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Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children

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Abstract

We investigated whether the tendency to imitate or emulate is influenced by the availability of causal information, and the amount of information available in a display. Three and 5-year-old children were shown by either a live or video model how to obtain a reward from either a clear or an opaque puzzle box. Some of the actions in the sequence were causally relevant to retrieving the reward, whereas others were irrelevant. The clear box made the causally irrelevant actions visible, whereas the opaque box prevented them from being seen. Results indicated that both 3- and 5-year-old children imitated the irrelevant actions regardless of the availability of causal information following a live demonstration. In contrast, the 3-year-olds employed an emulative approach, omitting irrelevant actions, when the information available was degraded in a video demonstration. However, the 5-year-olds were unaffected by the degraded information and employed an imitative approach. We suggest that imitation develops to be such an adaptive human strategy that it may often be employed at the expense of task efficiency.

Keywords: Imitation; Emulation; Social learning; Children; Tool use; Causality

Imitation research is presently undergoing a major revival, stimulated in large part by the integration of developmental and comparative contributions. A key consequence of this integration is that distinctions between different social learning processes made by comparative researchers have begun to filter into developmental research. One such process is emulation, where the observer attempts to reproduce the results of a model's actions, rather than the more complete copy of the model's behaviour that distinguishes imitative learning (Horner & Whiten, 2005; Tomasello, Kruger, & Ratner, 1993; Whiten & Ham, 1992). In recent years, experimental studies have begun to examine the conditions under which young children will employ either an imitative or an emu-

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lative approach (Horner & Whiten, 2005; Huang & Charman, 2005; Huang, Heyes, & Charman, 2002; Thompson & Russell, 2004).

Horner and Whiten (2005) explored whether 3-year-old children and chimpanzees would switch between imitation and emulation, depending on the availability of causal information. Participants observed an adult perform an identical series of actions, on either a clear or an opaque box, in order to retrieve a reward from inside. Some of the actions witnessed were causally relevant to reward retrieval, whilst others were causally irrelevant. Only in the clear box demonstration was the causal relevance of the actions visible. Surprisingly, children imitated with a high level of fidelity, regardless of the availability of causal information, whereas the chimpanzees were found to switch to an emulative approach with the clear box, neglecting to copy actions that could be seen to be ineffectual.

In this paper we set out to replicate and extend the Horner and Whiten (2005) study with a substantially larger sample of 3-year-olds, and also a group of 5-year-olds. This new age group comparison is important to investigate, as it has been suggested that the ability to emulate emerges later than imitation, due to age-related changes in cognitive sophistication that allow greater insight into the goal-directed nature of a model's actions (Want & Harris, 2002). We, therefore, predicted that 5-year-olds would be more likely to switch strategies depending on the availability of causal information, whereas a less efficient, 'blanket' imitative approach was expected at 3 years.

The second addition was the presentation of the task in a video viewing condition. The inclusion of a video format was important for two reasons. First, the use of video allowed the social learning processes described above to be further dissected. Video presentations have the clear benefit of being highly controllable and readily manipulated in order to vary the amount of information available to a child. Second, the "over-imitation" witnessed in the original study could have masked important cognitive factors that may only become apparent when information presented to a child is somewhat degraded. The information presented in the video viewing condition was degraded by presenting a small 2D image, showing only the hands of an unknown model, performing the critical actions on the box. The availability of information is potentially crucial to the social learning approach employed, with decreasing availability of information predicted to make emulation more likely. Indeed, several previous studies have found a lower level of fidelity following video as opposed to live demonstrations (Barr & Hayne, 1999; Hayne, Herbert, & Simcock, 2003; McCall, Parke, & Kavanaugh, 1977).

We predicted that the younger children would "over-imitate" in the live viewing condition, whereas the greater cognitive sophistication of the older children would allow them to switch approach depending on the availability of causal information. However, when the children were exposed to degraded information in the video viewing condition it was less clear how they would perform. It might be the case that the visibility of the model's hands would provide sufficient information to allow imitation, in which case we would expect a similar pattern of responding across both viewing conditions. Alternatively, the video information may be reduced to such an extent that children need to employ a more emulative approach. If so, we would expect to see differences in the fidelity of copying across viewing conditions, particularly in the youngest age group.

1. Method

1.1. Participants

Ninety-six children participated in the study. Two age groups were recruited: a 3-year-old group (27 females, 21 males; mean age = 43 months, range 38–48 months, S.D. = 3 months) and a 5-year-old group (24 females, 24 males; mean age = 65 months, range 60–70 months, S.D. = 3 months).

1.2. Apparatus

The apparatus consisted of two structurally identical polycarbonate boxes (20 cm × 20 cm × 20 cm; see Fig. 1). Each box was identical save for the fact that one was clear and one was opaque. Two square holes (2 cm × 2 cm), each covered by a defence, were positioned on two separate locations on the box. The first hole was positioned on the top of the box and was covered by a bolt defence. The bolt defence consisted of two bolts, which had to be moved before access to the hole was possible. The second hole was positioned on the front face of the box and was covered by a door defence; again the door had to be moved before access to the hole was possible. The front hole was connected to a sloping tube, opaque in both boxes, which contained a reward (a velcro-backed sticker). In order to retrieve the reward it was necessary to open the door, insert an aluminium tool (22 cm long) with velcro on the end into the front hole and pull out the reward. The actions directed to the front of the box were essential for retrieving the reward. In contrast, actions directed to the top hole in the box were not necessary to retrieve the reward. Inserting the tool into the top hole simply resulted in hitting a barrier that prevented physical contact between the tool and the tube containing the reward. Therefore, tool use directed towards the box could be divided into two categories: *relevant* (directed to the front of the box) versus *irrelevant* (directed towards the top of the box).

1.3. Two-action design

In order to further measure the extent to which participants imitated demonstrated actions, both the bolt and the door defences could be opened in either of two ways, thus utilising a ‘two-action’ design common in comparative psychology, and becoming more so in developmental psychology (Whiten, Flynn, Brown, & Lee, 2006). The door, which was hinged at the top, could either be manually *lifted* or *slid* to one side to reveal the hole beneath. Similarly, the bolts could either be *dragged* from the left with the tool, or *pushed* from the right with the tool in order to reveal the top hole. The children were shown these actions in one of two combinations: *method 1*, push-bolts then lift-door; or *method 2,* drag-bolts then slide-door. To control for stimulus enhancement, each bolt was initially tapped three times on the opposite side from where it would subsequently be dragged or pushed.

1.4. Design

Children in each age group were allocated to one of three conditions: live demonstration, video demonstration or no demonstration. Children were matched within each condition on the basis of age group (3 or 5 years) and verbal mental age, as measured by the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Pintilie, 1982). In the live and video conditions children observed either a live or video adult demonstrator retrieve a reward from either the opaque or clear box. In addition, within each of the opaque and clear conditions, half of the children witnessed *method 1* (push-bolts and lift-door) and half witnessed *method 2* (drag-bolts and slide-door). The children in the no demonstration condition were simply allowed to interact with one of the boxes; no demonstration of successful retrieval was provided. Therefore, in total, there were 10 conditions, presented in a between-participants design: live opaque method 1, live opaque method

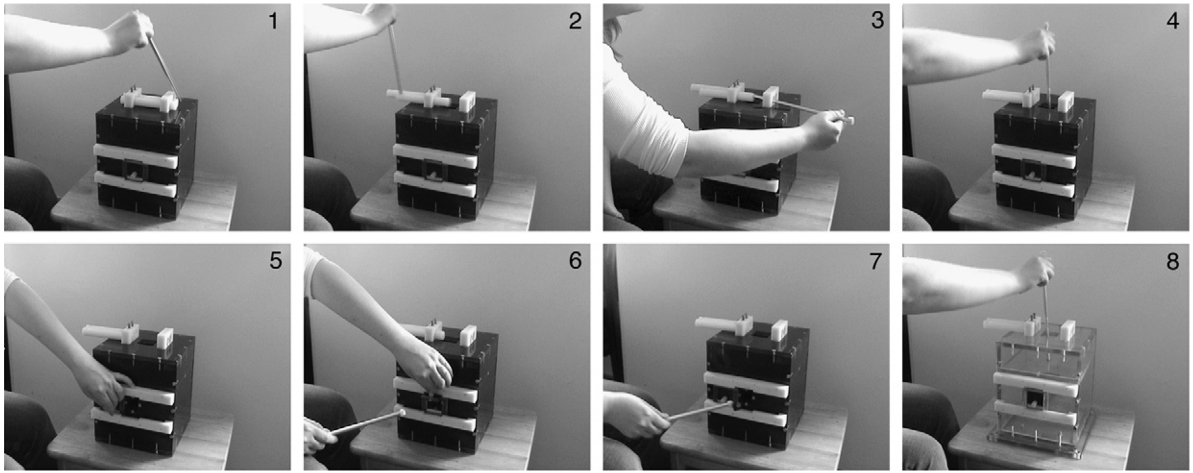

Fig. 1. Images from video clips shown on laptop screen. (1) Tapping one end of bolts. (2) Pulling bolt out. (3) Pushing bolt out. (4) Stabbing into the opaque box. (5) Sliding door open. (6) Lifting door open. (7) Removing reward. (8) Stabbing into the clear box.

2, live clear method 1, live clear method 2, video opaque method 1, video opaque method 2, video clear method 1, video clear method 2, control opaque and control clear.

1.5. Procedure

Children were tested individually in a quiet room within a school or nursery. Upon entering the room, a child was asked to sit on the right-hand side of the experimenter, directly in front of the box (live condition) or directly in front of a laptop computer (video condition). Once the child was seated comfortably, he/she was asked either to *'watch what happens because I'm going to let you have a go in a minute*' or '*watch what happens on the computer because I'm going to let you have a go (pointing to the test box which was covered by a cardboard box) in a minute*.' The experimenter then provided either three live or three video demonstrations of the task with either the opaque or the clear box. Examples of the laptop display presented to the children are shown in Fig. 1. The first stage of each demonstration involved causally *irrelevant* actions – tapping bolt ends three times, removing both bolts and stabbing the tool into the top hole three times. The second stage involved causally *relevant* actions – opening the door and inserting the tool in the front hole in order to retrieve the reward. Following three task demonstrations the first test trial commenced. The identical box to that which children had witnessed in the demonstration phase, that is, either opaque or clear, was placed in front of the child, bolted to a small table. The child was then told '*now it's your turn*.' The child was allowed to interact with the box until either (i) he/she retrieved the reward successfully, (ii) 5 min had elapsed or until (iii) he/she became frustrated or refused to continue. The experimenter then provided two further live or video demonstrations interspersed with test trials 2 and 3 (demo > demo > demo > trial 1 > demo > trial 2 > demo > trial 3), replicating the procedure followed by Horner and Whiten (2005). It is important to note that children were neither told nor encouraged to imitate or copy what the demonstrator had done: any imitation would be spontaneously generated by the child. The children did not witness the re-baiting of the box in any of the trials or conditions.

In the control condition each child was asked to sit directly in front of either the opaque or clear box and simply requested '*What do you think you do with this? Can you show me?*' As in the live and video conditions, the child was allowed to interact with the box until he/she retrieved the reward successfully, until 5 min had elapsed or until he/she became frustrated or refused to continue. All demonstrations and trials for each of the three conditions were videotaped. In each condition, the experimenter remained in the testing room, but was seated as far away as possible from the child so as not to influence task performance.

1.6. Coding and data analysis

The videotaped behaviour of each participant was analysed by recording each occurrence of the following:

PB	Push bolt from right (method 1)
DB	Drag bolt from left (method 2)
ITT	Insert tool in top, "irrelevant" hole
H	Hit barrier (proportion of times recorded)
LD	Lift door (method 1)
SD	Slide door (method 2)
ITF	Insert tool in front, "relevant" hole
RR	Retrieve reward

Of most interest was the proportion of irrelevant actions made by each participant. This was determined by dividing the total number of times the tool was inserted into the top irrelevant hole (ITT) by the total number of tool insertions (ITT + ITF) made across the three trials. Each participant received an 'irrelevant imitation score' which could potentially range from 0 to 1. If the participant only inserted the tool into the top irrelevant hole they received a score of 1, whereas insertions into the lower hole only received a score of 0. If the child performed three insertions into the top hole and one insertion into the lower hole (as demonstrated), he/she received an irrelevant imitation score of 0.75. The participants' tendency to reproduce whichever of the two-action methods to remove the bolt and door defences that he/she had observed was calculated in a similar way. For example, to calculate the proportion of bolt pushes, the total number of times the child pushed the bolts (PB) was divided by the total number of bolt removals performed (PB + DB). Again, scores could range from 0 to 1, with no reproduction of the demonstrated method scoring 0, and reproduction of the demonstrated actions only scoring 1.

Of further interest was whether an increase in task fidelity would result in a decreased level of efficiency in completing the task. In order to explore this possibility, each participant was timed, from the point at which they first made contact with the box to the point at which they retrieved the reward successfully. The first element with which the participants made contact varied depending on the social learning strategy employed. The first point of contact for the children who adopted an imitative strategy was the bolt defence, whereas the first point of contact for the children who emulated was the door defence. The number of seconds taken from the first point of contact to reward retrieval was recorded for each participant, for each of the three trials.

2. Results

2.1. Inter-rater reliability

The data from sixteen children, representing 17% of the total sample, were re-coded by an independent observer, who was naïve to the hypothesis of the experiment. Inter-rater reliability was extremely high for both the number of irrelevant tool insertions (Cohen's Kappa = .95) and the number of relevant tool insertions (Cohen's Kappa = 1.00). Inter-rater reliability was also high for both the methods of bolt defence removal (Cohen's Kappa = .81) and door defence removal (Cohen's Kappa = .93) performed.

2.2. Reproduction of irrelevant actions

A univariate ANOVA with age group (3 or 5 years), viewing condition (live, video or control) and box transparency (clear or opaque) as between-participants factors was conducted on the proportion of irrelevant actions performed across the three trials. The analyses revealed no significant difference in the proportion of irrelevant actions performed with the opaque and clear apparatus ($F(1, 84) = .85$, $p = .36$, partial $\eta^2 = .01$). However, significant effects of age group ($F(1, 84) = 9.5$, $p = .003$, partial $\eta^2 = .10$) and condition ($F(1, 84) = 53.9$, $p < .001$, partial $\eta^2 = .56$) were revealed, as well as a significant interaction between condition and age group ($F(1, 84) = 7.7$, $p = .001$, partial $\eta^2 = .16$; see Fig. 2). The *post hoc* Tukey LSD tests indicated that children in the live viewing condition performed significantly more irrelevant tool insertions (mean = .63) than children in the video condition (mean = .36; $p < .001$), and that the children in both demonstration conditions performed significantly more insertions than the control children (mean = .06; $p < .001$ in both cases). With respect to the age group differences, the 5-year-olds (mean live = .67; mean

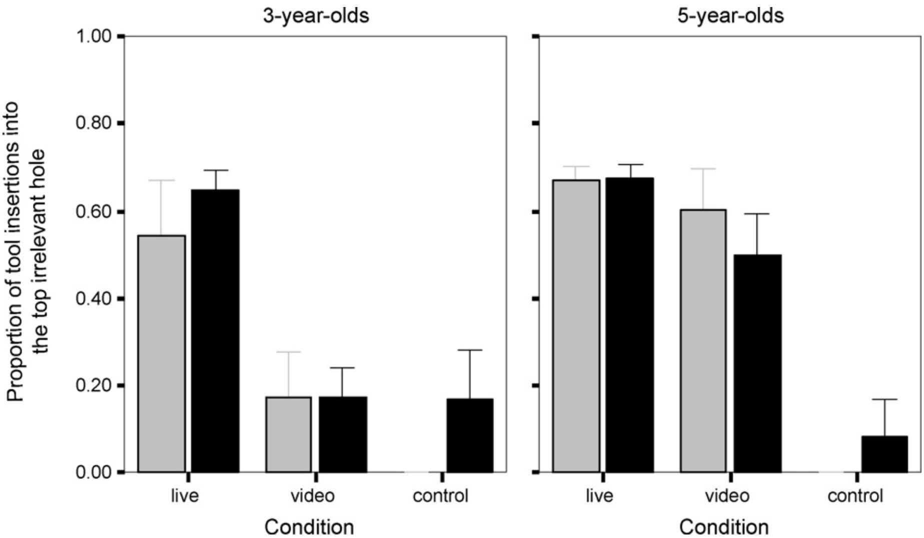

Fig. 2. Proportion of tool insertions into the top irrelevant hole as a function of age group, viewing condition (live vs. video) and box transparency (grey = clear box; black = opaque box).

video = .55) were found to perform significantly more tool-irrelevant insertions than the 3-year-olds (mean live = .59; mean video = .17), a difference which was due to the lack of irrelevant insertions by the younger children in the video viewing condition.

2.3. Reproduction of two-action method of bolt and door removal

Of further interest was the extent to which children adopted whichever of the two demonstrated action sequences they witnessed. Two univariate ANOVAs with method witnessed (drag-slide or push-lift), age group (3 or 5 years) and viewing condition (live, video or control) as between-participants factors were conducted on the proportion of bolt pushes and door lifts performed across the three trials. An analysis of the drag-slide data was not performed as the participants' drag-slide scores are simply the converse of the push-lift scores, due to the proportional nature of the index used.

2.3.1. Bolt pushes

The analysis of bolt pushes revealed no significant difference in the occurrence of bolt pushing between the live (mean push = .54) and video (mean push = .66) conditions ($F(1, 52) = 3.5$, $p = .07$, partial $\eta^2 = .06$), or between the younger (mean push = .58) and older (mean push = .61) children ($F(1, 52) = .03$, $p = .87$, partial $\eta^2 = .001$). The analyses did, however, reveal a highly significant effect of method witnessed ($F(1, 52) = 106.8$, $p < .001$, partial $\eta^2 = .67$), as well as a significant interaction between method witnessed and viewing condition ($F(1, 52) = 10.6$, $p = .002$, partial $\eta^2 = .17$; see Fig. 3a and b). In the live viewing condition the children who observed method 1 (push-bolt) were faithful to that method (mean push = .99), employing the push technique significantly more often than children who observed the drag-bolt technique (mean push = .08). However, fidelity to the model was somewhat reduced following a video demonstration, with children in the video viewing condition frequently pushing the bolts irrespective of whether they witnessed a push-bolt (mean push = .92) or drag-bolt (mean push = .43) demonstration.

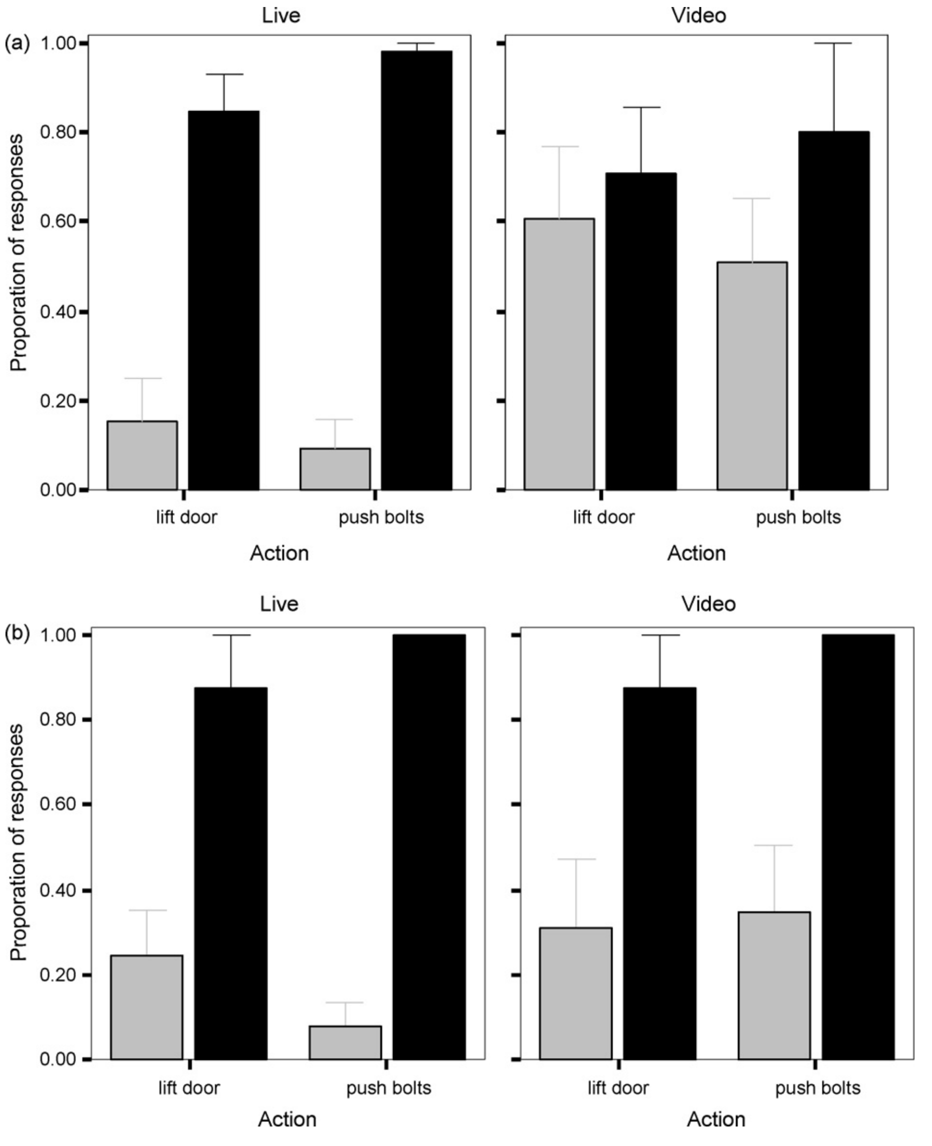

Fig. 3. (a). Proportion of lift-door and push-bolt actions performed by 3-year-olds as a function of viewing condition (live vs. video) and method of demonstration (grey = witnessed drag-bolts then slide-door; black = witnessed push-bolts then lift-door). (b). Proportion of lift-door and push-bolt actions performed by 5-year-olds as a function of viewing condition (live vs. video) and method of demonstration (grey = witnessed drag-bolts then slide-door; black = witnessed push-bolts then lift-door).

2.3.2. Door lifts

The pattern of door defence removal was highly similar to that witnessed with bolt defence removal. The analysis of door lifts revealed no significant difference in the occurrence of door lifts between the live (mean lift = .53) and video (mean lift = .62) conditions ($F(1, 56) = 1.1$, $p = .31$, partial $\eta^2 = .02$), or between the younger (mean lift = .58) and older children (mean lift = .58;

$F(1, 56) = .01$, $p = .98$, partial $\eta^2 < .001$). The analyses did, however, reveal a highly significant effect of method witnessed ($F(1, 56) = 29.8$; $p < .001$, partial $\eta^2 = .35$), as well as a marginally significant interaction between method witnessed and viewing condition ($F(1, 56) = 3.3$; $p = .06$, partial $\eta^2 = .06$; see Fig. 3a and b) .The children in the live viewing condition who observed the model lifting the door employed the lift technique (mean lift = .86) significantly more often than children who observed the slide-door technique (mean lift = .20). Fidelity to the model was, however, somewhat reduced following a video demonstration, with children in the video viewing condition frequently lifting the door regardless of whether the lift (mean lift = .79) or slide technique was observed (mean lift = .46).

2.4. *Time to reward retrieval*

In order to explore the level of efficiency with which children performed the task, the number of seconds the 64 children in the live and video viewing conditions took to retrieve the reward following initial contact with the box (bolts or door) was analysed for each trial. In total, there were 192 trials, of which 9 resulted in no reward retrieval, 169 resulted in an imitative approach and 14 resulted in an emulative approach. Of interest was whether the children who employed an imitative approach would take longer to complete the task than those who adopted an emulative approach. A univariate ANOVA with age group (3 or 5 years), box transparency (clear or opaque), viewing condition (live or video) and strategy employed (imitation or emulation) as between-participants factors was conducted on the time taken to retrieve the reward. The analyses revealed no significant differences between the younger (mean = 27 s) and older (mean = 30 s) children ($F(1, 173) = .04$, $p = .85$, partial $\eta^2 < .001$); the opaque (mean = 28 s) and clear (mean = 29 s) apparatus ($F(1, 173) = .27$, $p = .60$, partial $\eta^2 = .002$) or the live (mean = 29 s) and video (mean = 29 s) conditions ($F(1, 173) = 1.4$, $p = .24$, partial $\eta^2 = .008$). The analysis did, however, reveal a significant effect of strategy employed ($F(1, 173) = 11.1$, $p = .001$, partial $\eta^2 = .06$) with the children who employed an emulative approach (mean = 13 s), retrieving the reward more quickly than those who employed an imitative (mean = 30 s) approach.

3. Discussion

The current study aimed to replicate and extend the finding of Horner and Whiten (2005) that 3-year-olds can be "over-imitators", in the sense that they tend to imitate irrelevant actions at the expense of task efficiency. We were interested in whether this over-imitation would be evident, first in a larger sample of 3-year-olds, secondly in a group of older children (5-year-olds) and thirdly, even when the information available to the child was degraded by only presenting the hands and actions of a model. Surprisingly, we witnessed increasing imitativeness with age. Rather than becoming more selective in the actions that they reproduced, older children performed as "super-imitators", continuing to copy even irrelevant elements of action sequences.

The tendency towards over-imitation was generally most clearly evident in the live viewing condition. Three-year-olds imitated with a high level of fidelity on each box in terms of both the reproduction of irrelevant actions and the method used to remove the box defences. These findings replicate and extend those of Horner and Whiten (2005), and support the results of previous studies with this age group (Nagell, Olgin, & Tomasello, 1993; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). In contrast, the results from the 5-year-olds were startling and counter to predictions. We predicted that the greater cognitive sophistication and causal understanding of the 5-year-olds would allow them to switch approach depending on the availability of causal information. However, the extent to which the 5-year-olds reproduced the irrelevant actions did not differ across the clear and opaque boxes. Even when the children could see that their actions had no effect, they continued to reproduce them.

It could be argued that this extremely high level of fidelity is in fact what should be predicted with an advance in causal understanding. A greater awareness of causality might lead to an increased ability to see the irrelevant actions as not bound by physical constraints and thus as intentional, resulting in an imitative approach. However, performance in the video viewing condition would seem to speak against a key role for the attribution of intention. In the video viewing condition the degradation of information had little effect on the behaviour of 5-year-olds. As in the live viewing condition, these children reproduced the irrelevant actions for both boxes, as well as the method used to remove the box defences with a high level of fidelity. As no model was present in this condition it would seem unlikely that the high level of fidelity witnessed was due to awareness of the intentionality of the model. Nevertheless, the role of intentionality in the reproduction of irrelevant actions is an extremely important question, and is the focus of our ongoing research with this paradigm.

In contrast to the high level of fidelity witnessed following a video demonstration at 5 years, the younger children were heavily influenced by the degraded information. In the video viewing condition, the 3-year-olds were less likely to reproduce both the irrelevant actions, and the demonstrated method of defence removal. There are several differences between the live and video displays which could have led to the lesser fidelity of copying in the younger children. The first is that the video condition may involve a greater cognitive load, as information must be transferred between 2D and 3D. Second, the video display was fairly small, resulting in perceptual degradation of the actions and a discrepancy in size between the live and video stimuli. Third, the children's attention may have been less focused on the video display than the equivalent live display. Fourth, the younger children may not have understood the verbal instruction linking the laptop display to the real object in the same way as the older children. However, it seems unlikely that these factors would have a large influence on task performance. Previous studies have shown that 3-year-old children can imitate complex sequences equally well from live and video displays, when the test object was (1) substantially larger than its video image or (2) hidden from view during the video display. This suggests children understood the connection between the real object and the video display (McCall et al., 1977). An explanation based on a lack of attention also seems unlikely as the experimenter actively monitored the child's attention towards the video display throughout, and added vocal encouragement to attend on the rare occasions where it was necessary.

A fifth explanation is that the degraded information led to a differential focus on the task outcome, as opposed to the actions of the model, resulting in an emulative approach. Although the younger children failed to make irrelevant tool insertions in the video condition, the rate of successful retrieval was high, with reward retrieval occurring in 44 of the 48 trials. This suggests that the 3-year-olds were more emulative in the video condition, reproducing only the actions that were related to the goal. It seems as though the presence of the box, plus the model's hands and actions only, did not convey enough information to support imitation at this age. With the limited information presented, these young children appeared less able to complete the pattern of the model's actions. In contrast, the 5-year-olds appeared to be capable of filling in the missing information and imitating the overall pattern of the action sequence.

Surprisingly, it appears as though humans become increasingly imitative over the age range we studied, even at the expense of task efficiency. One potential explanation for "over-imitativeness" in our species is that imitation is such an adaptive human strategy in general that it is on occasion over-employed (Whiten et al., 1996). If imitation is indeed adaptive overall, then we may expect to see a continuation in its use through childhood into adulthood. Such progression in imitation was seen in the study of Whiten et al. (1996), with 4-year-olds imitating with a greater degree of fidelity than either 2- or 3-year-olds. Similarly, in an extension of this work Custance, Prato Previde, Spiezio, Rigamonti, and Poli (2006) found that even in adulthood, human participants were what Custance et al. called "optimum imitators", copying even the particular finger used to perform an action. Furthermore, this unnecessarily high level of fidelity in human observers has been witnessed irrespective of the identity (human or non-human), or physical presence of the model (Custance et al., 2006; Horner & Whiten, 2005). Other studies have revealed a capacity for more selective imitation than that which our study has emphasised (Gergeley, Bekkering, & Kiraly, 2002) and the reasons for such disparities merit further research. Our results are consistent with the theory that imitation is generally such a highly adaptive human strategy that it may frequently be employed by young children in situations where it is locally inefficient to do so.

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