Over-imitation is better explained by norm learning than by distorted causal learning

Ben Kenward*, Markus Karlsson and Joanna Persson

Department of Psychology, Uppsala University, Box 1225, 751 42 Uppsala, Sweden

In over-imitation, children copy even elements of a goal-directed action sequence that appear unnecessary for achieving the goal. We demonstrate in 4-year olds that the unnecessary action is specifically associated with the goal, not generally associated with the apparatus. The unnecessary action is performed flexibly: 4-year olds usually omit it if it has already been performed by an adult. Most 5-year olds do not verbally report the unnecessary action as necessary when achieving the goal, although most of them report an equivalent but necessary action as necessary. Most 5-year olds explain the necessary action in functional terms, but are unsure as to the function of the unnecessary action. These verbal measures do not support the hypothesis that children over-imitate primarily because they encode unnecessary actions as causing the goal even in causally transparent systems. In a causally transparent system, explanations for over-imitation fitting the results are that children are ignorant of the unnecessary action's purpose, and that they learn a prescriptive norm that it should be carried out. In causally opaque systems, however, for children and for adults, any action performed before achieving the goal is likely to be inferred as causally necessary—this is not over-imitation, but ordinary causal learning.

Keywords: social learning; over-imitation; children; norm acquisition; causal learning

1. INTRODUCTION

In comparison with other species, human children imitate observed action very faithfully, focussing on the manner in which a goal is achieved as much as the goal itself [1–3]. It has been suggested that this faithfulness may be crucial in facilitating the progression of cumulative cultural evolution, which by its uniqueness is a defining property of human society ([4–6], although see [7]). One particular aspect of children's faithful imitation remains a puzzle, however. Despite young children's well-documented abilities to distinguish between efficient and inefficient demonstrated actions [8–12], they frequently reproduce elements of a demonstrated action sequence that do not appear to be causally necessary to achieve the ostensive goal [13–17]. For example, with a transparent box with two compartments, only one of which contains a reward item, 3- to 4-year olds will faithfully copy the action sequence of first manipulating the empty compartment before manipulating the other compartment to retrieve the reward [3].

A variety of mechanisms have been proposed to explain this phenomenon, which has been dubbed over-imitation ([15,17], although see [18]), and which is puzzling not least because it increases with age [15,16,19]. One hypothesis is that the function of imitation in childhood is not simply to learn new behaviour, but also to serve an inherently social purpose of providing shared experience and a context for shared intention, which is crucial for social development (the shared experience hypothesis [14,20–22]). In this context, the causal relation between any particular action and the final state is not important.

Alternatively, it has been argued that children may imitate the unnecessary action because they interpret it as intentional and therefore purposeful, although they may not know what the purpose is (the unspecified purpose hypothesis [3,15,18,23]). Children do interpret situations accompanied by ostentatious social cues, as the staged demonstrations in imitation experiments frequently are, as opportunities to learn important information, not just to share experiences [22,24,25].

Recently Lyons *et al.* [17] have argued in favour of a new hypothesis, in which they specify that what children learn in such contexts is that the unnecessary action is in fact causally necessary to achieve the goal. They refer to this as a 'distortion in children's causal beliefs', so we refer to this hypothesis as the distorted causal belief hypothesis. To understand its implications, one must first consider the normal mechanisms of causal understanding in physical systems. Cause can be understood on the basis of prior knowledge of mechanics (e.g. how force is transferred through physical contact), but when such understanding is impossible because a system is mechanically opaque, causal relations between events can be learned on the basis of their co-occurrence [26–30]. The distorted causal belief hypothesis specifies that, rather than mechanistic understanding taking precedence over co-occurrence as normally occurs, co-occurrence overrides the mechanistic understanding which would have been available to the children, had they not been misled by the demonstration.

It can be argued, however, that certain of the assumptions that led Lyons *et al.* [17] to decide in favour of the distorted causal belief hypothesis may be flawed. First, they argue that because children carry out an unnecessary action in the absence of any social partner (see also [3]) and under time pressure to achieve the goal, then children believe the action is causally necessary for the goal. This

* Author for correspondence (ben.kenward@wolfson.oxon.org).

Electronic supplementary material is available at <http://dx.doi.org/10.1098/rspb.2010.1399> or via <http://rspb.royalsocietypublishing.org>.

assumption overlooks the possibility that children believe the action may be important but for a non-social reason secondary to the primary goal. Precautionary measures are one type of action which should not be omitted in the course of achieving a goal, even under time pressure, but which do not cause the goal. A belief that the action may cause something important related to the goal, although not necessarily the goal itself, could also account for the observation that the unnecessary action is performed less frequently when it is performed on an apparatus physically disconnected from the goal apparatus [17].

Further, Lyons *et al.* [17] argue that because children could spontaneously open their apparatuses without demonstration and without performing unnecessary actions, then the apparatuses were causally transparent. This argument is not watertight—as the locations on the apparatuses where unnecessary actions were carried out were relatively far from the goals, this behaviour pattern could result from goal-directed exploratory manipulation without full causal understanding. Subjectively, the mechanisms of their apparatuses are somewhat complex. If a mechanical causal understanding was not available to the children, even without the distraction of a demonstrated unnecessary action, then replication of the unnecessary action is not over-imitation, but a normal result of co-occurrence-based causal learning.

We agree that a strong argument has been made that although shared experience is important, the shared experience hypothesis cannot fully explain over-imitation. Furthermore, we agree that the distorted causal belief hypothesis is plausible; it is known, for example, that salient perceptual effects can distort children's causal beliefs about mechanical systems that they would otherwise understand [31]. However, owing to the above concerns, among others (such as the fact that over-imitation increases with age even in a sample of 2- to 13-year olds [15]), the case for the distorted causal belief hypothesis is not yet proved. The primary goal of this study is to further test this hypothesis against alternatives such as the unspecified purpose hypothesis.

In discussing these alternatives, we put forward a new hypothesis that over-imitation is related to the phenomenon of norms and their social acquisition by children [32]. This phenomenon is receiving growing attention from developmental psychologists (see [33] for a recent starting point), and is of clear relevance to the phenomenon of over-imitation, but has not yet been linked to it, to our knowledge. As we shall discuss, the hypothesis that over-imitation represents an example of norm acquisition neither excludes nor requires any of the other hypotheses mentioned, because individuals can acquire a behaviour as a norm with or without understanding of the behaviour's purpose.

We use a novel method to investigate the mechanism behind over-imitation—we ask over-imitating children to verbally justify their behaviour. There are three threats to the validity of this method. First, it is possible that the motivation for over-imitation is not a declarative belief and is therefore not available for verbal report. We therefore establish (in experiment 2 and in questions 1 and 2 of experiment 3) that this is not the case. Secondly, self-reported justifications of behaviour are often constructed post hoc [34]. We therefore do not ask children

to justify behaviour they have already performed, instead ask them to justify their intended actions before they perform them. Thirdly, children's verbal responses may show systematic biases such as answer-switching [35] or a 'yes' bias [36]. We control this possibility by comparing children's justifications for the necessary and unnecessary actions, which are otherwise equivalent.

2. EXPERIMENT 1

(a) *Introduction*

Before testing children verbally, we begin with a preliminary experiment intended to test a basic assumption that has generally been made regarding over-imitation, but that has not to our knowledge been explicitly tested, although it is required by the distorted causal belief hypothesis. We examine whether children encode the unnecessary action as part of an action sequence specifically directed at the final goal (the specific goal hypothesis), or whether they associate the action more generally with the apparatus on which it is performed. Studies of the early development of children's goal-directed instrumental behaviour have asked the same question regarding necessary actions and the outcomes they do cause [37,38]. By showing that that the tendency to perform an action depends on the current value of the outcome it is associated with, it can be demonstrated that the outcome, and not simply the stimulus of the apparatus, motivates the performance of the action [39].

We adopt this method in order to test the specific goal hypothesis for unnecessary actions. We demonstrate the retrieval from an apparatus of two different object types, pairing an unnecessary action with the retrieval of one of them only. We then specify that one object type is valued and ask the children to retrieve that type. The specific goal hypothesis predicts that children will be more likely to perform the unnecessary action in the context of retrieving the object with which it was paired than when retrieving the other object. The distorted causal belief hypothesis requires the specific goal hypothesis and therefore makes the same prediction. Because the unspecified purpose hypothesis does not specify the purpose of the unnecessary action it makes no prediction in this experiment.

(b) *Methods*

Included in the final sample were 32 4-year olds ($M = 51$ months, $s.d. = 1.2$, 13 girls), recruited by mail to all children of the appropriate age in Uppsala, a medium-sized Swedish city. The same participants took part in experiments 1 and 2. To maintain orthogonality of counterbalanced variables, included participants were required to provide acceptable data in both experiments. Twelve additional children were tested but excluded from analysis owing to experimenter error (four children), refusal to participate (three), prematurely grabbing the stick from the experimenter in experiment 2 (two), and one each because of disturbance by a sibling, removal of the wrong object in experiment 2, and managing to retrieve an item without the stick in experiment 1.

The experiment took place in a room separated into two by a curtain, with the apparatus on one side and the child's parent seated on the other side. The apparatus was a transparent rectangular plastic box, divided

internally into a left and right side, each containing four small objects (electronic supplementary material, figure S1). White rectangles were retrieved from the left side by inserting a stick into a front hole and pulling them out, facilitated by velcro on the rectangles and on one end of the stick. Glass marbles were retrieved from the right side by inserting the stick into a small front hole and pushing them out through a larger hole behind them on the bottom. On the top of the apparatus, positioned centrally over the side divider, was a black dial which connected to a blue paddle inside, protruding into both sides through a hole in the divider. The paddle was at least 20 cm away from any of the small objects. The action unnecessary for object retrieval was making the paddle rotate by fitting the non-velcro tipped end of the stick onto a bolt on the dial and turning, causing the paddle to spin.

The procedure began by the experimenter demonstrating to the child how to retrieve the objects. He demonstrated twice for each object in an ABAB order, giving each object to the child and asking the child to take the object to the parent behind the curtain, who had been instructed to accept it without comment. Retrieval of one object type only was always preceded by the unnecessary action, with the object type and order counterbalanced.

After the four demonstrations, the experimenter and child returned to the parent, who had been cued to exclaim at this point that they liked one of the object types (counterbalanced) and that they wanted one more of those, not the other type. The experimenter and parent waited while the child went to retrieve an object. If the child retrieved more than one object, only the first retrieval is analysed. The unnecessary action was coded as performed if the child inserted the stick into the dial. Rotation was not required although note that of 30 unnecessary actions coded across experiments 1 and 2, 27 included clear rotation. In this study, all statistical tests are two-tailed and all confidence intervals (CI) given for effect sizes are 95 per cent.

(c) *Results and discussion*

Children always retrieved the requested object first. Each of the 16 participants who were requested to retrieve the object paired with the unnecessary action preceded retrieval with the unnecessary action, whereas only three of 16 asked to retrieve the other object did so ($p < 0.001$, Fisher's exact test, relative risk = 5.3, CI 1.9 to 14.8).

This result confirms the specific goal hypothesis for over-imitation, in other words that the unnecessary action is associated specifically with the goal of the action sequence. This result is therefore consistent with the distorted causal belief hypothesis. This hypothesis is not proved, however, because it is possible that children might associate the action with the goal without necessarily believing that the action causes the goal.

3. EXPERIMENT 2

(a) *Introduction*

Having established in the previous experiment that there is indeed an association between the unnecessary action and the goal, this experiment sets out to begin to determine what form this association takes. To use children's

verbal reports of their causal beliefs in order to test the distorted causal belief hypothesis, as we later shall, it is required that children's motivation for performing the unnecessary action is a declarative belief accessible to introspection. This is not yet established, however, because it is conceivable that the association demonstrated in experiment 1 took the form of an implicit procedural rule: turn the dial before retrieving the object. We now test these alternatives by asking the child to retrieve the object paired with the unnecessary action, but sometimes after the experimenter has already turned the dial. If children have a declarative belief that the dial should be turned before retrieving the object, we predict that they will be more likely to omit turning it themselves if the action has already been carried out. The hypothesis of a procedural rule that they should first turn the dial does not make this prediction and indeed may be subject to the opposite effect of an increase in dial turning because of local enhancement [40].

(b) *Methods, results and discussion*

Immediately after experiment 1, the experimenter explained to the child that they would retrieve another object together. It was always the object paired with the unnecessary action. For half the children (counterbalanced), the experimenter himself first turned the dial with the stick, then passed the stick to the child. For the other half, the experimenter passed the stick without turning.

Of the 16 children for whom the experimenter first performed the unnecessary action, none of the children did so themselves. Of the other 16, 13 performed the unnecessary action ($p < 0.001$, relative risk undefined). This is compatible with the hypothesis that children have a declarative belief that the dial should be turned before retrieving the object, a belief that can be flexibly used to determine appropriate behaviour. It is not compatible with the hypothesis that they learnt an implicit rule that they should first turn the dial. There is, however, a third hypothesis which also fits the data. Children may have learnt an implicit rule specifying that the dial should be turned before object retrieval, without specifying that the same agent who retrieves the object should turn the dial. Because of this ambiguity, we return to this issue in experiment 3.

4. EXPERIMENT 3

(a) *Introduction*

In this experiment, we begin by further ruling out the possibility that a procedural process is responsible for over-imitation, by asking children to verbally describe the actions they will take before they perform them. We then compare children's verbally reported beliefs about the causal status of necessary and unnecessary actions. We use new apparatuses, each of which has two actions which are directly comparable because each action is configurable as either necessary or unnecessary.

An important aspect of the procedure is that we question children before they act, meaning their answers are based entirely on understanding gained from observation of the demonstration, rather than interaction with the apparatus. This also ensures that children's justifications of their planned actions are produced in the context of

their expressed belief that the actions should be performed, rather than in the context of the fact that they have performed the action. This keeps reasoning on a hypothetical level, ruling out post hoc justifications for past behaviour.

In one question, we ask the children why they believe each action should be performed. The distorted causal belief hypothesis, but not the unspecified purpose hypothesis, predicts that justifications in terms of causality should occur frequently for both the necessary and unnecessary actions. In another question, we ask if the object can be retrieved without performing each action. The distorted causal belief hypothesis predicts that children should answer 'no' regarding each action, whereas the unspecified purpose hypothesis predicts that children should be more likely to answer 'no' regarding the necessary action.

The second purpose of this experiment is to test another hypothesis, that children may be more likely to encode the unnecessary action as causally effective when the true causal structure of the apparatus is less obvious. We argued earlier that some of Lyons *et al.* [17]. results might be explicable without the distorted causal belief hypothesis, if the baseline causal transparency of their apparatuses was lower than they assumed. We therefore compare two groups of children using two different apparatuses: one with extremely simple mechanical causality and one in which mechanical causality is more complex, although still transparent for adults at least.

(b) *Methods*

(i) *Participants and materials*

Included in the final sample were 46 5-year olds ($M = 61$ months, $s.d. = 1.5$, 16 girls), recruited as before, allocated randomly to the simple and complex apparatus groups. Children were older than those previously tested to improve the quality of verbal responses. Nineteen additional children were tested but were excluded from analysis owing to refusal to participate (seven children), experimenter error (six), non-compliance of the parent (four) and inability to retrieve a marble (two).

As before, the parent sat on one side of the curtain and the apparatus was on the other side, but this time inside a cupboard with a transparent door. Two new apparatuses, one simple and one complex, both consisted as before of a transparent plastic rectangular box (electronic supplementary material, figures S2 and S3). One apparatus only was used with each child (simple or complex groups). Marbles could be obtained, with an appropriate action, from the left side or the right side, but were only present on one side (counterbalanced) for each test subject. The unnecessary action consisted of acting on the side with no marbles, performing the action which would have retrieved marbles had they been present.

The simple apparatus box contained nothing except six flattened glass marbles. On the front left was a small blue hole and on the front right was a smaller red hole. The marbles were positioned behind either the left or right hole. They could be retrieved by inserting a stick into the appropriate hole and pushing them out of a hole in the bottom panel behind them. The unnecessary action was therefore inserting the stick into the hole behind which there were no marbles.

The complex apparatus box contained two independent mechanical mechanisms, separated by 20 cm, both of which could dispense marbles when manipulated. Each mechanism consisted of a wooden block with a hole for a marble, connected by a rod to a handle outside the box. Moving the handle caused the block to move, which caused it to carry a marble from a magazine to a hole in the box's bottom plate, out of which it dropped. On the left the mechanism was blue with a handle protruding from the box's top that was rotated; on the right the mechanism was red with a handle protruding from the box's front that was moved back and forth. The six-marble magazine was positioned with either the left or right mechanism. The unnecessary action was therefore manipulating the handle attached to the mechanism with no marbles.

(ii) *Procedure*

The procedure began with the experimenter demonstrating three times the retrieval of a marble, always preceding the necessary action with the unnecessary one. She then closed the cupboard door to prevent apparatus access while maintaining view and explained that before it was the child's turn, they would explain to their parent how they would retrieve a marble. Leaving the child alone in front of the apparatus, she went to the parent and prompted them by pointing at a list to ask the following questions, with questions 2, 3 and 4 repeated afterwards for the second action (order counterbalanced, see electronic supplementary material for untranslated Swedish):

1. 'What will you do to get out a marble?'
2. 'Will you (perform the unnecessary/necessary action)?' (Skipped if the child had already stated that they would.)
3. 'Why will you (perform the unnecessary/necessary action)?' (Skipped if the child had stated that they would not.)
4. 'Can¹ one get out a marble without (performing the unnecessary/necessary action)?'

The simple action was described: 'put the stick in the red/blue hole'; the complex action 'use the red/blue handle'. Questions were repeated once if the child answered 'don't know', did not answer or answered incomprehensibly. After the questions, the experimenter came back to the child, opened the cupboard and asked the child to take out a marble, returning to the parent before the child did so.

Question 1 answers were coded as containing or not containing a description of each action. Questions 2 and 4 answers were coded on a five-point scale: no (1), uncertain (3), yes (5), with unclear answers coded as missing. Question 3 answers were coded on a six-point ordinal scale of belief that the action caused marble retrieval (figure 1). To determine inter-observer reliability, a second individual blind to the necessary and unnecessary actions coded 20 randomly selected participants (10 for each apparatus): Cohen's kappa was 1.0 for question 1, and linear weighted kappas for questions 2, 3, and 4 were 0.97, 0.97, and 0.87, respectively.

(c) *Results*

Five simple group children and one complex group child did not perform the unnecessary action and are therefore not included in the subsequent analysis of reasons for

Figure 1. 'Why will you (perform the unnecessary/necessary action)?' (question 3, experiment 3): frequency histograms of answers, by simple and complex groups. Answers are classed on an ordinal scale representing grades of belief that the action is physically causally necessary for marble retrieval. The difference between necessary and unnecessary and the interaction between necessary/unnecessary and complex/simple are both significant (see main text); $n = 20$ for all except for the simple group, unnecessary action, for which $n = 19$ because a child answered incomprehensibly. Children who had previously stated they would not perform an action (question 2) were not asked why they would perform it: they score 0. All children subsequently performed both actions.

over-imitation (children were tested until 20 in each group performed the unnecessary action). This group difference is not significant ($p = 0.138$, fisher's exact test, relative risk = 1.19, CI 0.96 to 1.48).

Of the 40 children, 33 spontaneously said that they would perform the necessary action (question 1), and the remaining seven all said they would when specifically asked (scoring 5 on question 2). Similarly, 30 stated spontaneously that they would perform the unnecessary action, with seven of the remaining scoring 5 on question 2.

Justifications for intending to perform the necessary action (question 3) were more likely to include claims that it caused marble retrieval than were justifications for intending to perform the unnecessary action (figure 1). This effect was very strong in the simple group but weaker in the complex group. To confirm these observations statistically, a difference score s was calculated for each individual as the answer score for the necessary action minus the answer score for the unnecessary action. For all children, mean s (1.6, s.d. = 2.0) is greater than zero (signed-rank Wilcoxon's $W = 446$, $p < 0.001$, $d = 0.80$, CI 0.16 to 1.43). Comparing the groups, mean s_{simple} (2.4, s.d. = 1.8) is greater than mean s_{complex} (0.8, s.d. = 1.9) (rank sum Wilcoxon's $W = 318$, $p = 0.022$, $d = 0.86$, CI -0.03 to 1.70). The difference in justifications is significant within the simple group (mean s_{simple} is greater than zero, signed-rank Wilcoxon's $W = 134$, $p = 0.001$, $d = 1.32$, CI 0.49 to 2.14), but not quite so within the complex group (mean s_{complex} is not significantly greater than zero, signed-rank Wilcoxon's $W = 93$, $p = 0.065$, $d = 0.44$, CI -0.40 to 1.29).

Whereas over three-quarters of children answered that the marble could not be obtained without performing the necessary action (question 4), less than half answered that it could not be obtained without performing the unnecessary action (figure 2). Answers were significantly

closer to 'no' for the necessary action than for the unnecessary action (signed-rank Wilcoxon's $W = 1$, $p < 0.001$, $d = 0.76$, CI 0.27 to 1.24). Answers for the unnecessary action did not differ significantly between the simple and complex groups (rank sum Wilcoxon's $W = 126.5$, $p = 0.379$, $d = 0.34$, CI -0.47 to 0.96). The analyses and figure exclude the answers of four children who had obviously misunderstood the question, but including these children did not alter the results.

5. GENERAL DISCUSSION

In a series of experiments, we first demonstrated that over-imitating 4-year olds associated an unnecessary action with a specific goal, and that the form of this association was a flexible declarative belief that the unnecessary action should be performed in the context of the specific goal. The observation of a flexible declarative belief enabled the final method, which was to ask 5-year olds to explain why they believed that the unnecessary action should be performed in the context of the goal.

The first important question was 'Why will you (perform the unnecessary/necessary action)?' The majority of all children clearly stated that the necessary action caused marble retrieval. Regarding the unnecessary action, however, the majority in the simple apparatus group stated either that they were unsure why it should be performed, or stated that they would not perform the action, or stated that it did not retrieve a marble. Only 10 per cent of these children reported a belief that the unnecessary action caused marble retrieval. The distorted causal belief hypothesis cannot be straightforwardly reconciled with these data. This is, however, the exact pattern predicted by the unspecified purpose hypothesis.

When children in the complex apparatus group were asked the same question regarding the unnecessary

Figure 2. 'Can¹ one get out a marble without (performing the unnecessary/necessary action)?' (question 4, experiment 3): relative frequency histograms of answers, by simple and complex groups. The difference between (a) necessary and (b) unnecessary actions is significant (see main text). Missing values ($n < 20$) are owing to incomprehensible answers or because children had clearly misunderstood the question. All children subsequently performed both actions. (a) Grey bar, simple ($n = 18$); black bar, complex ($n = 20$). (b) Grey bar, simple ($n = 16$); black bar, complex, ($n = 19$).

action, answers were more varied, and a more substantial minority stated that the action caused marble retrieval. Apparatus complexity therefore had an effect on how children interpreted the unnecessary action, with complexity increasing the proportion of children forming a belief that the unnecessary action causes marble retrieval. The natural interpretation of this result is that with a more complex device, children are less able to perceive the mechanical causality, and fall back onto causal judgement mechanisms used for causally opaque systems. In such cases, causality is inferred from perception of co-occurrence [26–30] so the actions that preceded marble retrieval are inferred to have caused it. This effect is reinforced by the actions' ostentatiously pedagogical context, which further increased the probability of the children assuming a relevant role for the actions [22,24].

If it is the case that some children encoded the unnecessary action as causal because they could not have grasped the mechanical causality even without a misleading demonstration, then over-imitation is not an appropriate term to describe their copying behaviour. This is because implicit in the definition of the phenomenon of over-imitation is the assumption that the unnecessary nature of the action would be clear to the observing child, were it not for the misleading demonstration [15,17]. Because we have not assessed baseline causal understanding, however, we cannot rule out that the minority of children reporting belief that the unnecessary action caused marble retrieval might have had an accurate baseline causal understanding which was distorted by demonstration. A weak version of the distorted causal belief hypothesis, in which causal distortion can occur when the mechanical system is on the threshold of the child's ability to understand, is therefore consistent with, though not necessary to explain, the behaviour of a minority of children in this study.

It is worth noting that, to our knowledge, all studies of over-imitation have involved apparatuses that were more

complex than our simple apparatus. Unlike previous devices, it has no moving parts except the marbles to be retrieved and the stick that is used. This experiment therefore reinforces the robustness of the over-imitation effect even in a system so simple that it is highly unlikely that the participants did not understand it fully on a mechanical level.

An objection to our method is that there might be a dissociation between 5-year-olds' causal understanding and their verbally reported beliefs. Except for lying, which we discount, this would only be possible if there is a level of causal understanding inaccessible to and contradictory to declarative thought. Although there are many automatic processes inaccessible to declarative thought [41], in the realm of adult causal learning there is no evidence for understanding that is not available to declarative thought, and some evidence that there is no such separation [42,43]. By the age of five, children display advanced causal reasoning abilities qualitatively similar to those of adults [44]. It cannot, however, be ruled out that an unconscious encoding of the causal effectiveness of the unnecessary action was unconsciously processed to produce a declarative belief that the action should be performed, without producing an accompanying justification. We note simply that there is no need to postulate such an unprecedented mechanism to explain available data.

In response to the second important question: 'Can¹ one get out a marble without (performing the unnecessary/necessary action)?', the vast majority of children answered 'no' with respect to the necessary action, but a majority were uncertain or answered 'yes' with respect to the unnecessary action. Again, this result is inconsistent with the distorted causal belief hypothesis but consistent with the unspecified purpose hypothesis. The fact that a substantial minority answered 'no' with respect to the unnecessary action requires attention, however. This particular result is consistent with the interpretation that causal belief distortion has occurred in a minority of children. We offer, however, an alternative explanation. Although the Swedish original is much less ambiguous than our English translation,¹ it is possible that a minority of children misinterpreted the question as asking about permissibility rather than possibility.

This links to our final discussion point. Our data demonstrates that the distorted causal belief hypothesis is unlikely, which leaves unanswered the question of why children copy an action without a clear purpose. The unspecified purpose hypothesis can answer this: children may copy because they believe that the action has a purpose of which they are unaware. We propose, however, that the type of learning we have demonstrated here also closely fits a further hypothesis: children learn a prescriptive norm [32,45] that the unnecessary action should be performed in the context of retrieving a marble.

From 2 to 3 years of age children are capable of rapidly acquiring arbitrary norms [33,46] and reasoning deontically, i.e. regarding the permissibility or obligatoriness of actions [45,47,48]. It has even been suggested that deontic reasoning is an inherited cognitive specialization [49]. The fact that prescriptive norms play a crucial role in young children's everyday behaviour was vividly illustrated by an observational study of pre-schoolers, in which the majority of speech describing peers' behaviour concerned norm violations [50]. Importantly for the

current study, children also rapidly acquire arbitrary norms about appropriate uses for novel artefacts, protesting when these norms are violated [51].

This behavioural norm hypothesis is agnostic as to children's beliefs about the purpose of the action. It therefore neither excludes nor requires any of the other hypotheses considered here. Children acquiring an action as a norm may have no specific belief as to the action's purpose. For individuals to adopt norms it is sufficient that they observe that the action is normative—the detection of norms creates an intrinsic motivation to follow them, a motivation of which the norm follower may not even be aware [32,52]. In fact, the level of fidelity with which young children imitate has been shown to be reduced when they understand the purpose of an action, because this enables comprehension of exactly which action details are necessary or optional for the purpose [23]. Although the function of norm adherence is often discussed in terms of how conventions facilitate social interaction, some norms, such as precautionary ones [53], have instrumental rather than social functions. A further function of norm adherence might be to provide an intrinsic motivation to perform behaviour with an instrumental purpose, without needing to understand the purpose.

In summary, in this study children over-imitated (on the simplest apparatus yet tested) because they acquired a flexible declarative belief that an action causally unnecessary for achieving a goal should anyway be performed while achieving that goal. Children's verbal justifications for this belief were not consistent with the distorted causal belief hypothesis, according to which children believe that an unnecessary action causes the goal. Instead, most children indicated through verbal responses that they were unsure why the action should be carried out. The distorted causal belief hypothesis fits the data well only if one makes unnecessary and unsupported assumptions about the nature of children's causal belief. In contrast, the data are very consistent with the unspecified purpose hypothesis, and in general over-imitation harmonizes parsimoniously with existing data and theory regarding children's norm acquisition. Either or both of the unspecified purpose hypothesis and norm-acquisition hypothesis are likely to be true. Future studies in the areas of over-imitation and norm acquisition will benefit from a synthesis of their empirical and theoretical frameworks.

This work was supported by European Grant CONTACT FP6-NEST 5010 and by Riksbankens Jubileumsfond Grant P2008-01039:1. Thanks to Claes von Hofsten, Kerstin Rosander and Fredrik Agmén for invaluable assistance with the study. The study was approved by the ethics committee at the Research Council in the Humanities and Social Sciences and therefore in accordance with the ethical standards specified in the 1964 Declaration of Helsinki. Informed consent was obtained from the parents of all participants.

ENDNOTE

¹Swedish differs from modern spoken English in that the word for *can* in this context: *kan*, is less interchangeable with the word for *may*: *få*. To an adult at least, the original untranslated question is therefore clearly asking about physical possibility, not permissibility. It is not unknown, however, for *kan* to be used by children in contexts of permissibility.

REFERENCES

- 1 Nagell, K., Olguin, R. S. & Tomasello, M. 1993 Processes of social-learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *J. Comp. Psychol.* **107**, 174–186. (doi:10.1037/0735-7036.107.2.174)
- 2 Whiten, A., Custance, D. M., Gomez, J. C., Teixidor, P. & Bard, K. A. 1996 Imitative learning of artificial fruit processing in children (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). *J. Comp. Psychol.* **110**, 3–14. (doi:10.1037/0735-7036.110.1.3)
- 3 Horner, V. & Whiten, A. 2005 Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children. *Anim. Cogn.* **8**, 164–181. (doi:10.1007/s10071-004-0239-6)
- 4 Shea, N. 2009 Imitation as an inheritance system. *Phil. Trans. R. Soc. B* **364**, 2429–2443. (doi:10.1098/rstb.2009.0061)
- 5 Boyd, R. & Richerson, P. J. 1996 Why culture is common but cultural evolution is rare. *Proc. Br. Acad.* **88**, 73–93.
- 6 Tennie, C., Call, J. & Tomasello, M. 2009 Ratcheting up the ratchet: on the evolution of cumulative culture. *Phil. Trans. R. Soc. B* **364**, 2405–2415. (doi:10.1098/rstb.2009.0052)
- 7 Enquist, M. & Ghirlanda, S. 2007 Evolution of social learning does not explain the origin of human cumulative culture. *J. Theor. Biol.* **246**, 129–135. (doi:10.1016/j.jtbi.2006.12.022)
- 8 Brugger, A., Lariviere, L. A., Mumme, D. L. & Bushnell, E. W. 2007 Doing the right thing: infants' selection of actions to imitate from observed event sequences. *Child Dev.* **78**, 806–824.
- 9 Gergely, G. & Csibra, G. 2003 Teleological reasoning in infancy: the naive theory of rational action. *Trends Cogn. Sci.* **7**, 287–292. (doi:10.1016/S1364-6613(03)00128-1)
- 10 Flynn, E. & Whiten, A. 2008 Imitation of hierarchical structure versus component details of complex actions by 3- and 5-year-olds. *J. Exp. Child Psychol.* **101**, 228–240. (doi:10.1016/j.jecp.2008.05.009)
- 11 Williamson, R. A., Meltzoff, A. N. & Markman, E. M. 2008 Prior experiences and perceived efficacy influence 3-year-olds' imitation. *Dev. Psychol.* **44**, 275–285. (doi:10.1037/0012-1649.44.1.275)
- 12 Schulz, L. E., Hoopell, C. & Jenkins, A. C. 2008 Judicious imitation: children differentially imitate deterministically and probabilistically effective actions. *Child Dev.* **79**, 395–410. (doi:10.1111/j.1467-8624.2007.01132.x)
- 13 Meltzoff, A. N. 1988 Infant imitation after a 1-week delay: long-term memory for novel acts and multiple stimuli. *Dev. Psychol.* **24**, 470–476. (doi:10.1037/0012-1649.24.4.470)
- 14 Nielsen, M. 2006 Copying actions and copying outcomes: social learning through the second year. *Dev. Psychol.* **42**, 555–565. (doi:10.1037/0012-1649.42.3.555)
- 15 Nielsen, M. & Tomaselli, K. 2010 Overimitation in Kalahari Bushman children and the origins of human cultural cognition. *Psychol. Sci.* **21**, 729–736.
- 16 McGuigan, N., Whiten, A., Flynn, E. & Horner, V. 2007 Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children. *Cogn. Dev.* **22**, 353–364. (doi:10.1016/j.cogdev.2007.01.001)
- 17 Lyons, D. E., Young, A. G. & Keil, F. C. 2007 The hidden structure of overimitation. *Proc. Natl Acad. Sci. USA* **104**, 19751–19756. (doi:10.1073/pnas.0704452104)
- 18 Whiten, A., McGuigan, N., Marshall-Pescini, S. & Hopper, L. M. 2009 Emulation, imitation, over-imitation and the scope of culture for child and chimpanzee.

- Phil. Trans. R. Soc. B* **364**, 2417–2428. (doi:10.1098/rstb.2009.0069)
- 19 McGuigan, N. & Whiten, A. 2009 Emulation and 'overemulation' in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. *J. Exp. Child Psychol.* **104**, 367–381. (doi:10.1016/j.jecp.2009.07.001)
 - 20 Uzgiris, I. C. 1981 Two functions of imitation during infancy. *Int. J. Behav. Dev.* **4**, 1–12.
 - 21 Tomasello, M., Carpenter, M., Call, J., Behne, T. & Moll, H. 2005 Understanding and sharing intentions: the origins of cultural cognition. *Behav. Brain Sci.* **28**, 675–691.
 - 22 Nielsen, M., Simcock, G. & Jenkins, L. 2008 The effect of social engagement on 24-month-olds' imitation from live and televised models. *Dev. Sci.* **11**, 722–731. (doi:10.1111/j.1467-7687.2008.00722.x)
 - 23 Williamson, R. A. & Markman, E. M. 2006 Precision of imitation as a function of preschoolers' understanding of the goal of the demonstration. *Dev. Psychol.* **42**, 723–731. (doi:10.1037/0012-1649.42.4.723)
 - 24 Csibra, G. & Gergely, G. 2009 Natural pedagogy. *Trends Cogn. Sci.* **13**, 148–153. (doi:10.1016/j.tics.2009.01.005)
 - 25 DiYanni, C. & Kelemen, D. 2008 Using a bad tool with good intention: young children's imitation of adults' questionable choices. *J. Exp. Child Psychol.* **101**, 241–261. (doi:10.1016/j.jecp.2008.05.002)
 - 26 Griffiths, T. L. & Tenenbaum, J. B. 2009 Theory-based causal induction. *Psychol. Rev.* **116**, 661–716. (doi:10.1037/a0017201)
 - 27 Perales, J. C. & Catena, A. 2006 Human causal induction: a glimpse at the whole picture. *Eur. J. Cogn. Psychol.* **18**, 277–320.
 - 28 Cheng, P. W. 1997 From covariation to causation: a causal power theory. *Psychol. Rev.* **104**, 367–405. (doi:10.1037/0033-295X.104.2.367)
 - 29 Gopnik, A., Glymour, C., Sobel, D. M., Schulz, L. E., Kushnir, T. & Danks, D. 2004 A theory of causal learning in children: causal maps and Bayes nets. *Psychol. Rev.* **111**, 3–32. (doi:10.1037/0033-295X.111.1.3)
 - 30 Penn, D. C. & Povinelli, D. J. 2007 Causal cognition in human and nonhuman animals: a comparative, critical review. *Annu. Rev. Psychol.* **58**, 97–118. (doi:10.1146/annurev.psych.58.110405.085555)
 - 31 Schlottmann, A. 1999 Seeing it happen and knowing how it works: how children understand the relation between perceptual causality and underlying mechanism. *Dev. Psychol.* **35**, 303–317. (doi:10.1037/0012-1649.35.1.303)
 - 32 Sripada, C. S. & Stich, S. 2007 A framework for the psychology of norms. In *The innate mind (vol. 2) culture and cognition* (eds P. Carruthers, S. Laurence & S. Stich), pp. 280–301. Oxford, UK: Oxford University Press.
 - 33 Rakoczy, H., Wameken, F. & Tomasello, M. 2008 The sources of normativity: young children's awareness of the normative structure of games. *Dev. Psychol.* **44**, 875–881. (doi:10.1037/0012-1649.44.3.875)
 - 34 Johansson, P., Hall, L., Sikstrom, S. & Olsson, A. 2005 Failure to detect mismatches between intention and outcome in a simple decision task. *Science* **310**, 116–119. (doi:10.1126/science.1111709)
 - 35 Siegal, M., Waters, L. J. & Dinwiddy, L. S. 1988 Misleading children—causal attributions for inconsistency under repeated questioning. *J. Exp. Child Psychol.* **45**, 438–456. (doi:10.1016/0022-0965(88)90041-0)
 - 36 Okanda, M. & Itakura, S. 2010 When do children exhibit a 'yes' bias? *Child Dev.* **81**, 568–580. (doi:10.1111/j.1467-8624.2009.01416.x)
 - 37 Kenward, B., Folke, S., Holmberg, J., Johansson, A. & Gredebäck, G. 2009 Goal directedness and decision making in infants. *Dev. Psychol.* **45**, 809–819. (doi:10.1037/a0014076)
 - 38 Klosssek, U. M. H., Russell, J. & Dickinson, A. 2008 The control of instrumental action following outcome devaluation in young children aged between 1 and 4 years. *J. Exp. Psychol. Gen.* **137**, 39–51. (doi:10.1037/0096-3445.137.1.39)
 - 39 Dickinson, A. & Balleine, B. W. 2000 Causal cognition and goal-directed action. In *The evolution of cognition* (eds C. Heyes & L. Huber), pp. 185–204. Cambridge, MA: The MIT Press.
 - 40 Want, S. C. & Harris, P. L. 2002 How do children ape? Applying concepts from the study of non-human primates to the developmental study of 'imitation' in children. *Dev. Sci.* **5**, 1–13. (doi:10.1111/1467-7687.00194)
 - 41 Bargh, J. A. & Chartrand, T. L. 1999 The unbearable automaticity of being. *Am. Psychol.* **54**, 462–479. (doi:10.1037/0003-066X.54.7.462)
 - 42 Reed, P. 2001 Schedules of reinforcement as determinants of human causality judgments and response rates. *J. Exp. Psychol. Anim. Behav. Process* **27**, 187–195. (doi:10.1037/0097-7403.27.3.187)
 - 43 Shanks, D. R. 2007 Associationism and cognition: human contingency learning at 25. *Q. J. Exp. Psychol.* **60**, 291–309. (doi:10.1080/17470210601000581)
 - 44 Gopnik, A. & Schulz, L. 2004 Mechanisms of theory formation in young children. *Trends Cogn. Sci.* **8**, 371–377. (doi:10.1016/j.tics.2004.06.005)
 - 45 Harris, P. L. & Nunez, M. 1996 Understanding of permission rules by preschool children. *Child Dev.* **67**, 1572–1591. (doi:10.2307/1131719)
 - 46 Schmidt, M., Rakoczy, H. & Tomasello, M. In press. Young children attribute normativity to novel actions without pedagogy or normative language. *Dev. Sci.*
 - 47 Beller, S. 2010 Deontic reasoning reviewed: psychological questions, empirical findings, and current theories. *Cogn. Process.* **11**, 123–132. (doi:10.1007/s10339-009-0265-z)
 - 48 Cummins, D. D. 1996 Evidence of deontic reasoning in 3- and 4-year-old children. *Mem. Cogn.* **24**, 823–829.
 - 49 Cosmides, L. & Tooby, J. 2005 Neurocognitive adaptations designed for social exchange. In *Evolutionary psychology handbook* (ed. D. M. Buss). New York, NY: Wiley.
 - 50 Ingram, G. P. D. & Bering, J. M. 2010 Children's tattling: the reporting of everyday norm violations in preschool settings. *Child Dev.* **81**, 945–957. (doi:10.1111/j.1467-8624.2010.01444.x)
 - 51 Casler, K., Terziyan, T. & Greene, K. 2009 Toddlers view artifact function normatively. *Cogn. Dev.* **24**, 240–247. (doi:10.1016/j.cogdev.2009.03.005)
 - 52 Cialdini, R. B. 2007 Descriptive social norms as underappreciated sources of social control. *Psychometrika* **72**, 263–268. (doi:10.1007/s11336-006-1560-6)
 - 53 Fiddick, L., Spampinato, M. V. & Grafman, J. 2005 Social contracts and precautions activate different neurological systems: an fMRI investigation of deontic reasoning. *Neuroimage* **28**, 778–786. (doi:10.1016/j.neuroimage.2005.05.033)