

## RESEARCH ARTICLE

An Evaluation of the Efficacy of Video Displays for Use With Chimpanzees (*Pan troglodytes*)LYDIA M. HOPPER<sup>1,2\*</sup>, SUSAN P. LAMBETH<sup>2</sup>, AND STEVEN J. SCHAPIRO<sup>2,3</sup><sup>1</sup>Language Research Center, Georgia State University, Atlanta, Georgia<sup>2</sup>The Michale E. Keeling Center for Comparative Medicine and Research, The University of Texas MD Anderson Cancer Center, Bastrop, Texas<sup>3</sup>Department of Experimental Medicine, University of Copenhagen, Copenhagen, Denmark

Video displays for behavioral research lend themselves particularly well to studies with chimpanzees (*Pan troglodytes*), as their vision is comparable to humans', yet there has been no formal test of the efficacy of video displays as a form of social information for chimpanzees. To address this, we compared the learning success of chimpanzees shown video footage of a conspecific compared to chimpanzees shown a live conspecific performing the same novel task. Footage of an unfamiliar chimpanzee operating a bidirectional apparatus was presented to 24 chimpanzees (12 males, 12 females), and their responses were compared to those of a further 12 chimpanzees given the same task but with no form of information. Secondly, we also compared the responses of the chimpanzees in the video display condition to responses of eight chimpanzees from a previously published study of ours, in which chimpanzees observed live models. Chimpanzees shown a video display were more successful than those in the control condition and showed comparable success to those that saw a live model. Regarding fine-grained copying (i.e. the direction that the door was pushed), only chimpanzees that observed a live model showed significant matching to the model's methods with their first response. Yet, when all the responses made by the chimpanzees were considered, comparable levels of matching were shown by chimpanzees in both the live and video conditions. *Am. J. Primatol.* 00:1–8, 2012. © 2012 Wiley Periodicals, Inc.

**Key words:** chimpanzees; *Pan troglodytes*; video displays; social learning; video deficit

## INTRODUCTION

Since the 1970s [Jenssen, 1970], video images have been used in behavioral and cognitive investigations with a wide range of species. The availability of video-manipulation technology in recent years has further facilitated the use of video footage and expanded the range of potential applications for its use in experimental settings [see D'earth, 1998; Rosenthal, 1999; Rowland, 1999 for reviews]. Experimentally, compared to showing live conspecific models, video footage has three major potential benefits. First, video stimuli remain constant across trials [Price et al., 2009]. Second, footage can be edited to show only specific behavioral sequences or forms of demonstration [Flynn & Whiten, 2008] and such "videosection" [Clark & Uetz, 1990] can involve either morphological or temporal alterations made to video sequences. Third, the use of videotaped models can reduce the number of animals required by repeatedly reusing the same animal model for multiple observing subjects [Price & Caldwell, 2007].

Video stimuli have been used widely in a captive setting with nonhuman animals, with species including octopi [*Octopus tetricus*, Pronk et al.,

2010], spiders [*Schizocosa ocreata*, Uetz & Smith, 1999], fish [*Poecilia reticulata*, Nicoletto & Kodric-Brown, 1999], birds [*Melopsittacus undulates*, Moravec et al., 2010; *Psittacus erithacus*, Pepperberg, et al., 1998], monkeys [*Colobus guereza*, Price & Caldwell, 2007; *Macaca mulatta*, Paxton et al., 2010; *M. radiata*, Plimpton et al., 1981], chimpanzees [*Pan troglodytes*, Morimura & Matsuzawa, 2001], and humans [Flynn & Whiten, 2008; Huang & Charman, 2005]. Videos are also used in many zoos and other captive facilities as a form of enrichment and for training purposes [Perlman et al., 2010]. In such applied settings, the efficacy of video has been noted for

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both chimpanzees [Bloomsmith & Lambeth, 2000; Brent & Stone, 1999; Lambeth et al., 2001] and rhesus macaques [*M. mulatta*, Platt & Novak, 1997; Schapiro & Bloomsmith, 1995, but see Washburn et al., 1997; Washburn & Hopkins, 1994].

Unlike in the field of developmental psychology, no systematic investigation of the efficacy of using videos with nonhuman animals has been conducted, which is surprising given that for our own species, reports of successful learning from videos and other two-dimensional (2D) images are inconsistent [see Barr, 2010 for a review]. It has been noted that children suffer from a so-called “video deficit” [Anderson & Pempek, 2005, but see Schmitt & Anderson, 2002] whereby children who observed video footage show reduced learning compared to those that watched a live model perform the same act. Depending on the task in question, this “deficit” ranges from poorer fidelity of fine-detailed copying to an inability to learn any aspects of the task [e.g. McGuigan et al., 2007]. Such reduced learning has been suggested to arise from the perceptual difficulty of transferring 2D information to a three-dimensional real-world setting [Barr, 2010]. However, despite the potential complexities required for such knowledge transfer, like for nonhuman animals, successful learning from videos [e.g. O’Doherty et al., 2011] and photos [e.g. Ganea et al., 2011] has been reported for children. With the interest in applying video demonstrations to experimental designs, further insights into captive animals’ abilities to understand or learn from videos is essential.

Taking a lead from developmental psychologists, the aim of the present study was to directly test the efficacy of video stimuli for use with captive chimpanzees in a social learning context. When using video displays with nonhuman animals, a number of key aspects must be noted. Historically, video demonstrations were presented on cathode ray tube (CRT) televisions, developed for human vision and not necessarily suitable for all species (The refresh-rate for CRT screens in America is 60 Hz [National Television Standards Committee], suitable for human’s critical flicker-fusion [CFF] of 60 Hz [Landis, 1954]). Animals with a faster CFF, however, will be aware of screen flicker and may be unable to detect the image on the screen [Death, 1998]. More recently, to overcome the potential limitations of CRT televisions, thin film transistor liquid crystal displays (LCD), which have a much-reduced CFF (around 200 Hz), have been utilized successfully with nonhuman animals [Mottley & Heyes, 2003; Ophir & Galef, 2003]. Chimpanzee vision is very similar to that of humans [Landis, 1954]—both species have the same CFF (60 Hz) and are trichromatic—suggesting that chimpanzees should be capable of perceiving images on both television screens and LCD monitors. It cannot be automatically assumed, however, that chimpanzees are able to *understand*

the images in the same way that humans do. Encouragingly, studies have suggested chimpanzees perceive video stimuli as meaningful in a variety of experimental paradigms including tests of self-recognition [Eddy et al., 1996; Hirata, 2007], memory [Morimura & Matsuzawa, 2001], social learning [Price et al., 2009], and causal relations [Cacchione & Krist, 2004; O’Connell & Dunbar, 2005]. Chimpanzees have also shown the ability to use video footage as a reference for real-world events in order to locate out-of-sight items [Menzel et al., 1978, 1985; Poss & Rochat, 2003].

Our aim was to investigate the ability of captive chimpanzees to learn a novel task after observing video footage of a conspecific completing the task using one of two different methods. If the chimpanzees recognized what they were shown on the video screen, then it was predicted that they should be able to both operate the apparatus and use the same method as that seen. Previous research by us, investigating chimpanzee social learning, revealed that after groups of chimpanzees had been shown video footage of an unfamiliar conspecific operating a tool-use task, four (of 19) observers were able to copy the video model and complete the task, using it in the same manner demonstrated [Hopper, 2008]. However, in this study, chimpanzees were presented with the video footage in small groups, making it difficult to determine whether the subjects learnt solely from the video footage, from their cage-mates, or from a combination of the two. In the present study, therefore, chimpanzees were tested individually to ensure that any apparent learning was from the video display and not from observing group members. Furthermore, following the field of developmental psychology [e.g. Barr & Hayne, 1999; Nielsen et al., 2008], the success of these chimpanzees would be compared to others who saw a live model [previously collected data, Hopper et al., 2008] and to control chimpanzees who were provided with no information about the task.

## METHODS

### Subjects and Testing Environment

This study was conducted at the Michale E. Keeling Center for Comparative Medicine and Research, UT MD Anderson Cancer Center, Bastrop, TX, USA, (KCCMR), a facility that is fully accredited by the American Association for the Accreditation of Laboratory Animal Care-International (AAALAC-I). Approval for this study was gained from the Institutional Animal Care and Use Committee (IACUC approval number: 07-92-03887) of the University of Texas MD Anderson Cancer Center and this research complies with the American Society of Primatologists’ Principles for the Ethical Treatment of Nonhuman Primates.

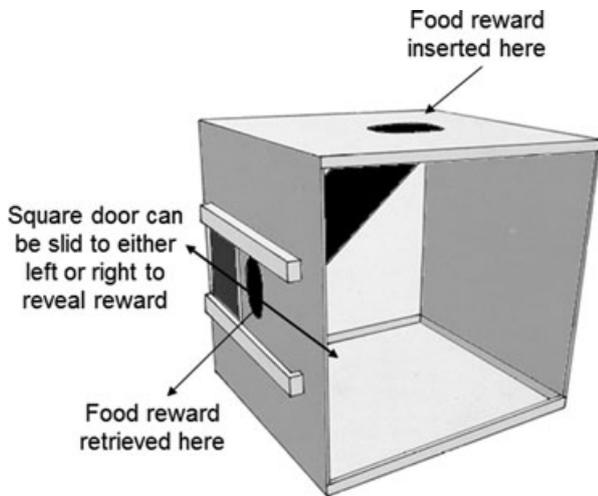


Fig. 1. The Slide-box with the door pushed to the left revealing the hole from which the food rewards are retrieved.

The test subjects were 35 group-housed chimpanzees (*P. troglodytes*) that were not deprived of food or water at any time. Twenty-four of these animals (12 females and 12 males) were tested in the video display condition and ranged from 12 to 39 years of age, with a mean age of 22.7 years. The remaining 12 chimpanzees (5 females, 7 males) ranged in age from 13 to 44 years (mean age = 24.1 years) and were tested in a control condition. An additional adult male chimpanzee (KM, 18 years old), unfamiliar to the test subjects, acted as the “model” shown on the video display. During the test phase, chimpanzees were presented with the video demonstration in one-half of their indoor enclosure, which measured 2.4 m × 2.4 m × 1.8 m. During nontesting times, chimpanzees lived in their social groups (ranging in size from 5 to 13 animals) and had access to a large and highly enriched enclosure.

### Apparatus

A bidirectional “Slide-box” apparatus (Fig. 1) was employed for this experiment [Hopper et al.,

2008]. It consisted of an acrylic cube, measuring 32 cm on each side, from the top panel of which a reward-chute led to a 4-cm diameter hole in the center of the front panel. The experimenter could drop food rewards (grapes) into the chute and they would roll to the hole at the front. Across the center of the front panel was an opaque acrylic door (8 cm × 8 cm) that could be moved to either the left or right by a subject with equal ease to reveal and gain the reward in the central hole. When the sliding panel was in the “start” position, the reward was hidden behind the door.

### Video Footage

Video footage of a male chimpanzee trained to push the door to the left was filmed on a Sony miniDV digital handycam (CDR-TRV27) (Sony Corporation of America, New York, NY, USA). The model chimpanzee, KM, was trained using positive reinforcement training techniques by the experimenter (LH), to push the door on the Slide-box only to the left in order to gain grapes. Once trained, KM was presented with the Slide-box on one side of his outdoor Primadome® enclosure and was filmed so that no bars obscured the camera view of him operating the apparatus (exemplar stills from the footage are presented in Fig. 2).

The 4-min long footage was edited using iMovie software to show the chimpanzee operating the Slide-box successfully 50 times, and gaining a grape for each successful manipulation. To make the video display as comparable to a live demonstration as possible, the clip was not merely a repetition of a single “push” repeated 50 times, but rather a series of novel actions edited to show it from a number of perspectives (i.e. from the side, from behind, from the far side of the cage, and close-up). This video footage was used as the “push-left” stimulus. The edited clip was additionally flipped through 180 degrees using QuickTime Pro (Apple Inc., Cupertino, CA, USA) to create an identical sequence of demonstrations, but showing

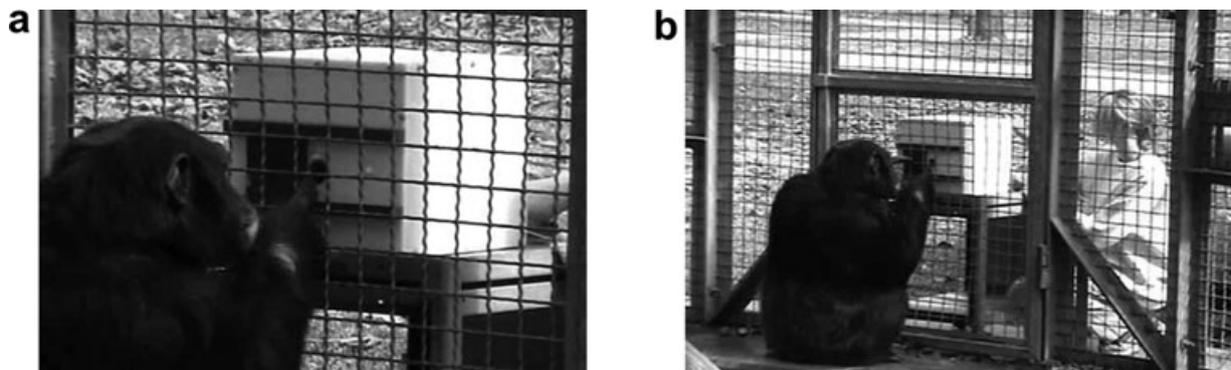


Fig. 2. Frames from the video demonstration showing (a) a close up of the male model pushing the door of the Slide-box to the left and (b) a wide-angle view showing the whole body of the chimpanzee model, the Slide-box, caging, and experimenter (LH) rebaiting the Slide-box.

the chimpanzee moving the Slide-box door to the right (“push-right”).

### Procedure

Each of the 24 chimpanzees in the video display condition was isolated in one-half of the inside of their enclosure. The trolley with the laptop (a 15" MacBook Pro, Apple Inc., Cupertino, CA, USA) inside a protective clear case, was placed directly in front, but out of reach, of the chimpanzee. Throughout the presentation, the Slide-box was also in full view, but out of reach, of the observing chimpanzee. Twelve of the chimpanzees (6 male, 6 female) were shown the 4 min of push-right footage and the other 12 (6 male, 6 female) were shown the 4 min of push-left footage. After the presentation of the video, the apparatus was moved within reach of the chimpanzee and the experimenter baited the Slide-box with a grape, in view of the chimpanzee. The subject was then given a 20-min free-access period with the Slide-box (or until they had completed 30 successful responses). If a chimpanzee was able to retrieve a grape, the experimenter (LH) would rotate the Slide-box through 180 degrees away from the chimpanzee so that it could not see LH move the door back to the central position [and be affected by social learning cues potentially provided by LH, see e.g. Whiten et al., 2004]. The Slide-box was then re-presented to the chimpanzee and rebaited with another grape.

Each test session was recorded on a Sony miniDV digital handycam (DCR-HC35E) and a running commentary was provided by LH. For the free-access period, any successful response by the chimpanzee during the response period was recorded together with the direction the door was pushed. A “successful response” was defined as one where a chimpanzee retrieved a reward from the Slide-box by sliding the door to either the left or right sufficiently far to allow the grape to fall from the apparatus. Six (17%) of the video-taped test sessions were shown to a coder unfamiliar with the procedure and blind to each condition. They reported 100% agreement with our coding decisions for these tapes.

Like those chimpanzees that were shown a video demonstration, the 12 control chimpanzees were also tested while temporarily housed alone in their home cages. Unlike the observer chimpanzees, however, the control chimpanzees were presented with the Slide-box with no form of demonstration. The chimpanzee was then shown the experimenter (LH) baiting the apparatus with a grape and was then given free-access to the task.

### Live Model Condition

In a study we conducted previously [Hopper et al., 2008], chimpanzees also housed at KCCMR, but different from those tested in this study, were

presented with the same Slide-box in one of four experimental conditions. In one of these conditions, eight chimpanzees (six females and two males, age range 20–44 years, average age = 33.6 years) individually observed a familiar chimpanzee operate the Slide-box. Four of these chimpanzees saw their model push the door to the right and the other four saw a demonstration of the door pushed to the left. All were then given a 20-min free-response period, in which they could act freely on the Slide-box [see Hopper et al., 2008, for full details of methods used].

## RESULTS

### Overall Success

Twenty of the 24 observer chimpanzees presented with the video demonstrations completed one or more successful actions on the Slide-box during the free-access period (11 males and 9 females). There were significantly more (83%) chimpanzees classed as “successful” than “unsuccessful” (Binomial test,  $P = 0.001$ ). Furthermore, significantly more chimpanzees were successful after having watched the video display (20/24) compared to those provided with no form of demonstration in the control condition (6/12, Fisher’s Exact Test,  $P = 0.05$ , Fig. 3).

### Matching to the Video Display

Six of the nine successful chimpanzees in the push-left condition and seven of the 11 successful chimpanzees in the push-right condition matched the demonstration with their first response. As there was no significant difference between the level of matching across the two conditions (Fisher’s Exact Test,  $P > 0.05$ ), the chimpanzees’ responses were considered collectively, revealing no significant

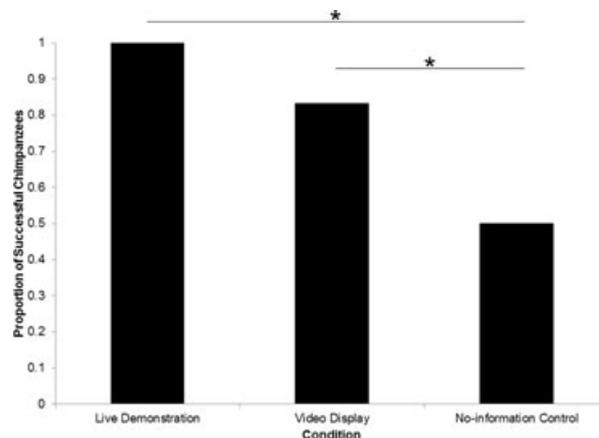


Fig. 3. The proportion of successful chimpanzees in the video display condition compared to those that saw a live model [data from Hopper et al., 2008] and those tested in the no-information control. \*Significant differences ( $P < 0.05$ ).

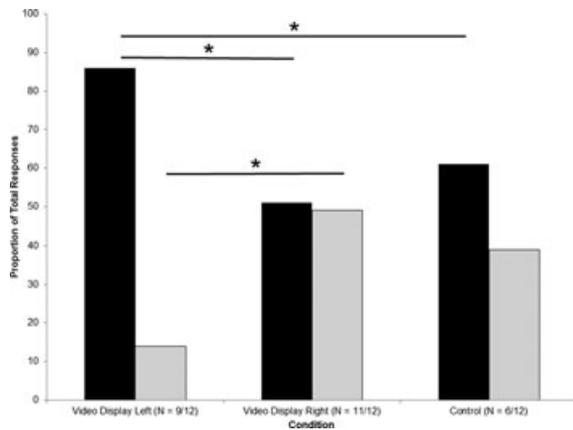


Fig. 4. The responses made by the successful chimpanzees in the two video display conditions and the control condition. Black bars represent push-left responses and the gray bars depict push-right responses. \*Significant differences ( $P < 0.05$ ).

matching to the demonstration with their first responses (13/20, binomial test,  $P > 0.05$ ).

When all the responses made by successful chimpanzees that observed a video display are considered collectively, 65% of their total responses matched the demonstration they observed. There was no difference in the proportion of matching to demonstration by females (median matching proportion = 0.500) and males (median matching proportion = 0.50, Mann–Whitney U test:  $U = 46.0$ ,  $n_1 = 10$ ,  $n_2 = 10$ ,  $P > 0.05$ ). In both conditions (push-left and push-right), chimpanzees were more likely to push the door in the same direction as that shown in their video than compared to chimpanzees in the alternative condition (Fig. 4). Specifically, chimpanzees in the push-left condition made a greater proportion of push-left responses (median = 1.00) than those in the push-right condition (median = 0.27, Mann–Whitney U test:  $U = 78.5$ ,  $n_1 = 9$ ,  $n_2 = 11$ ,  $P = 0.02$ ) and chimpanzees in the push-right condition made a greater proportion of push-right responses (median 0.73) than those in the push-left condition (median = 0.00, Mann–Whitney U test:  $U = 27.5$ ,  $n_1 = 11$ ,  $n_2 = 9$ ,  $P = 0.05$ ).

Compared to those chimpanzees tested in the control condition however, only those in the push-left video display condition showed a greater tendency to push the door to the left (Mann–Whitney U test:  $U = 10.0$ ,  $n_1 = 9$ ,  $n_2 = 6$ ,  $P = 0.03$ , chimpanzees in the push-right condition showed no such difference: Mann–Whitney U test:  $U = 32.0$ ,  $n_1 = 11$ ,  $n_2 = 6$ ,  $P > 0.05$ ).

### Comparison to Chimpanzees that Observed a Live Model (Previously Collected Data)

All eight of the chimpanzees that witnessed a live conspecific model were successful at operating the Slide-box [Hopper et al., 2008]. There was no significant difference in the level of success shown

by chimpanzees that saw the video display (20/24) compared to those that observed a live model (8/8, Fisher Exact test:  $P > 0.05$ , Fig. 3). Like those chimpanzees that had seen the video display, chimpanzees that had observed a live model were significantly more successful than those provided with no form of demonstration (8/8 vs. 6/12, Fisher Exact Test:  $P = 0.04$ ).

The majority (7/8) of successful chimpanzees that saw a live model matched the demonstration with their first response (binomial test,  $P = 0.04$ ). This level of first-response matching was not significantly different from those successful chimpanzees that saw the video display (13/20, Fisher’s Exact Test  $P > 0.05$ ). Comparably, considering all responses by chimpanzees that saw video demonstrations, the proportion of matching responses were comparably high (median = 0.50 and mode = 1.00) to those chimpanzees that had seen a live model (median and mode = 1.00, Mann–Whitney U test:  $U = 101.0$ ,  $n_1 = 20$ ,  $n_2 = 8$ ,  $P > 0.05$ ).

## DISCUSSION

Video displays provide an opportunity for researchers to exert great experimental control over what naïve observers see. By using video, experimenters can guarantee that all subjects observe the same demonstration, allowing for stronger comparisons to be drawn across the responses of subjects. In this study, we increased such control further by counterbalancing the push-left and push-right displays with footage that were mirror images of each other; no differences, aside from the direction of door push, existed between the displays. Due to the high control and flexibility that video displays offer, there has been much interest in their use as applications in both experimental and husbandry settings with chimpanzees; however, we report the first direct comparison between chimpanzees’ responses to video and live displays.

Promisingly, chimpanzees were equally likely to solve the task whether they had seen live or video displays and, importantly, chimpanzees that had observed either form of demonstration were also more likely to be successful than chimpanzees tested in a control condition, in which they were provided with no form of information about the task. Not only was the success of chimpanzees that had seen a video display comparable to those that observed a live model, there was also no difference in the level of matching to the demonstration between these two conditions. This suggests that such learning was mediated by more than simply “social facilitation” [Dindo et al., 2009], as the specific actions used by the model were also copied [Hopper et al., 2007, 2008].

Chimpanzees in the two experimental conditions (video vs. live) did differ significantly in fidelity of their matching however. Only chimpanzees that saw

a live model showed significant matching with their first responses. Of the successful chimpanzees that saw a video display, 65% (13/20) matched the demonstration with their first response. When considering each individual's total responses, the chimpanzees in the two video display conditions appeared to "canalize" [Whiten et al., 2005]. These chimpanzees appeared to conform to the method they had seen, showing overall levels of matching in line with the chimpanzees that saw a live model. Despite being equally successful, why would chimpanzees that saw a video display show reduced immediate matching compared to those that saw a live model and why should their responses canalize in such a manner? We answer these two seemingly opposing questions in turn.

A likely explanation for why chimpanzees showed reduced matching to the video, with their first responses, in comparison to those that saw a live model, is that a live model may represent a more salient form of information [Barr & Hayne, 1999; Nielsen et al., 2008, but see Strouse & Troseth, 2008]. Videos are proposed to be a suitable stimulus to present to chimpanzees because their vision is comparable to that of humans, for whom television screens were designed. Chimpanzee vision is so similar to that of humans that it may be assumed that because chimpanzees are able to *perceive* an image on a television, they can therefore *understand* it [D'earth, 1998; Landis, 1954]. There is clear evidence that children have to gain experience to learn how to interpret video images [e.g. O'Doherty et al., 2011, see Troseth & DeLoache, 1998 for a review] and, like the chimpanzees tested here, children show a video deficit, responding less well to video than to live displays [Anderson & Pempek, 2005; Suddendorf et al., 2007]. Encouragingly, Troseth [2003] found that 2-year-old children's ability to learn a task from video demonstrations improved after increased exposure to watching televisions and after seeing themselves appear on live television. Accordingly, we propose that when incorporating video demonstrations into an experimental paradigm or husbandry routine with captive chimpanzees, people should be mindful to give subjects pretraining and exposure to videos before testing in order to maximize their understanding of the medium.

If chimpanzees can perceive video images, why then would their understanding of, or response to, them be reduced? This could be due to impaired "social salience" of the chimpanzee shown on the video. For example, the observing chimpanzees were unable to interact with the images and so may not have perceived the stimuli to be realistic [Ord & Evans, 2002]. Alternatively, this deficit could be a result of the fact that an unfamiliar chimpanzee was shown on the video footage in our experiment. Those chimpanzees that saw a live model, observed a chimpanzee that was familiar to them (a fellow cage-

mate), whereas the chimpanzee shown on the video footage was an unfamiliar member of the colony. It has been suggested that chimpanzees are more likely to copy familiar individuals with whom they relate [de Waal, 1998, 2001; Hopper et al., 2011, but see Bates & Byrne, 2010] and this may explain why, although the chimpanzees could learn from the unfamiliar chimpanzee (20/24 were successful), they did not match its actions as closely as those that saw a familiar (live) model. Note, however, that a recent study that reported high rates of social learning by captive chimpanzees from video footage also used an unfamiliar model to demonstrate the action [Price et al., 2009], so further investigation is required as to whether specific characteristics of a model could affect the efficacy of such stimuli.

The second curious finding was that although the chimpanzees that saw a video display did not show significant matching with their first response, across all their responses they showed comparable levels of matching to those chimpanzees that saw a live model; for both conditions, the modal matching proportion for the individual chimpanzees was 1.00. Such a finding is reminiscent of the responses from groups of chimpanzees reported by Whiten et al. [2005], which, after observing a cage-mate perform a tool-use task, copied the method used and converged more strongly to match the demonstrated method over time. Whiten et al. [2005] referred to this canalization as "conformity" and this may explain the responses shown by the chimpanzees observed for the current study.

It is worth not only comparing the responses of chimpanzees that saw a video display to those that saw a live model using the Slide-box tested by Hopper and colleagues, but also to another condition reported in that same article [Hopper et al., 2008]. In this third group, chimpanzees were presented with the Slide-box in a "ghost" condition (in which the movements of the door were revealed by the experimenter moving it discretely with fishing-line with no conspecific present, see also Hopper 2010). These chimpanzees showed the greatest exploration of which direction to push the door, compared to those that saw a live model [also Hopper et al., 2008] and a video display (present study). Perhaps then, the strength of canalization shown by chimpanzees is affected by both the presence of a conspecific and the familiarity or salience of that model [see Hopper et al., 2011]. That there is variation in the strength of matching—or conversely the amount of exploration—by chimpanzees that have all encountered the same Slide-box, depending on the form of social display, reveals a greater flexibility in their learning than some previous research would suggest [e.g. Hrubesch et al., 2009; Price et al., 2009] and begs for further studies to address the role of familiarity and social salience in the acquisition of novel behaviors and the emergence of conformity.

## SUMMARY AND CONCLUSIONS

- (1) Given the wealth of successful research that has already utilized video displays with nonhuman animals, it is clear that videos provide reliable and consistent models and allow for image and temporal manipulations. Furthermore, because only one video display need be created to test or train multiple animals, they potentially allow researchers and trainers to save both time and money, while simultaneously reducing the number of animals required for certain procedures.
- (2) Chimpanzees, although unable to reliably solve the novel task via trial-and-error learning, were successful after being provided with a video of a conspecific performing the task. We also found comparable levels of overall matching by chimpanzees to the video display compared to chimpanzees that saw a live conspecific do the task. However, initial matching was only found to be significant for those chimpanzees that saw a live model. Therefore, although the use of video models appears to be efficacious under specific circumstances, for this simpler task, we suggest that a live model provides more salient information to the naïve observer than video footage of an unfamiliar conspecific.
- (3) Given the flexibility and efficiency of video displays, along with their tight rigorous control (i.e. the exact same display is shown to all subjects), their use in both experimental and husbandry protocols has multiple applications. Therefore, future research is welcomed to investigate the potential applications of video footage with chimpanzees and other species including the impact of showing familiar or unfamiliar conspecific models.

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