning in humans and animals

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(Received 22 June 2009; revised 17 December 2009; accepted 3 January 2010)

ABSTRACT

The focus of this review is the experimental techniques used to identify forms of social learning shown by humans and nonhuman animals. Specifically, the ‘ghost display’ and ‘end-state’ conditions, which have been used to tease apart imitative and emulative learning are evaluated. In a ghost display, the movements of an apparatus are demonstrated, often through the discrete use of fishing-line or hidden mechanisms, without a live model acting directly upon the apparatus so that the apparatus appears to be operated as if by a ‘ghostly’ agent. In an end-state condition, an observing individual is shown the initial state of the test apparatus, the apparatus is then manipulated out-of-sight and then represented to the individual in its final state. The aim of the ghost display condition is to determine whether individuals are able to emulate by replicating the movements of an apparatus, or perform a task, without requiring information about the bodily movements required to do so (imitation). The end-state condition is used to identify goal-emulation by assessing whether the observer can replicate the steps required to solve the task without having been shown the required body actions or task movements. The responses of individuals tested with either the ghost display and/or end-state conditions are compared to those of further individuals who have observed a full demonstration by either a human experimenter or a conspecific. The responses of a control group, to whom no information has been provided about the test apparatus or required actions, are also compared and evaluated. The efficacy of these experimental techniques employed with humans, nonhuman primates, dogs, rats and birds are discussed and evaluated. The experiments reviewed herein emphasise the need to provide ghost displays and end-state conditions in combination, along with full live demonstrations and a no-information control. Future research directions are proposed.

Key words: ghost condition, end-state condition, imitation, emulation, social learning, experimental technique, observational learning

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I. INTRODUCTION

There is a growing interest in the use of experimental techniques to identify social learning mechanisms evidenced by humans and nonhuman animals (hereafter termed 'animals'). This review will evaluate the merit and efficacy of methodological techniques used for this purpose. Of a number of approaches that have been used by developmental and comparative psychologists, two are the foci of this present review — ‘ghost’ display and ‘end-state’ conditions — both of which remove the agent from the demonstration. These methods have been selected for discussion because not only is their use for dissecting social learning mechanisms becoming increasingly popular but they have also been used with a number of species allowing for a more in-depth and wide-reaching evaluation. However before these methods can be described, the social learning mechanisms they are used to identify will first be defined.

Humans and animals have been shown to be capable of social learning. This describes a process through which information is transmitted between individuals, and down generations, by a process of learning, rather than inherited genetically (Mesoudi & Whiten, 2004, 2008; for reviews of the efficiency of social learning see Laland, 2004; Kendal et al., 2005). Boyd & Richerson (1985) proposed that social learning would be beneficial when the costs accrued from individual learning outweigh those of social learning (Templeton & Giraldeau, 1996) and/or when the environment is relatively stable (Galef & Whiskin, 2004), both of which have been supported empirically (see Kendal et al., 2005 for a review; but see Eriksson, Enquist & Ghirlanda, 2007).

Social interactions that facilitate observational learning are common within the daily experiences of humans and other social animals. Even at an early age, both humans (Meltzoff & Moore, 1977; Meltzoff, 1988; Uzgiris, 1991; Want & Harris, 2002) and primates (Maestripieri, Ross & Moore, 1977; Meltzoff, 1988; Uzgiris, 1991; Want & Harris, 2002) and primates (Maestripieri, Ross & Moore, 1977; Meltzoff, 1988; Uzgiris, 1991; Want & Harris, 2002; Whiten & van Schaik, 2007, p. 605), however, then it has been described, not just among humans, but also nonhuman primates including wild chimpanzees (Pan troglodytes, Whiten et al., 1999, 2001), orangutans (Pongo pygmaeus, van Schaik et al., 2003; van Schaik & Pradham, 2003; Russon et al., 2008), capuchins (Cebus capucinus, Perry, 2008) and Japanese macaques (Macaca fuscata, Leca, Gunst & Huffman, 2007, 2008) as well as other nonprimate species (see Laland & Galef, 2009).

In each of these species, when an individual observes another perform a novel behaviour there are numerous ways in which the information can be acquired. The fidelity of transmission depends upon the observers’ understanding of what they see and to what they attend. The critical question is to ask how this learning occurs (Want & Harris, 2002; Whiten et al., 2004). The focus of this review is to discuss methods used to identify underlying mechanisms of social learning, allowing for distinctions between imitation and emulation in particular. These forms of social learning are defined and discussed in Section II and the ghost display and end-state conditions employed to identify them are described and evaluated in Section III. The Discussion, Section IV, will consider the efficacy of these methods for researching observational learning mechanisms. Future considerations and research directions are proposed in Section V.

II. FORMS OF SOCIAL LEARNING

Many classifications have been proposed to describe the forms of social learning evidenced by humans and animals and, for clarity, an overview of the major definitions will be presented. This overview does not aim be exhaustive, but merely to note those definitions that will be later referred to throughout this review (for more detailed definitions and discussion see Whiten & Ham, 1992; Heyes, 1993; Nicol, 1995; Byrne & Russon, 1998; Call & Carpenter, 2002, 2003; Zentall, 2003, 2006; Hopper et al., 2008; Whiten et al., 2009). Put simply, individuals can either replicate the bodily actions of others (imitation) or the outcomes and goals of their actions (emulation).
Identifying social learning mechanisms

(1) Imitation

Whiten & Ham (1992) defined imitation simply as a process in which “B learns some aspect(s) of the intrinsic form of an act from A” (p. 250). Others consider that imitation incorporates an understanding of the model’s intentions (Tomasello, 1999; Horowitz, 2003; Bellagamba, Camaioni & Caloneesi, 2006; Huang, Heyes & Charman, 2006). Heyes (1998) proposed that the act of imitating another’s physical actions is potential evidence of higher intelligence, as along with Boyd & Richerson (1996), Heyes (1998) suggests that perspective-taking is an essential element of true imitation. Perspective-taking implies an understanding of the demonstrator’s goals (Gattis, 2002) and Bekkering, Wohlschlager & Gattis (2000) suggested that imitation by children is mediated by perceived goals (see also Bekkering & Prinz, 2002). Following Bekkering et al. (2000) and Gleissner, Meltzoff & Bekkering (2000), Wohlschlager, Gattis & Bekkering (2003) developed a theory of goal-directed imitation (GOADI). According to the GOADI theory a “similarity between the movement of the model and the imitator is only superficial and incidental: the underlying similarity is a similarity of action goals” (Wohlschlager et al., 2003, p. 512). Zentall (2001), however, argued that because imitation has been shown in “species as varied as rats, pigeons, and Japanese quail . . . the responsible mechanism is not likely to be theory of mind or perspective taking. But in cases in which stimulus matching is inadequate to account for imitation, some precursor of perspective taking is likely to be involved” (p. 85). Following Zentall (2001), for the purpose of this review, imitation will be defined following Whiten & Ham (1992).

(2) Emulation

Emulation was first defined by Wood (1989) to describe the responses of children who achieved the same end-state of a demonstrated action but used a novel way to reach that goal. Emulative learning can be subdivided into three specific forms: ‘goal emulation’, ‘affordance learning’ and ‘object movement reenactment’ (Byrne, 2002a; Custance, Whiten & Fredman, 1999; Huang & Charman, 2005).

(a) Goal-emulation

An example of goal-emulation was provided by Tomasello (1990, referring to Tomasello et al., 1987). Young chimpanzees saw either another chimpanzee use a tool in one of two specific ways to retrieve an out-of-reach food item or an inactive chimpanzee not using the tool. When presented with the same task, the chimpanzees (aged four to six years old) that had observed a successful conspecific also used the tool to access the food. However they did not replicate the exact behavioural strategies demonstrated. Instead they learnt that the tool could be used to retrieve the food, but not necessarily the precise manner with which the model chimpanzees had used it. Specifically, this form of emulation can be classed as goal-emulation because the chimpanzees attained the same goal through a novel method (Tomasello, 1990, 1999).

(b) Affordance learning

Affordance learning describes what an individual learns about the physical properties of the environment and relations among objects (Byrne, 1998). An example of affordance learning was proposed by Zentall & Akins (2001) to describe the findings of Bugnyar & Huber (1997). Marmosets (Callithrix jacchus) observed cage mates entering a box, to retrieve food, from behind a door which could either be pulled or pushed. Observers showed a tendency to use the same method as that which they observed. Rather than revealing imitation, as Bugnyar & Huber (1997) proposed, Zentall & Akins (2001) suggested that the marmosets might have learnt about the affordances of the door (‘it can be pulled’ or ‘it can be pushed’).

(c) Object movement enactment

In their review of social learning mechanisms, Whiten et al. (2004) were careful to distinguish imitation from object movement re-enactment (OMR; Custance et al., 1999). Whiten et al. (2004) defined OMR as “copying what the object does” (p. 39), distinct from imitation which requires the observer to replicate the bodily movements of the demonstrator. Caution should be maintained when reporting evidence of imitation, as OMR may often be a more parsimonious explanation.

(3) Simpler forms of social learning

Although this review will focus on methods used to distinguish imitation and emulation, acknowledgement should also be made of other forms of social learning.

(a) Contagion, mere presence effect and response facilitation

Contagion describes the phenomenon by which species-typical behaviours are elicited from an animal when it observes another (Thorpe, 1963), for example when an animal eats after observing a conspecific feeding, even if the observer is satiated (Tolman, 1964).

Mere presence effect describes how the presence of a conspecific can affect the ability and speed with which an observer can acquire a new behaviour. The presence of a conspecific may not necessarily facilitate learning, and indeed Zajonc (1965) believed that the presence of a conspecific was detrimental to the observer. However, Caldwell & Whiten (2003) found that the presence of scrounging conspecifics facilitated observational learning by marmosets.

Response facilitation (Byrne, 1994), describes the increased probability of an animal to perform a familiar (not novel) act that it has observed a conspecific perform. Crucially, Byrne (1994) noted, response facilitation differs from imitation because the actions done are already in the repertoire of the observing animal (but see Hopfitt, Blackburn & Laland, 2007). As has often been pointed out, defining what is a ‘novel’ action for a particular animal or individual is a notoriously difficult task.
(b) Local and stimulus enhancement

Local enhancement and stimulus enhancement occur when an individual’s attention is drawn to a particular locale or object merely by the presence of another animal, or the change in the environment resulting from such an interaction (Whiten & Ham, 1992; see also Zentall, 2001 for a review). Local enhancement refers to when an animal’s attention is drawn to a particular location. Stimulus enhancement refers to when the observer’s attention is focused on a specific part of an apparatus or object.

III. METHODS FOR IDENTIFYING OBSERVATIONAL LEARNING MECHANISMS

As highlighted above, there are a number of ways an individual can gain new information by observing another, and experimental techniques have been developed to help identify and distinguish these. Specifically, this review will provide an overview of experiments that have employed ghost displays (Fawcett, Skinner & Goldsmith, 2002) and/or end-state (Melzoff, 1985) conditions with both humans and animals (Table 1). These methods have been used with the aim to distinguish forms of social learning, in particular separating imitative from emulative learning. Further to this, it is useful first to describe and define the two-action (Dawson & Foss, 1965) and bidirectional (Heyes & Dawson, 1990) methods that are commonly used in such experiments.

(1) The two-action versus the bidirectional methods

To test for imitation, Dawson & Foss (1965) developed a two-action method in which the goal of the task was always the same, but the behaviour required to achieve it could be demonstrated in more than one way. Imitation could then be determined if the observer used the same body movement as the model observed, to complete the task. In Dawson & Foss’s (1965) original study, budgerigars (Melopsittacus undulatus) observed conspecifics remove a square of card (lid) from a dish containing food using one of three methods; ‘edged off by the beak’, ‘lifted off by the beak’ or ‘used foot to dislodge the square’. The budgerigars tended to use the same method as that demonstrated, but due to the paucity of detail provided in the report, the conclusion should be regarded with caution (Galef, Manzig & Field, 1986).

However Zentall & Akins (2001) criticised the two-action method, focusing on the conclusions drawn by Galef et al. (1986) who replicated Dawson & Foss’ design. Zentall & Akins (2001) stated that as the lid moved in different ways (slide off versus lift off) the observing birds may actually have learnt about the affordances of the lid rather than matched the model’s behaviour. To overcome such limitations, Zentall and colleagues designed experiments in which a pedal could be depressed by either a bird’s beak or foot. Thus, the resultant movement of the target object was the same for both actions (Akins & Zentall, 1996; Zentall, Sutton & Sherbourne, 1996; Kaiser, Zentall & Galef, 1997, but see Hoppitt et al., 2007).

A bidirectional task, by contrast, is composed of an apparatus with a manipulandum that can be moved in one of two directions; left/right or up/down. This has the advantage of being able to control against stimulus enhancement insofar as the demonstrator always interacts with the same part of the device. If a subject replicates the movement of this one target, without the presence of a demonstrator, it is likely that they have relied on object movement reenactment.

(2) Ghost display conditions

In a ghost display (coined by Fawcett et al., 2002) the pertinent parts of an apparatus or tool are moved discretely and surreptitiously by the experimenter; the apparatus appears to move as if operated by a ‘ghostly’ agent. This is often achieved through the use of hidden mechanisms or fishing line. When describing emulation, Byrne (2002b) stated “the important distinction from other kinds of imitation is that motor behavior per se is not copied. Thus, in principle, emulation could be as effective if the behavior were not seen” (p. 90). It is following this rationale that ghost display conditions were developed, as they allow for the demonstration of the movements of an apparatus without a live demonstrator acting on it.

To date, ghost display conditions have been employed with humans (Jacobson & Sisemore, 1976; Thompson & Russell, 2004; Tennie, Call & Tomasello, 2006; Subiaul et al., 2007; Hopper et al., 2008, in press), nonhuman primates (Subiaul et al., 2004; Tennie et al., 2006; Hopper et al., 2007, 2008), dogs (Canis familiaris, Miller, Rayburn-Reeves & Zentall, 2009), rats (Rattus norvegicus, Groesbeck & Duerfeldt, 1971; Denny, Clos & Bell, 1988; Heyes et al., 1994) and birds (Akins, Klein & Zentall, 2002; Fawcett et al., 2002; Klein & Zentall, 2003). These provide a growing corpus of literature on the abilities of these species to learn emulatively (Table 1 provides an overview). The fact that this method has now been used with such a diverse number of species allows a review of the ghost condition to be particularly informative.

Before a discussion of the ghost display condition can be made, the distinction between goal-emulation and object movement reenactment (OMR) should again be defined as the conclusions drawn from studies that have presented ghost displays have often failed to acknowledge this distinction. As described in Section II, goal-emulation is a form of emulative behaviour in which the individual replicates the outcome of an action regardless of whether he/she use the same physical behaviour or not. Indeed, Wood’s (1989) original definition of emulation was that children try to emulate others “by achieving similar ends or objectives” (p. 71). OMR, by contrast, refers to an individual replicating the movements of the apparatus to achieve the same end state. Through the use of ghost and end-state conditions in combination steps can be made to distinguish goal-emulation and OMR with greater confidence as will be discussed below.
Table 1. An overview of studies which have incorporated ghost display and/or end-state conditions. OMR, object movement reenactment

<table>
<thead>
<tr>
<th>Study</th>
<th>Condition</th>
<th>Species tested</th>
<th>Evidence for emulation? (Yes/No/Unclear)</th>
<th>Other forms of observational learning identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akins et al. (2002)</td>
<td>Ghost display</td>
<td>Japanese quail (<em>Coturnix japonica</em>)</td>
<td>Unclear</td>
<td>Imitation identified but simpler forms of learning could explain results such as stimulus enhancement</td>
</tr>
<tr>
<td>Bellagamba &amp; Tomasello (1999)</td>
<td>End state</td>
<td>Infants (12 and 18 months)</td>
<td>Unclear (perhaps OMR)</td>
<td>Imitation</td>
</tr>
<tr>
<td>Call et al. (2005)</td>
<td>End state</td>
<td>Children (2 years)</td>
<td>Unclear (perhaps affordance learning)</td>
<td>Imitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chimpanzees (<em>Pan troglodytes</em>)</td>
<td>Yes (goal-emulation) but non-social cues confounded results</td>
<td></td>
</tr>
<tr>
<td>Denny et al. (1988)</td>
<td>Ghost display</td>
<td>Rats (<em>Rattus norvegicus</em>)</td>
<td>Yes (OMR)</td>
<td>Evidence suggests stimulus enhancement</td>
</tr>
<tr>
<td>Groesbeck &amp; Duerfeldt (1971)</td>
<td>Ghost display</td>
<td>Rats</td>
<td>Yes (OMR)</td>
<td>No (experimental confounds)</td>
</tr>
<tr>
<td>Heyes et al. (1994)</td>
<td>Ghost display</td>
<td>Rats</td>
<td>No (experimental confounds)</td>
<td>No (experimental confounds)</td>
</tr>
<tr>
<td>Hopper et al. (2007)</td>
<td>Ghost display</td>
<td>Chimpanzees</td>
<td>Yes (OMR)</td>
<td>Stimulus enhancement and imitation</td>
</tr>
<tr>
<td>Hopper et al. (2008)</td>
<td>Ghost display</td>
<td>Children (3 to 4 years)</td>
<td>Yes (affordance learning, OMR and goal-emulation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chimpanzees</td>
<td>Yes (affordance learning, OMR and goal-emulation)</td>
<td></td>
</tr>
<tr>
<td>Hopper et al. (in press)</td>
<td>Ghost display</td>
<td>Children (3 to 4 years)</td>
<td>Yes (OMR)</td>
<td>Evidence suggests stimulus enhancement</td>
</tr>
<tr>
<td>Huang et al. (2002)</td>
<td>End state</td>
<td>Infants (19 months)</td>
<td>Yes (affordance learning and goal-emulation)</td>
<td>Stimulus enhancement</td>
</tr>
<tr>
<td>Huang &amp; Charman (2005)</td>
<td>Ghost display</td>
<td>Infants (17 months)</td>
<td>Yes (OMR and affordance learning)</td>
<td></td>
</tr>
<tr>
<td>Huang et al. (2006)</td>
<td>End state</td>
<td>Infants (31 and 41 months)</td>
<td>Yes (OMR)</td>
<td>Possible evidence for imitation</td>
</tr>
<tr>
<td>Fawcett et al. (2002)</td>
<td>Ghost display</td>
<td>Starlings (<em>Sturnus vulgaris</em>)</td>
<td>No</td>
<td>Imitation identified, but stimulus enhancement could explain results</td>
</tr>
<tr>
<td>Jacobson &amp; Sisemore (1976)</td>
<td>Ghost display</td>
<td>Undergraduate students</td>
<td>Yes (OMR)</td>
<td></td>
</tr>
<tr>
<td>Klein &amp; Zentall (2003)</td>
<td>Ghost display</td>
<td>Pigeons (<em>Columba livia</em>)</td>
<td>Unclear (results explained more parsimoniously by stimulus enhancement affordance learning and OMR)</td>
<td>Imitation identified</td>
</tr>
<tr>
<td>Meltzoff (1985)</td>
<td>End state</td>
<td>Infants (14 months)</td>
<td>Unclear (possible evidence for OMR)</td>
<td>Unable to learn from end-state condition so matching adult demonstration potentially due to imitation and/or OMR</td>
</tr>
<tr>
<td>Miller et al. (2009)</td>
<td>Ghost display</td>
<td>Dogs (<em>Canis familiaris</em>)</td>
<td>Unclear (possible evidence for OMR)</td>
<td></td>
</tr>
<tr>
<td>Subiaul et al. (2004)</td>
<td>Ghost display</td>
<td>Rhesus macaques (<em>Macaca mulatta</em>)</td>
<td>No</td>
<td>Cognitive imitation proposed as the monkeys only learnt from the conspecific</td>
</tr>
</tbody>
</table>
Thompson & Russell (2004) conducted the first study to investigate the ability of children to learn from ghost displays. Although the majority of ghost studies run with humans have been with infants and children, the first was conducted with young adults (undergraduate students, Jacobson & Sisemore, 1976). Students in a ‘model’ condition saw a fellow student move a lever, after receiving a cue from a sequence of lights, to gain a reward (a USD five cent coin). In a ghost display condition (‘model-absent condition-apparatus operative’) the lever moved automatically, with no human present. Students in a third, no-information, control group were just shown the apparatus in a static state (‘apparatus inoperative condition’). Unlike more recent ghost studies interested in spontaneous responses, the students in this study were instructed to copy what they had seen.

Not only did the students in the model condition make more responses than those in the control, but they also made more correct responses. Interestingly, Jacobson & Sisemore (1976) reported that there was no significant difference in the level of success or number of responses made by the students in the ghost display condition compared to those that saw a model. They too performed better than those students in the control. This early study provides no breakdown of the specific observational learning mechanisms involved. The success of the students in the ghost display condition suggests emulation, specifically OMR. However, this apparatus did not allow for the identification of goal-emulation as there was no alternative way for the students to manipulate the lever to gain the reward. Furthermore, unlike the classic two-action study conducted with budgerigars by Dawson & Foss (1965), the demonstrator in the model condition only moved the lever using one method (their hand) and so bodily imitation could not be identified from the success of the students in this condition.

Nearly 30 years after Jacobson & Sisemore (1976), Thompson & Russell (2004) conducted the first study to investigate the ability of children to learn from ghost displays. Fourteen to 26 month old children saw a toy on either one or two mats (the ‘single-mat’ and ‘double-mat’ conditions, respectively). The mats were moved either by an adult demonstrator or by a hidden pulley system (the ghost display). In the single-mat condition, when the mat was pushed backwards the toy would move forwards. In the double-mat condition, pulling the mat that did not have the toy placed on it caused the second, with the toy on it, to move forward. Thus, the actions needed to retrieve the toys were counterintuitive. The adult demonstrations for the single- and double-mat conditions resulted in a greater number of retrieval acts by the children than by those in a no-information baseline. In the single-mat condition, children replicated the actions after both the adult demonstration and ghost display. In fact, in this condition children were more successful in the ghost condition, which Thompson & Russell (2004) concluded was evidence of emulative learning. The same was not true for the double-mat condition. Thompson & Russell (2004) suggested that the ghost display condition did not enhance children’s responses for the double-mat task because it did not result in a single, unambiguous, movement (both mats moved simultaneously).

The failure of the children to replicate the movements of apparatus in the double-mat, but not the single-mat, condition in the ghost display condition would indicate that they were not relying on OMR. If they were using OMR they would have moved both mats in the double-mat condition. The results suggest that the emulative learning in the single-mat condition was goal-emulation. If the children were trying to replicate the outcome in the ghost display of the double-mat condition, the ambiguity of task may have prevented them from doing so.

In a more rigorous study, Huang & Charman (2005) employed a series of experimental controls to tease apart imitation, affordance learning and OMR with infants (aged around 17 months old). Videos of five object-manipulation tasks, (i) a dumbbell, (ii) box and stick tool, (iii) prong and loop, (iv) cylinder and beads and (v) square and post, similar to those used by Meltzoff (1995), were presented to the infants in a series of conditions. The responses of the infants, after seeing a video in which an adult manipulated the objects successfully (full demonstration), were recorded. These responses were compared to those of infants who had seen either (i) a ghost display (‘object movement video’) in

<table>
<thead>
<tr>
<th>Study</th>
<th>Condition</th>
<th>Species tested</th>
<th>Evidence for emulation? (Yes/No/Unclear)</th>
<th>Other forms of observational learning identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subiaal et al. (2007)</td>
<td>Ghost display</td>
<td>Children (3 and 4 years)</td>
<td>Yes</td>
<td>Cognitive imitation</td>
</tr>
<tr>
<td>Tennie et al. (2006)</td>
<td>Ghost display</td>
<td>Infants (12, 18, 24 months)</td>
<td>Yes</td>
<td>Cognitive imitation</td>
</tr>
<tr>
<td>Thompson &amp; Russell (2004)</td>
<td>Ghost display</td>
<td>Infants (14 to 26 months)</td>
<td>Yes (single-mat task only)</td>
<td>Possible imitation</td>
</tr>
</tbody>
</table>
Identifying social learning mechanisms

which the objects were manipulated but the human operator was digitally removed or (ii) a ‘body movement video’ in which the objects were removed showing only the adult’s actions. Finally, a control (‘baseline’) video showed only the initial state of the objects. Huang & Charman (2005) aimed to determine whether OMR or body mimicry (imitation) would explain the infants’ copying.

After seeing the full demonstration and object movement (ghost display) videos, the infants were more likely to produce the target actions than were those infants in the body movement condition or control. OMR was proposed to explain the children’s responses because the end state was shown for both conditions. Huang & Charman (2005) theorised that showing the object movements may have provided the infants with more salient information as to how to reach the end state, and thus the affordances of the test objects (see also Goldenberg & Hagman, 1998, who discuss the ability of children to infer a tool’s affordances from its physical properties).

Huang & Charman (2005) concluded that the success of the children in the full demonstration condition could be due to combined effects of emulation, stimulus enhancement, mimicry and goal-directed intention reading and that their data ‘...do not confirm that object-based emulation was the only responsible mechanism in the full demonstration condition” (p. 297). Although Huang & Charman (2005) acknowledge that from the conditions they ran, no single form of learning could be identified, they should be commended. They ran a series of experimental conditions (including a failed-attempt condition not discussed here) and considered a range of social learning mechanisms to explain their findings to elucidate a better understanding of the learning observed.

The first study to use a ghost display condition with children and to compare their responses with those of nonhuman primates was conducted by Tennie et al. (2006). Infants aged 12, 18 and 24 months old were presented with a box which had a hinged door that could either be pushed or pulled to retrieve a reward. Four great ape species were also tested in the same experimental conditions and their responses are discussed below. The infants were shown how to open the box (push or pull) in one of two conditions: (i) a full demonstration by an adult, or (ii) a ghost display in which the door was moved discretely with fishing-line by the experimenter. The apparatus used by Tennie et al. (2006) replicated that used by Bugnyar & Huber (1997, described in Section II) and represents an improvement of that used by Thompson & Russell (2004) because the actions demonstrated were not ambiguous or counterintuitive.

An interesting age-difference in the responses of the infants was identified. Tennie et al. (2006) found that 24 months old infants matched the action demonstrated in both conditions, those aged 18 months old only matched the adult demonstration while the 12-month-olds failed to match in either condition. Tennie et al. (2006) concluded that their results "with 24-month-old children the idea that emulation tasks may be too complex for human infants” (p. 1166). However, the infants were also able to open the box successfully in a no-information baseline. Accordingly, Tennie et al. concluded that the information from the demonstrations was somewhat redundant and could not infer which social learning mechanism was used.

All of the above studies describe ghost display conditions that have tested typically developing children, by contrast Subiaul et al. (2007) compared the responses of typically developing children and individuals with autism. Individuals with autism aged eight to 20 years old (mean ‘socialization’ age was 3.94 years and mean ‘communication’ age was 4.79 years), and two groups of children (aged three and four years old) were presented with a ‘simultaneous chaining paradigm’ in one of three experimental conditions or a no-information baseline. The task consisted of a series of four images presented concurrently, at random locations, on a touch-screen monitor. The participants were required to select the images in a specific order. The three experimental conditions were: (i) a ‘social human demonstration’, (ii) a ‘nonsocial computer-only condition’ with each correct response paired with a sound (comparable to a ghost display), and (iii) a ‘social-plus-computer condition’ in which the participant observed an adult select the images in the correct order along with sound cues from the computer. The aim was to test for cognitive imitation as this design removed the confound of physical ability which may impair a child’s ability to imitate (see Barr, 2002).

The individuals with autism and children of both age groups were significantly more successful in the three experimental conditions compared to those in the no-information baseline. Although the children and individuals with autism responded successfully in the computer-only condition, Subiaul et al. (2007) concluded that (goal-) emulation could not explain what they termed ‘cognitive imitation’ because the images had to be selected in the correct order and there was not an alternative way to reach the same end state. However, the participants did repeat the actions shown in the absence of a demonstrator, indicative of Byrne’s (2002b) definition of emulation. Subiaul et al. (2007) reasoned that the participants learnt from the ghost display condition because, despite being an inanimate object, it “behaved as if it were animate and displayed the characteristics of social agents including, agency and goal-directedness [and]... children, from infancy, are sensitive to cues that index animacy and goal-directedness” (p. 240).

More recently, and following from Tennie et al. (2006), Hopper et al. (2008) presented three to four year old children with a bidirectional task (the ‘Slide-box’) from which a reward could be gained by sliding a door to either the left or right. The children were presented with one of three forms of demonstration for the Slide-box which were: (i) a fellow child moving the door, (ii) a ghost display in which the door was moved discretely by the experimenter using fishing-line, or (iii) an ‘enhanced ghost’ display condition in which the children saw a ghost display but a second child sat in front of the Slide-box, collecting the rewards, acting as a passive model. This third experimental condition was run to rule out
a mere presence effect as a possible cause for why individuals may perform better in a full demonstration, compared to a ghost display condition (Klein & Zentall, 2003). A fourth group of children was presented with the Slide-box in a no-information control.

Hopper et al. (2008) found that children copied the direction that the door was pushed with their first response after seeing an active model, ghost and enhanced ghost displays. When all their responses are considered, the children continued to match the direction shown by the active model and the enhanced ghost display (passive model), when compared to chance, but not after seeing a ghost display. These findings suggest that children copied by OMR, as not only did they learn that the door could be moved (affordance learning), but they also replicated the specific direction of door movement (OMR).

All the ghost display conditions reviewed thus far have involved the use of simple bidirectional or object manipulation tasks, none have required the use of a tool. This is surprising given the number of social learning studies with children which have involved problem-solving and/or tool-use tasks (e.g. Want & Harris, 2001; Horner & Whiten, 2005; McGuigan et al., 2007; Flynn & Whiten, 2008a, but see Nielsen, 2006). It has been proposed that children are able to ascertain the purpose of a tool from its physical properties (Goldenberg & Hagman, 1998) suggesting that children could learn new tool-use tasks through emulative (affordance) learning rather than relying on imitation. However it has commonly been reported that children learn imitatively (Nagell, Olguin & Tomasello, 1993; Horner & Whiten, 2005) but this could be due to the unfamiliar nature of the tasks children are presented with in experimental situations which are often designed specifically so that they are novel to preclude the child employing previously held knowledge.

Potentially, both imitation and emulation could allow for the acquisition of tool-use by children and to answer this, Hopper et al. (in press) showed three to four year old children ghost displays of a tool-use task, the Pan-pipes (Whiten, Horner & de Waal, 2005; Hopper et al., 2007). Two methods for operating the Pan-pipes with a stick-tool (lift or poke) were shown to the children in one of three ways: (i) a demonstration by an adult, (ii) a ghost display showing the pertinent moving parts of the task (moved discretely by the experimenter using fishing-line) or (iii) a ghost-with-tool condition, in which the tool was incorporated into the ghost display. A fourth group of children, in a no-information control, were given no form of demonstration and only three of these 16 control children were able to solve how to operate the Pan-pipes by trial-and-error.

Despite the apparent complexity of the task, the children that saw an adult demonstration were significantly more successful than those in the control. Over three-quarters (77%) of the children that saw an adult demonstration (of either lift or poke) were able to operate the Pan-pipes and all did so using the same method as that shown to them. As might be predicted, the contrast between the responses of the children in the adult demonstration and two ghost conditions was greatest for the basic ghost condition, which provided the least information to the observing children. In the basic ghost condition, not only did the children show reduced success, but they were also less likely to use the same method as that shown. This suggests that the success of those children in the adult demonstration condition was due to more than emulative of the movements of the Pan-pipes alone (OMR).

The ghost-with-tool condition yielded an intermediate picture. Hopper et al. (in press) noted that the children were less successful than those that saw an adult demonstration and were not significantly more successful than children in the basic ghost conditions or control. However, with their first attempts at the task they revealed a significant tendency to match what they had seen. They tried to make the tool do what it had done in the ghost display. Overall, just under a third of these children succeeded and all employed the method displayed in the ghost display, just as children in the demonstration conditions were highly faithful to the method they had seen, suggesting OMR of the tool, perhaps combined with affordance learning.

From the use of ghost display conditions with humans, evidence for emulative learning has been provided for children (Thompson & Russell, 2004; Huang & Charman, 2005; Tennie et al., 2006; Hopper et al., 2007, in press; Subiaul et al., 2007); adults (Jacobson & Sisemore, 1976), and individuals with autism (Subiaul et al., 2007). These reports of emulative learning provide further information about the variety of social learning mechanisms that humans employ. This highlights the importance of providing participants with more than one form of demonstration to determine which forms of social learning are at play. In the future, the challenge will be not only to identify the form of social learning employed, but also to determine which contexts predict their use.

(b) Ghost display conditions employed with nonhuman primates

Ghost display conditions have been conducted with a variety of nonhuman primate species, often as part of comparative studies with children. The first such study was conducted with rhesus macaques (*Macaca mulatta*) using a simultaneous chaining paradigm to test for cognitive imitation (Subiaul et al., 2004). Like the methodology described for Subiaul et al. (2007), rhesus macaques observed either a conspecific or computer-generated responses ('computer-feedback condition') for selecting a series of four images presented on a computer screen in a specific order.

The rhesus macaques that observed a fellow monkey perform the task took fewer attempts to complete the trial accurately compared to those in a no-information baseline (Subiaul et al., 2004). However those in the computer-feedback (ghost display) condition showed no greater success than those in the baseline and nor did a third group who were merely tested in the presence of a passive conspecific ('social-facilitation condition') to rule out a mere presence effect. This study was comprehensive, including controls for social (computer-feedback condition) and social
motivation (social-facilitation condition), and the authors were careful to consider, and rule out, different social learning mechanisms including local and stimulus enhancement and affordance learning. However, the study only included two subjects (both male) and they both acted as the ‘expert’ (model) and ‘student’ (observer) on separate trials in the social learning condition. Furthermore, there was no alternative way to reach the goal because a successful response was deemed when the macaque selected four images in a specific order rather than attaining a final end state. Due to the design of this experiment, therefore, goal-emulation could not be identified.

Tennie et al. (2006, described above), in addition to testing children, conducted a series of comparative experiments with chimpanzees, bonobos (Pan paniscus), gorillas (Gorilla gorilla) and orangutans. Through the use of the ‘push/pull’ bidirectional task, Tennie et al. (2006) aimed to test specifically for OMR. The apes observed either a live demonstration by a conspecific, a ghost display or were presented with the task in a no-information control. Tennie et al. (2006) concluded that they “… found no evidence that apes copied the information that they had observed; neither the observation of results nor results with actions changed the apes’ behavior. This is consistent with past studies showing [that] children are more adept than apes at matching the actions of others’” (p. 1165–1166). Due to these negative results by the great ape species Tennie et al. (2006) were unable to draw conclusions as to the learning mechanism involved and whether it be OMR or not, and no comparisons could be made with the children who potentially learnt via asocial learning.

Following an ‘open diffusion’ experiment which found that chimpanzees were able to learn a tool-use task (the Pan-pipes) from conspecifics in a group setting, Hopper et al. (2007) ran a series of ghost display conditions to determine what form of learning would explain this faithful spread of the introduced technique. In the open diffusion experiment a chimpanzee, trained how to operate the Pan-pipes using either the lift or poke methods, was allowed to perform the task in the presence of their cage mates. Hopper et al. (2007) reported that the group seeded with a chimpanzee proficient in the lift method was more likely to use the lift than the poke method. To investigate the forms of observational learning at play, chimpanzees were shown either a ghost lift display or a ghost-with-tool display as described above with children for Hopper et al. (in press).

Unlike children presented with ghost displays of the Pan-pipes (Hopper et al., in press), Hopper et al. (2007) reported that providing chimpanzees with either form of ghost display did not affect their level of success; chimpanzees in the ghost display conditions were no more successful than when tested in a no-information baseline (Hopper et al., in press, provides a detailed comparison of the responses of the chimpanzees and children to ghost displays of the Pan-pipes). One proposed explanation for the lack of response by the chimpanzees was because they were tested in isolation, which may have made them nervous and unresponsive. However, further investigation found that even when presented with comparable ghost displays when in groups with their familiar cage mates, chimpanzees were still unable to learn how to operate the Pan-pipes (Hopper, 2008).

The studies which have employed ghost display conditions with nonhuman primates have all reported negative results i.e. the primates were unable to learn from a ghost display, even for motorically simple tasks like a bidirectional task (Tennie et al., 2006). The major confound of Tennie et al.’s (2006) study, however, was the inherent bias of the task so that the apes were more likely to pull the door than push it regardless of which demonstration they had seen. Therefore Hopper et al. (2008) presented chimpanzees with the Slide-box (described above). Although also a bidirectional task, because the two actions (left and right) were more motorically similar (than push and pull) it was predicted that the responses of the chimpanzees were less likely to be affected by a personal bias.

Like children, chimpanzees matched the direction that the door was moved in the full demonstration and ghost displays (Hopper et al., 2008). This provided the first evidence of emulative learning by chimpanzees from a ghost display. With their first responses, the chimpanzees matched the direction in which the door was moved in the enhanced ghost and ghost display conditions suggesting OMR. This pattern of responses was not maintained however. Across all their responses, the chimpanzees ‘explored’ more than the children, showing an increased likelihood of moving the door in both directions, which could possibly be evidence for affordance learning. Rather than concluding that the success of chimpanzees in the full demonstration and ghost display conditions was purely due to OMR, it seems more likely that it was an interplay between all three forms of emulative learning (OMR, affordance learning and goal-emulation).

The failure of the chimpanzees to learn how to operate the Pan-pipes from seeing a ghost display (Hopper et al., 2007) could have been because the chimpanzees learnt to be ‘passive observers’; that the food would be delivered to them whether they acted upon the device or not. However the success of chimpanzees presented with the ghost display of the Slide-box (Hopper et al., 2008) disputes this. It seems a more parsimonious suggestion that the reduced success of the chimpanzees shown a ghost display of the Pan-pipes, whether a tool was involved or not, is due to the complexity of the task, especially in comparison to the simpler bidirectional Slide-box. The interplay between task complexity and social learning mechanism may also explain the differing success of children to learn these tasks from ghost displays. This may also be applied to the varying success of children presented with other complex (Thompson & Russell, 2004) and simple (Tennie et al., 2006) tasks.

(c) Ghost display conditions employed with dogs

To date, only one study has used ghost displays to test the observation learning mechanisms employed by dogs (Miller et al., 2009). Following Klein & Zentall (2003), Miller et al. (2009) presented dogs with a bidirectional task in one of
four conditions: (i) dog imitation (a full demonstration by a dog); (ii) social facilitation/emulation (an enhanced ghost display with a dog present); (iii) human imitation group (a demonstration by an unfamiliar human); and (iv) emulation group (a basic ghost display). In all conditions, a door slid to either the left or right, revealing a bowl of food. The first responses of the observing dogs showed significant levels of matching to the demonstration in only the dog imitation condition, however when all of the dogs’ responses are considered, significant matching was also shown by those dogs in the emulation (basic ghost) condition. Miller et al. (2009) concluded from this that the high levels of matching by those dogs in the dog imitation condition was evidence of imitation but that the dogs were also capable of emulating.

Unlike in other ghost displays discussed in this review, in all test conditions after the door was moved an experimenter behind the screen door gave praise (verbal reinforcement) and moved the food bowl (food reinforcement) within reach of the ‘demonstrators’ and observers. Miller et al. (2009) acknowledge that this could lead to social conditioning (an association developed between the door moving and the food reinforcement) however, they discredit it as an explanation for the matching behaviour shown by the dogs. Although this may not be the sole explanation for the matching shown by the dogs, it is likely to be a component in shaping their responses and Miller et al. (2009) provide no satisfactory explanation why such verbal reinforcement was included. Further, having an experimenter move the food reward towards the ‘demonstrator’ or observer could have provided a cue of reinforcement to the dogs; created a ‘clever Hans’ effect. This study, however, provides an insight into the learning mechanisms employed by dogs, a species currently receiving greater attention from those interested in social learning (see, for example, Range, Viranyi & Huber, 2007; Pongrácz et al., 2008).

(d) Ghost display conditions employed with rats

The earliest study that employed what could be considered a ghost display condition was conducted with rats (Groesbeck & Duerfeldt, 1971). Rats were presented with a Y-maze in one of a number of conditions [six in total], three of which are of interest here. At the entrance of each of the two branches of the maze was a flap-door that the rat had to push to walk along the passageway. The flap-door at the beginning to the arm with the reward (a water bottle) was black and white striped while the flap-door at the entrance of the incorrect arm (no reward) was solid black. Cards with the same design as the flap-doors were placed at the ends of the corresponding arms of the maze. In the full-demonstration condition the rats observed a conspecific select the correct arm of the maze, push the flap-door out of the way and walk along the arm to gain the reward. For the ghost display, the experimenter knocked down the correct flap-door with a pointer and tapped the water bottle, while a third group of rats were presented with the Y-maze in a no-information control.

Groesbeck & Duerfeldt (1971) reported that the rats in the full-demonstration and ghost display conditions learnt the maze quicker than those in the control group and performed fewer errors, but that those in the full-demonstration condition were the most successful. Although the authors did not define the form of learning responsible, they did conclude that the success of the rats in the ghost display condition could be explained by a “simpler construct such as stimulus enhancement” (p. 42). A likely explanation could be a combination of affordance learning and stimulus enhancement. The rats saw the movement of the flap-door and their attention was drawn to the specific branch of the maze and the water bottle by the experimenter with the pointer. Furthermore, although the rats were able to complete the maze successfully in the ghost display condition, there was no way they could attain the goal using a novel method, so goal-emulation could not explain the responses of the rats for this particular task.

Although not the focus of their study, Denny et al. (1988) used a ghost display to determine whether rats could learn to discriminate between a positive stimulus (a lever, which when pressed delivered a food pellet) and a negative stimulus (a lever, which when pressed delivered no pellet). Rats were trained by seeing the bars moved by a ‘hidden experimenter’ (a ghost display). This revealed that the rats were able to learn to press the bar which gave them a food reward from such a demonstration and Denny et al. (1988) concluded that “the necessary condition for the appropriate barpess appears to be the actual bar movement, that is, the response demonstration. In other words, the bar during training is not just spurious” (p. 221). These findings suggest that rats are capable of learning from a ghost display and are capable of emulative learning, specifically OMR.

More recently, Heyes et al. (1994) conducted a study using rats to test their ability to manipulate a rod from having seen a ghost display. Rats observed a rod move to either the left or right to release a food reward. In one condition rats observed a conspecific move the rod whilst in an alternative condition the rod was moved automatically with no demonstrator present (ghost display). Only those rats that had observed a conspecific move the rod also moved the rod, and did so in the same direction as that demonstrated, from which Heyes et al. (1994) concluded that the rats had imitated. However, Mitchell et al. (1999) later determined that the observing rats might have been affected by odour cues left on the bar by the demonstrating rats, casting doubt on the conclusion of imitation drawn by Heyes et al. (1994).

(e) Ghost display conditions employed with birds

Ghost display conditions have been conducted with three bird species, all including enhanced ghost display conditions to control for a mere presence effect (Akins et al., 2002; Fawcett et al., 2002; Klein & Zentall, 2003). Although the apparatus and test species used by Akins et al. (2002) and Fawcett et al. (2002) are different, the overall methodology for both experiments is the same because the birds either saw a full demonstration by a conspecific or an enhanced ghost
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display condition (see Hopper et al., 2008; Miller et al., 2009, described above).

In the study conducted by Akins et al. (2002), Japanese quail (*Coturnix japonica*) observed a door move to either the left or right (to reveal food pellets) by either a conspecific ("imitation condition") or an enhanced ghost display (termed the "control"). Akins et al. (2002) reported that the first response of quail in the imitation condition significantly matched the direction in which the door had been moved during the demonstration, but the same was not true for those in the enhanced ghost display condition. Akins et al. (2002) concluded that Japanese quail are capable of imitative learning. A limitation of this experimental design was that the control condition was run to guard for both a mere presence effect and for OM. Using just this one condition does not provide sufficient control and running further conditions, including a basic ghost display, would be ideal. Due to the paucity of experimental control, no conclusion of imitation should be drawn because the matching responses of the birds could be due to other, unidentified, learning mechanisms.

In contrast to Akins et al. (2002), Fawcett et al. (2002) tested starlings (*Sturnus vulgaris*) with a two-action task. The advantage of the two-action task, in combination with a ghost condition, is that it offers potentially the most convincing way to tease apart imitation from emulation as the two-action method allows for imitation to be identified with greater confidence than in other experimental settings, especially when used in combination with a control group (Kaiser et al., 1997, see also Voelkl & Huber, 2000). The starlings saw a plug either being pulled out of or pushed down into a box containing mealworms, to allow access to the food. The action was done by either a conspecific demonstrator or with an enhanced ghost display, in which the plug was moved discretely by the experimenter with a passive conspecific present. Despite a tendency of the observers to push, rather than pull, the plug regardless of condition, of those that did respond there was a significant correlation between the action demonstrated and the action performed by the observer. By contrast, those starlings in the enhanced ghost display condition showed no significant matching.

Like Akins et al. (2002), Fawcett et al. (2002) concluded that "...observation of the demonstrator’s behaviour was a crucial component in acquisition of the response, and that the observers were not simply paying attention to the movement of the plug. Our results provide strong evidence of imitation in starlings" (p. 554). Such a claim for imitation may be overstated. Like Akins et al. (2002), perhaps it was some combination of the movement of the apparatus in conjunction with the bird acting upon it which made it more salient to the observing bird in the demonstration condition, for which stimulus enhancement would be a more parsimonious explanation. To allow the experimenter to tease apart the interplay of OM, a mere presence effect and imitation more fully, birds should also be exposed to a basic ghost display.

Although claims of imitative learning by birds made by Akins et al. (2002) and Fawcett et al. (2002) may be premature, the responses of the birds in the enhanced ghost display condition are suggestive of goal-emulation. In the study run by Fawcett et al. (2002), although the birds did not match the specific method shown in the enhanced ghost display, 67% of subjects responded and were able to retrieve the food reward regardless of the method used. This would suggest that the birds were capable of goal-emulation and possibly affordance learning. The birds were able to learn the properties of the plug (that it could be moved to reveal a food reward) and of the task (that there was food inside) but not necessarily the specific way it should be acted upon. The same is true for the birds tested by Akins et al. (2002) All but one bird responded in the enhanced ghost display condition, regardless of the direction in which they moved the screen door. This is comparable to the responses of chimpanzees in the enhanced condition reported by Hopper et al. (2008).

Extending upon Akins et al. (2002), Klein & Zentall (2003) conducted a study with pigeons (*Columbia livia*) with four experimental conditions. The subjects saw a screen door move to either the left or right to reveal food pellets, in one of the following ways: (i) a full demonstration by a conspecific; (ii) an enhanced ghost display; (iii) a ghost display; or (iv) a vision-blocked condition. The first three conditions listed were those replicated with children and chimpanzees by Hopper et al. (2008) and the rationale for all has been described above. The fourth condition was run like a full demonstration but a piece of cardboard was placed between the observer and demonstrator, blocking visual access between the two cages to control for possible odour cues (a potential limitation identified by Mitchell et al., 1999).

Klein & Zentall (2003) claimed evidence for imitation because, like the Japanese quail (Akins et al., 2002), the pigeons made significantly more matching responses in the full demonstration condition compared to those in the enhanced ghost display condition. Klein & Zentall (2003) concluded further that, despite being a non-significant trend, because the pigeons made more responses in the enhanced ghost display compared to the ghost display condition, social facilitation could be responsible (they used this term interchangeably with a mere presence effect despite the differences highlighted in Section II).

Unfortunately, no direct comparison was drawn between the responses of the pigeons in the ghost display condition to those in the full demonstration group; rather, the responses were compared to chance. The pigeons made significantly more matching responses in the ghost display condition than would have been expected by chance from which Klein & Zentall (2003) concluded evidence of affordance learning. However, it seems more appropriate that such responses are evidence of OM because the pigeons did not merely learn the affordances of the door (that it could slide) but also which direction to move it. The success of the pigeons in the ghost display condition undermines the conclusion that they showed evidence of imitation. A more comprehensive conclusion could be that those pigeons that saw a live model may have been learning though a combination of
OMR enhanced by a mere presence effect and stimulus enhancement.

(3) End-state conditions

In the end-state condition, also termed the ‘emulation condition’ (Huang, Heyes & Charman, 2002), an individual is shown the initial state of the test object, which is then manipulated out-of-sight; the individual is then shown the resultant form of the object (Meltzoff, 1985). If the observer is able to complete the task from such information then goal-emulation is inferred. Unlike those studies that have employed ghost display conditions, the end-state technique has only been used with humans (infants and children) and nonhuman primates (Table 1); therefore the studies will be discussed collectively and not subdivided by subject species.

The end-state technique was pioneered by Meltzoff (1985) who showed 14-month-old infants a dumbbell-shaped toy, the ends of which could be removed. The initial-state was the intact dumbbell and the end state was the central shaft separated from the two end pieces. When shown a full demonstration of this action, infants were able to reproduce it, even after a 24 h delay. However when infants were shown only the initial and resultant end state, a non-significant number of children could re-enact the action to create the same end state when presented with the intact dumbbell. Meltzoff (1985) concluded that the failure of the infants in the end-state condition suggests that they were not capable of emulating.

To determine whether the failure of the infants tested by Meltzoff (1985) was due to their age Bellagamba & Tomasello (1999) replicated and extended Meltzoff’s (1985) study with 12 and 18-month-old infants. The infants were shown an object comparable to that used by Meltzoff (1985) and saw either an adult demonstrate the actions or only the start and end states. Across both conditions, the 18-month-old infants averaged more than twice as many target acts as the 12-month-olds. Furthermore, the infants performed more target acts after having seen the full demonstration than those in the end-state condition. Bellagamba & Tomasello (1999) concluded that “infants of this age also have a stronger tendency to imitate human intentional actions (imitative learning) than to reproduce interesting changes of states in objects in the absence of human behavior (emulation learning)” (p. 281). However, the success of the children who saw a full demonstration could be due to OMR, rather than imitation, and replicating this experiment with the inclusion of a ghost display condition would help address this.

Huang et al. (2002) employed the end-state test with a group of 19-month-old infants, demonstrating actions on five objects, which resembled those used by Meltzoff (1995), described for Huang & Charman (2005) above. As part of his original experiment, Meltzoff (1995) showed children an adult try, but fail, to complete an action with an object, a demonstration that was also replicated by a mechanical arm in order to assess the children’s sense of intentionality. Huang et al. (2002) ran their experiment specifically to test whether a simpler form of social learning could explain the success of children in Meltzoff’s (1995) ‘failed attempt’ condition, rather than, as Meltzoff (1995) posited, the children’s understanding of the model’s intentions. To answer this, Huang et al. (2002) tested children in one of four conditions, one of which was the end-state. The infants saw either a full-demonstration by an adult, an emulation (end-state) condition or an adult-manipulation condition in which the demonstrator interacted with the object in a non-directed manner. This third condition allowed the experimenter to control for the effect of stimulus enhancement created when the experimenter interacted with the test objects in the demonstration condition. Unlike the younger infants tested by Bellagamba & Tomasello (1999), Huang et al. (2002) reported that 19-month-old infants made just as many target acts in the end-state condition as those in the full-demonstration condition. Moreover, infants in both these conditions performed more target acts than did those in the adult manipulation control. Huang et al. (2002) concluded that infants were able to learn via stimulus enhancement and emulation. Specifically, I suggest, affordance learning and goal-emulation. Huang et al. (2002) also replicated this experiment with 17-month-old infants but unfortunately, none of the responses by the infants were at a significant level and so no age comparisons could be made.

Most recently, Huang et al. (2006) replicated their 2002 study with older children, aged 31 and 41 months. No effect of age was reported between the two groups. Unlike the younger children tested previously, Huang et al. (2006) reported that the children performed more target acts in the full-demonstration compared to the end-state condition. Such findings are in agreement with Bellagamba & Tomasello (1999), suggesting that age is not the only determinant in a child’s ability to understand and learn from an end-state display. Indeed, as Bauer & Kleinknecht (2002) stated, “…age alone does not determine whether children will evidence emulation. Rather, children can emulate novel causal sequences well before the age of 4, just so long as the task demands are manageable. In short, it appears that the learning strategy a young child is capable of using varies as a function of task demands, not age” (p. 19).

Employing a comparative approach, Call, Carpenter & Tomasello (2005) gave two year old children and chimpanzees one of four demonstrations: (i) a full demonstration; (ii) the actions only; (iii) an end state; or (iv) a no-information baseline control. The apparatus used was a tube, either transparent or opaque, with a reward inside. The reward could be retrieved by either twisting the ends off or pulling the tube apart, breaking it in the middle. Both methods resulted in distinct end states. Regardless of the method demonstrated, there was no significant difference in the number of tubes opened by the chimpanzees across the three experimental conditions, or between those and the baseline. However, more clear, than opaque, tubes were opened suggesting possible nonsocial enhancement; the chimpanzees were encouraged by seeing the reward inside the tube.

Chimpanzees in the end-state condition were more likely to match the method demonstrated than those in
the action-only condition. In fact, the chimpanzees often attempted the alternative method when having seen only the action demonstrated, possibly because they inferred that the model had tried, but failed, with one method and so they used the other. It is interesting to compare this with the responses of children presented with ‘failed attempt’ demonstrations (see for example Carpenter, Akhtar & Tomasello, 1998; Carpenter, Call & Tomasello, 2002; Heyes, 1998; Bellagamba & Tomasello, 1999; Myowa-Yamakoshi & Matsuzawa, 2000; Charman & Huang, 2002; Huang et al., 2002; Wood et al., 2002; Bellagamba et al., 2006; Biro, Csibra & Gergely, 2007).

Overall, for chimpanzees, the end state, rather than the action itself, appears to be of more importance. Call et al. (2005) concluded that this provided further evidence that chimpanzees are more likely to emulate (goal-emulation) than imitate. By contrast, the children performed better in the social (full-demonstration and action-only conditions) than in the nonsocial (end-state and baseline) conditions. Additionally, there was no significant difference between the two social conditions with regards to the level of matching the method showed. Like the chimpanzees, the children were more likely to open the transparent, rather than the opaque tubes. Call et al. (2005) concluded that, unlike chimpanzees, children are more likely to take advantage of the social information and thus imitate rather than emulate. I suggest that, as that more children were more likely to open the clear than opaque tubes affordance learning should also be considered.

### IV. DISCUSSION

#### (1) Ghost display condition evaluation

Since the first study run in the 1970s (Groosbeck & Duerfeldt, 1971), experiments that have incorporated ghost display conditions (Section III) have differed in a number of ways, allowing for the identification of the strengths and weaknesses of this experimental technique. The aim of employing a ghost display is to determine whether the observer is able to reach a predetermined goal from seeing only the pertinent parts of the task/apparatus move without an active model operating it.

Children appear better able to learn from seeing a ghost display when the action shown has an obvious cause-and-effect relationship. This is highlighted by the failure of children to learn how to solve the ambiguous double-mat condition used by Thompson & Russell (2004) and from the basic ghost display of the tool-use Pan-pipes task (Hopper et al., in press) compared to the success of children learning a bidirectional task (Hopper et al., 2008). The role of task complexity applies not just to children but also to animals, which were able to learn from ghost displays of simple (Klein & Zentall, 2003; Hopper et al., 2008; Miller et al., 2009) but not complex tasks (Hopper et al. 2007). However, the task should not be so simplistic that subjects are able to solve it via asocial learning (e.g. Tennie et al., 2006) and nor should it have an inherent bias so that one of the methods for solution is favoured over the other(s) (e.g. Call et al., 2005) as no conclusions as to the social learning mechanisms employed can be drawn.

Two common forms of ghost display condition have been used: the basic and the enhanced ghost. The basic ghost display condition has been employed with a variety of species including humans, nonhuman primates, rats and birds while fewer have included an enhanced ghost display condition (Akins et al., 2002; Fawcett et al., 2002; Klein & Zentall, 2003; Hopper et al., 2008). The enhanced ghost display condition is a useful extension as it helps to control for a mere presence effect. However, when the enhanced ghost display condition is used in isolation, as by Akins et al. (2002) and Fawcett et al. (2002), it loses much of its usefulness. Researchers should aim always to employ a basic ghost display if including an enhanced ghost display.

Three studies that used the ghost display condition presented the demonstrations on television screens or computer monitors (Subiaul et al., 2004, 2007; Huang & Charman, 2005). Huang & Charman (2005) used video footage of demonstrations in order to allow for the manipulations of the images – to create a ghost and an action-only display – which were presented to infants. This was an elegant way to create a ghost display because it removed the need for using potentially obvious fishing-line. A second benefit of video is that all participants observe exactly the same demonstration (McGuigan et al., 2007; Flynn & Whiten, 2008; Nielsen, Simcock & Jenkins, 2008; Strouse & Troseth, 2008; Price et al., 2009; see De’ath, 1998 for a review).

Despite the potential benefits of video demonstrations, their integrity compared to a live demonstration is limited as the images are not three-dimensional, nor life-sized and lack many of the features of a live interaction including olfactory cues and physical contact (Flynn & Whiten, 2008). Furthermore, there is evidence that children have to learn how to interpret video images (see Troseth & DeLoache, 1998, for a review) and in certain circumstances children show a ‘video deficit’ (Anderson & Penpek, 2005; Suddendorf, Simcock & Nielsen, 2007). Researchers working with nonhuman subjects should note that television screens have been developed for human vision and are not necessarily suitable for all species but this can be overcome using LCD flat-screens (De’ath, 1998). These potential disadvantageous should be acknowledged and, if possible, attended to when employing video demonstrations.

The two studies conducted by Subiaul et al. (2004, 2007), although with different species, were both designed to test for cognitive imitation using a simultaneous chaining paradigm presented on a computer monitor. This form of presentation was selected because it removed potential physical limitations of the participants, which may have hindered their ability to replicate the actions. However, this form of presentation has its own inherent limitations. The test subjects were either humans, who are familiar with computer monitors, or a pair of rhesus macaques, also familiar with interacting with...
touch-screen monitors. Caution should be observed when using such a method with subjects unfamiliar with computer monitors. As with televisions, the visual capacity of the test species should also be considered to ensure that they are able to perceive, and understand, all presented stimuli.

Although the ghost, and enhanced ghost, display conditions allow for the identification of forms of emulative learning they are also inherently unnatural. It is rare that objects move by themselves. The use of video could be used to overcome this limitation. A more naturalistic way to present a ghost display, rather than to remove the demonstrator, may be to conceal them. In the wild, a chimpanzee may observe a group member fishing for termites with the body of the fishing chimpanzee occluded (for example by a tree) so that all the observer is able to see is the movement of the tool. Manipulated videos may provide a new direction for the employment of ghost display conditions; creating more naturalistic displays.

(2) End-state condition evaluation

The end-state condition, unlike a ghost display which reveals the required movements of a task, just shows the start and end states of an object pre- and post-manipulation. If the observer is able to reach the same end state then goal-emulation and, following Goldenberg & Hagman (1998), affordance learning can be identified. All but one of the end-state studies published have tested infants and children, and the majority of these studies have represented replications of the first end-state study run by Meltzoff (1985).

Meltzoff’s (1985) original experiment with 14-month-old infants revealed no significant evidence that infants could deconstruct the dumbbell after having only seen the start and end states. Many of the end-state studies subsequently conducted replicated and extended upon Meltzoff’s (1985) first study, using the same dumbbells, sometimes in conjunction with other test objects (Bellagamba & Tomasello, 1999; Huang et al., 2002, 2006). This allows for comparisons to be drawn between the abilities of the participants tested to a greater degree than can be done between the different ghost display studies. To date, the end-state condition using the dumbbells, has tested 12-, 14-, 18-, 19-, 31- and 41-month-olds. Only one of these studies found that infants (those aged 19 months) in the end-state condition performed with equal success to infants that saw a demonstration by an adult (Huang et al., 2002).

The majority of the published studies have concluded that children are more likely to learn from observing an adult’s demonstration (imitative learning) than from an end-state condition (emulative learning). However the lack of response by children in end-state conditions may highlight limitations of the method itself. Furthermore, as the majority of the end-state studies have employed the dumbbells the failure of children may be due to the particular test objects used. The ghost display studies have employed a wide range of apparatus, reporting mixed levels of success by the individuals tested; possibly dependent on task complexity, as discussed (see also Nielsen, 2009 who discusses 12-month-olds’ understanding of intentions and ability to emulate as dependent on the clarity of the affordances of a task). It would therefore be interesting to see test how children respond to end-state conditions with a wider variety of test apparatus (Call et al., 2005).

Only one study has implemented the end-state condition with animals (Call et al., 2005). Call et al. (2005) compared the responses of chimpanzees and children. Although they did not use the dumbbell, the test object had similar physical properties as it was a single object that had to be deconstructed (broken in half). Call et al. (2005) reported that the responses of the chimpanzees provided evidence for emulative learning, however the chimpanzees made no more target actions in the end-state condition or full-demonstration condition compared to the no-information control and so asocial learning may have been at play.

(3) What forms of learning have been identified through the use of ghost display and end-state conditions?

The usually stated rationale for employing ghost display or end-state conditions is to tease apart emulative from imitative learning. Through the use of ghost display conditions, emulation have been identified in infants aged 14 to 26 months (Thompson & Russell, 2004), children aged three to four years (Hopper et al., 2008, in press), chimpanzees (Hopper et al., 2008), dogs (Miller et al., 2009), rats (Groesbeck & Duerfeldt, 1971; Denny et al., 1988) and pigeons (Klein & Zentall, 2003). Ghost display conditions have been conducted with a number of species and with a range of apparatus. This diversity does not preclude comparisons between studies and species. Indeed, two studies were run specifically to compare the responses of apes and children tested with the same apparatus (Tennie et al., 2006; Hopper et al., 2008). The methodology used by Subiaul et al. (2004, 2007) allows for comparisons to be drawn between typically developing children, individuals with autism and rhesus macaques. Further, direct comparisons can be made between two studies that measured the responses of different bird species tested with the same apparatus (Akins et al. 2002; Klein & Zentall, 2003). Lastly, Hopper et al. (2008) and Miller et al. (2009) replicated the methodology used by Klein & Zentall (2003) allowing for a comprehensive comparison with the responses of pigeons with those of children, chimpanzees, dogs and pigeons.

In comparison to the breadth of successful responses recorded of humans and animals to ghost displays, only one study has reported children learning how to perform an act from having seen an end-state demonstration (Huang et al., 2002). Observing only the start and end states of a test object provides the observer with no information about the physical movements required to complete the task, successful children must have relied on goal-emulation or affordance learning.

It is interesting to note that through the use of the ghost or end-state conditions emulative learning has been identified in
children ranging from as young as 14 months old (Thompson & Russell, 2004) to children aged four years (Hopper et al., 2008). The social dynamics that underscore the motivation of infants and children to imitate has been discussed in great detail (Uzgiris, 1981; Nadel et al., 1999; Carpenter, 2006; Nielsen, 2008). In contrast to Tennie et al. (2006), Nielsen (2006) demonstrated that 12-month-old infants showed a propensity to emulate while 18- and 24-month-olds were more likely to imitate with increased age and their likelihood to do so was also influenced by the ostensive cues provided by the model (see also Topál et al., 2008). Referring to his earlier study (Nielsen, 2006), Nielsen (2008) stated that “young infants emulate out of motivation to learn about the world, whereas todders show an increasing proclivity for imitation based on a desire to interact with, and to be like, others” (p. 33). Although the findings of the ghost and end-state conditions reviewed herein support this partially, it is interesting to note that those older children tested by Tennie et al. (2006) and Hopper et al. (2008, in press) showed evidence for emulative learning suggesting that perhaps not just age, but task complexity, influence a child’s social learning strategy (see also Bauer & Kleinknecht, 2002; Nielsen, 2009).

V. CONCLUSIONS

(1) To date, few studies have employed ghost display and end-state conditions in combination. Further work to identify the underlying social learning mechanisms of both human and animals is welcomed. The current corpus of literature has thus far provided evidence for forms of emulative learning in humans and animals but further research is required to identify, with greater accuracy, the specific forms of observational learning. Both ghost display and end-state conditions have proved their worth but are even more effective if used in combination, especially when both ghost and enhanced ghost conditions are employed.

(2) It is recommended that, in future studies, authors should be more precise when describing the social learning mechanisms they have identified (see Huang & Charman, 2005). This call for clarity is not a new one, but was one of the main conclusions drawn by Want & Harris (2002) and Whiten et al. (2004). Not only should researchers show greater detail when drawing their conclusions, but should also recognise the possibility that more than one social learning mechanism could be operating simultaneously.

(3) To enable researchers to be more specific in the identification of different social learning mechanisms, studies should be designed to incorporate a variety of experimental techniques in combination (e.g. Groesbeck & Duerfeldt, 1971; Klein & Zentall, 2003) and more than one test apparatus (e.g. Huang et al., 2002).

(4) The final recommendation is that future studies should investigate the role of the participants’ motivation to copy and how this differs between seeing a live model and a ghost or end-state display. To expand upon this, studies could incorporate the role of ostensive cues, task complexity and the status of the demonstrator on a participants’ motivation and understanding of the task.

VI. ACKNOWLEDGEMENTS

This review was written during an ESRC-funded postdoctoral fellowship whilst at Durham University, UK. Thanks are due to my postdoctoral mentor Emma Flynn. Appreciation is also felt to Andrew Whiten, Nicola McGuigan and Claudio Tennie for discussion and comments on earlier drafts of this manuscript.

VII. REFERENCES


