‘Over-imitation’: a review and appraisal of a decade of research

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Abstract

After seeing an action sequence children and adults tend to copy causally relevant and, more strikingly, even perceivably unnecessary actions in relation to the given goal. This phenomenon, termed "over-imitation", has inspired much empirical research in the past decade as well as lively theoretical debate on its cognitive underpinnings and putative role in the transmission of cultural knowledge. Here, we offer a comprehensive review of the existing literature to date, accompanied by a table including concise information on 54 published studies testing over-imitation in different species, age groups and cultures. We highlight methodological issues related to task and context that influence over-imitation rates and that should be carefully considered in study designs. We discuss the cognitive and motivational processes underlying and contributing to over-imitation, including normative action parsing, causal reasoning, motives of affiliation and social learning as well as their complex interplay. We conclude that despite the apparent irrationality of over-imitation behavior, recent studies have shown that its performance depends on the specific task, modeled actions and context variables, suggesting that over-imitation should be conceptualized as a contextually flexible and, in fact, a normally highly functional phenomenon.

Keywords: imitation, over-imitation, cultural learning, social norms, social learning

- We offer a comprehensive review of the existing literature on over-imitation.
- We discuss methodological issues affecting the behavior in experiments.
- Different theoretical perspectives are contrasted and critically assessed.
- Over-imitation is a contextually flexible and normally functional phenomenon.

Abstract

After seeing an action sequence children and adults tend to copy causally relevant and, more strikingly, even perceivably unnecessary actions in relation to the given goal. This phenomenon, termed "over-imitation", has inspired much empirical research in the past decade as well as lively theoretical debate on its cognitive underpinnings and putative role in the transmission of cultural knowledge. Here, we offer a comprehensive review of the existing literature to date, accompanied by a table including concise information on 54 published studies testing over-imitation in different species, age groups and cultures. We highlight methodological issues related to task and context that influence over-imitation rates and that should be carefully considered in study designs. We discuss the cognitive and motivational processes underlying and contributing to over-imitation, including normative action parsing, causal reasoning, motives of affiliation and social learning as well as their complex interplay. We conclude that despite the apparent irrationality of over-imitation behavior, recent studies have shown that its performance depends on the specific task, modeled actions and context variables, suggesting that over-imitation should be conceptualized as a contextually flexible and, in fact, a normally highly functional phenomenon.

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Imitation of actions that offer no discernable evidence of serving a function in achieving a given goal can be observed in everyday life and various human cultures. A real-life example of overzealous imitation without direct relation between action and goal can be found in the so-called *cargo cults*. Until the late 19th and early 20th century many Melanesia communities had no contact with the technologies of the industrialized world. With European colonialism, cargo cults spread across coastal New Guinea and island Melanesia. Members of these cults abandoned many of their own traditions and rituals in an intriguing attempt to copy the life-styles and rituals of the Europeans. For instance, cult members built (non-functional) wooden planes and radio stations, and they performed military exercises with wooden bayonets. All this, according to their own accounts, was hoped to convince their ancestors to send them *kago* (i.e., cargo). Remarkably, it seems that the members of cargo cults specifically imitated actions that were cognitively opaque (Umbres, 2017), actions that had no obvious goal and that were not perceivably causally related to the goal of receiving cargo. In other words, members of cargo cults in Melanesia did not mindlessly copy arbitrary behaviors of the colonialists. They selectively imitated actions whose purpose was unclear and that they, unaware of the processes of actual production of cargo goods, associated with the arrival of cargo on their islands (Umbres, 2017).

As illustrated by the example of cargo cults, humans have a pervasive tendency to copy such behaviors whose purpose may be unclear in relation to a given goal. Strikingly, even actions that are perceivably not causally relevant to goal achievement are often imitated. This phenomenon was first systematically tested and reported in a seminal study by Horner and Whiten (2005). The authors presented 3- to 4-year-old children and young chimpanzees with a puzzle box containing a hidden treat. An experimenter demonstrated how to retrieve

the reward with a series of actions containing both causally necessary and unnecessary actions. When the box was opaque, both chimpanzees and children tended to copy the unnecessary actions when retrieving the reward. This is unsurprising insofar as the mechanisms of the box were opaque, rendering the purpose of individual actions in the sequence unclear. Children and chimpanzees therefore often copied all actions performed on the box. A striking difference emerged between the two species when a transparent box was used instead: Whereas chimpanzees now omitted the visibly unnecessary actions, human children imitated these actions even though it led them to perform extra actions that were visibly unrelated to reward retrieval.

Since this first report, a rapidly growing number of studies has addressed this phenomenon, especially in children (a smaller number of ape studies generated results consistent with those of Horner and Whiten; Clay & Tennie, 2017; Nielsen & Widjojo, 2011). Lyons, Young, and Keil (2007) labeled the imitation of unnecessary actions "overimitation". Although this term is in some ways misleading, as we discuss further below, it has been successful in binding together a newly emerging area of research on this seemingly irrational behavior. Here, we review studies published on over-imitation since the first empirical investigation was conducted by Horner and Whiten (2005), which include 54 studies listed in supplementary Table S1, along with summary details of each study. We offer a comprehensive review of this literature structured according to three main questions:

a) Which factors relating to the task, experimental design and the context influence over-imitation, potentially leading to divergent conclusions across different studies and laboratories?

b) What are the cognitive and motivational processes underlying over-imitation, and can this phenomenon be explained within existing theoretical frameworks of imitation?

c) Which characteristics of the model and the imitator affect the extent to which causally unnecessary actions are copied?

We start our review by offering a definition of over-imitation and discussing the usefulness of the label itself.

Defining Over-Imitation

We define over-imitation (henceforth 'OI') as imitation of perceivably causally unnecessary actions in relation to the goal of an action sequence performed by a model. An action is defined as a deliberate and goal-directed behavior. Imitation, defined as faithful and intentional copying of observed actions or action sequences, has been contrasted with "emulation". The latter refers to a social learning mechanism that appears to be more often employed by non-human primates, though also occurring in human children, when the observer brings about the goal of an action without necessarily deliberately copying the means used by the model (Horner & Whiten, 2005; Tomasello, 1990).

Since the introduction of the term 'overimitation' by Lyons et al. (2007), it has become widely used in the literature. However, some authors have criticized the label OI as possibly implying that children imitate actions over and above the actions they observed, when in fact they are indeed imitating very precisely (Gardiner, 2014). Therefore, other terms have sometimes been used in the literature, such as 'indiscriminate imitation' (Gardiner, 2014) or 'blanket copying' (Whiten, 2017) to describe the same phenomenon. We would like to emphasize that following our definition, the term "over"-imitation neither implies that actions are performed that go beyond the actions performed by a model, nor that the behavior

is necessarily maladaptive or dysfunctional in children's everyday lives. What the term OI implies is that an individual is imitating more than is necessary in the context at hand, assuming a certain goal such as extracting a reward from a puzzle box. We understand that the label OI may be misinterpreted, but we suggest continuing to use the label simply because consistent terminology facilitates communication in science, and scores of studies over the last decade have referred to imitation of perceivably unnecessary actions as OI.

In order to gain clarity on the investigation of OI, below we differentiate OI from other types of imitation, as the term OI has sometimes been used to describe related but slightly different phenomena. Additionally, some phenomena have not necessarily been labeled OI originally, but are often cited in studies on OI.

Most researchers restrict OI to events in which it is possible for the participants to perceive the causal irrelevance of such actions, as when a necessary physical connection between a tool and its target is visibly lacking (Lyons, Damrosch, Lin, Macris, & Keil, 2011). Occasionally the term OI has been used in a broader sense, including events in which participants cannot infer the causal irrelevance of the modeled actions (Flynn & Smith, 2012). We note that imitation of such actions does not fall under our definition of OI and should rather be considered learning about object functions, as in the case of the actions performed on the opaque puzzle box in the original study by Horner and Whiten (2005).

In accordance with the original definition of OI by Lyons and colleagues (2007), we focus our definition of OI on unnecessary "extra" actions that are added by a model to an action or action sequence that ultimately achieves a certain goal, such as the retrieval of a reward. In a related line of research, the imitation of effective but *inefficient* or *unusual* actions has been studied (Buttelmann, Carpenter, Call, & Tomasello, 2007; Kiraly, Csibra, & Gergely, 2013; Nagell, Olguin, & Tomasello, 1993) or the copying of tool use when it would

be simpler to use one's hand to achieve the result at stake (Buttelmann, Carpenter, Call, & Tomasello, 2008; Nielsen & Hudry, 2010; Nielsen, Simcock, & Jenkins, 2008) or when a more efficient tool is available (Corriveau et al., 2017). In contrast to OI-actions, which, by definition, do not serve an obvious function, inefficient or unusual actions are principally functional and lead to the intended goal. Together with OI, these instances of high-fidelity imitation can be considered *faithful imitation*, which is sometimes operationalised as including imitation of irrelevant actions (Legare, Wen, Herrmann, & Whitehouse, 2015; Over & Carpenter, 2009). For example, Over and Carpenter (2009) calculated an imitation score including faithfulness of tool-selection, imitation of an irrelevant action (the one aspect of the task which we would define as OI) and the number of performed relevant actions (turning on a light). As such, the term faithful imitation can be considered an umbrella term encompassing OI but also other forms of high-fidelity imitation.

Some of the tasks involved in these studies are adopted from those investigating a phenomenon called *rational imitation* (Gergely, Bekkering, & Kiraly, 2002). Rational imitation describes the finding that 14-month-old infants tend to not imitate the use of inefficient means if there is a plausible explanation for why the model applied them (e.g. she used her head instead of her hands to operate an apparatus because her hands were occupied by holding something). There are links between rational imitation and OI insofar as the latter has also been reported to occur selectively in several studies (Schleihauf, Graetz, Pauen, & Hoehl, 2018), and indeed, perhaps initially counter-intuitively, there are reasons to consider OI *rational* imitation behavior (Keupp, Bancken, Schillmoller, Rakoczy, & Behne, 2016; Keupp, Behne, & Rakoczy, 2018) as discussed further below. Furthermore, children's performance in OI tasks involving irrelevant actions correlates with performance in imitation

tasks involving the inefficient execution of an action, suggesting related underlying mechanisms (Yu & Kushnir, 2016).

Main experimental approaches and potential "hidden factors" influencing OI

By now a great variety of tasks has been designed to investigate imitation of irrelevant actions. What all these tasks have in common is that participants observe at least one model performing both irrelevant and relevant actions on an object and that they are subsequently given a chance to operate the object themselves (see *Figure 1*). However, tasks differ in many aspects, such as their complexity, whether tools are needed to perform irrelevant or relevant actions, their transparency, or the outcomes which are achieved. Certain aspects of the task and context may systematically affect participants' behavior and consequently lead to diverging conclusions. Therefore, a systematic overview is warranted. In *Table 1* we provide an overview of variations of experimental approaches that may unnecessarily interfere with comparability between studies. In the electronic supplementary information we offer a more comprehensive overview and discussion of potentially "hidden factors" in experimental setups and designs that we hope will be useful for researchers designing OI studies. We complement this review with Supplementary Table 1 featuring concise summaries of 54 studies published between 2005 and 2018, in which OI was operationalized in accordance with our definition. In addition, Supplementary Table 2 consists of imitation studies not meeting our strict definition of OI. However, these studies are related to OI and often intrinsically relevant to the principal issues of interest, so for completeness we list them, as they may be helpful to researchers in this field.

- *Insert Figure 1 here* -

Table 1

Overview of "hidden factors" with regard to main experimental approaches (for a detailed discussion see electronic supplementary material)

Apparatus and types of actions	– Apparatus (e.g., puzzle boxes made from various materials) – Relevant action goal: reward extraction, change of materials, production of an effect (e.g., sound or light) or handicraft – Action type: tool (y/n), object-directed, self-directed, making contact with target (y/n), gesture
Demonstration format	– Live or video – Number of demonstration events
Verbal instructions	– Framing the action context (e.g., conventional, instrumental, neutral) – Additional instructions, e.g. to avoid "silly" actions
Test phase	– Presence of the model or another adult (e.g., experimenter, parent)
Characteristics of the model (complements those discussed in section 'characteristics of the	– Human or puppet – Gender – Number of models

model', see below)

Baseline condition	– Yes/no
Coding OI	– Proportional scores – Total frequency – Number of repetitions – Binary – Dealing with partially performed irrelevant actions

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Underlying and contributing cognitive processes and motivations

Since the first published reports, the phenomenon of OI has inspired lively debates on the underlying cognitive processes and mechanisms. Whereas early accounts stressed cognitive processes relating to causal reasoning (Lyons et al., 2011), soon many researchers focused more on social-cognitive mechanisms and social motivations (Kenward, Karlsson, & Persson, 2011; Nielsen & Blank, 2011). More recent accounts tend to be more integrative, taking into account several potentially relevant factors and their relative influence depending on the situation (Over & Carpenter, 2012). In general, imitation serves two distinguishable kinds of functions (Clegg & Legare, 2016; Over & Carpenter, 2012; Uzgiris, 1981): (1) cognitive and instrumental functions, such as understanding others' actions, learning about tool functions or learning a new skill, and (2) social functions, such as affiliating with the model or "communicating mutuality" as Uzgiris put it. Depending on the context and the identity of the model, children's goals may vary in a given situation, emphasizing learning

goals versus social goals, which will consequently affect their tendency to selectively imitate or over-imitate (Over & Carpenter, 2012; Schleihauf et al., 2018).

In the following section we first consider the influence of the experimental setting, as opposed to real-life situations, before discussing the influence of distinct cognitive processes such as causal reasoning and normative action parsing. We then consider the relationship between model and imitator in terms of affiliative motives and pedagogical settings.

Do OI rates in experimental scenarios reflect real-world OI rates?

Like most phenomena in cognitive developmental psychology, OI is commonly studied in controlled, child-friendly and playful experimental settings. Irrespective of where these studies take place (university laboratories, kindergartens, science museums, etc.), the participating children understand that this is some kind of special event on the one hand and that whatever they do, there will be no real harmful consequences, on the other hand (but see Whiten et al. 2016, for an approach designed to avoid such expectations). Of course, a friendly atmosphere is desirable to ensure the children's willingness to play along and have a positive experience. However, there might be some unwanted side-effects that might lead to mis-estimating the real-world occurrence of OI. It is important to note that OI is also robustly elicited in naturalistic contexts that are not particularly playful. OI can even be observed when participants, both children and adults, are unaware of taking part in an experiment (Whiten et al., 2016). Thus, we do not wish to imply that the phenomenon is the mere result of artificial circumstances in laboratory experiments. Nevertheless we think it is important and useful to point out some of the factors that might increase OI rates in common experimental setups, leading to a higher degree of occurrence than might be expected in children's daily lives.

Firstly, the experimental context in general might trigger expectations; for example, children might feel the need to "do well". Social desirability is a classic artefact in

psychological studies with adults (Paulhus, 1991) and might also apply to children and to OI scenarios (see Over & Carpenter, 2012). When children observe an experimenter perform an action sequence, in which some elements appear unnecessary to bring about a particular perceivable effect, and they do not get additional information (for example that "this is one of several possible ways to do this", but see Moraru, Gomez, & McGuigan, 2016), they may possibly infer that what is expected of them is more than just reproducing the outcome. From the participants' point of view, a very obvious additional aspect that the experimenter might care about is to verify that participants are attentive to the task. However, to confirm their attentiveness children might make more effort to faithfully reproduce what they saw than they would outside of an experimental context. High rates of OI in experiments might thus reflect a biased picture of OI rates in the real world. A related but slightly different aspect concerns children's still developing conversational understanding and pragmatic competence that might lead to different expectations in testing contexts compared to older participants. For example, preschoolers regularly change their answers when being asked the same question repeatedly by an experimenter, apparently attempting to satisfy the experimenter who is assumed to expect something different or otherwise would not ask the same thing again (see Siegal & Surian, 2004, for a review on conceptual development and conversational understanding and Donaldson, 1978, for a critique of Piaget's classic paradigms underestimating children's cognitive abilities due to ambiguous or misleading test questions). Similarly, children might perceive the exaggerated, obvious irrelevance of some demonstrated actions in staged OI test situations as differently restricting or implicative of the desired behavior than that intended by the researchers.

Secondly, most experimental contexts provide i) objects that naturally elicit children's attention and interest and ii) a playful atmosphere, in which children might instinctively

assume that there are some rules about how to play with the study materials (usually novel objects) and in which there is no pressure to do things in instrumentally efficient ways. There is ample evidence that children are prone to interpret situations with pedagogical character (especially if these involve ostensive cues) as potentially conveying something to learn (Csibra & Gergely, 2009; DiYanni & Kelemen, 2008). A setting that is presented as "participating in a study" will naturally have this character. Taken together, such experimental situations may foster exploratory rather than efficient behavior and emphasize social goals (i.e., to comply with behavioral standards relating to the new objects). This might result in children interpreting the actions they see in generic, normative terms, more than they would under natural conditions.

Might such effects explain why children in a study by Lyons and colleagues (2011) accepted to repeatedly lose a race game against an Orangutan puppet as a consequence of sticking to an inefficient method when retrieving a reward? It seems children readily jumped to normative conclusions ("Everyone ought to do it this way including the orangutan puppet - hence I play fair and adhere to the norm") when they would not have needed to. Findings of Nielsen, Cucchiaro, and Mohamedally (2012) further indicate that playful contexts might introduce a bias in OI rates: children transmitted irrelevant actions more faithfully along transmission chains when they were first introduced in a playful compared to a serious manner. Furthermore, children show much higher OI rates when first observing and performing inefficient action sequences to retrieve a reward, thus establishing a playful context, than when first observing and performing efficient action sequences (Schleihauf et al., 2018).

This raises the broad question of what one is actually measuring when investigating OI in experimental settings and whether the methods used present a valid measure of the

phenomenon. Some studies recently tried to address these concerns directly. Whiten et al. (2016) demonstrated that children (as well as adults) over-imitated a stranger's actions on a puzzle box in a real-world scenario, in which the participants were unaware that they were taking part in an experiment. This finding corroborates the notion that OI can be a vehicle for culturally opaque knowledge and thus play an important role in human cultural evolution (Legare & Nielsen, 2015; Nielsen et al., 2012) rather than being merely an artefact of experimental situations. However, this does not necessarily mean that OI rates in more controlled experimental settings are not biased towards pervading normative tendencies and implicit social demands that might affect participants' behavior.

Two studies that looked at preschoolers' OI in contexts designed to offer some privacy to participants after the official experiment had ended, found ambiguous results. While 3- to 5-year-old children continued to over-imitate outside of the experimental context and even with additionally introduced time constraints in an early study by Lyons and colleagues (Lyons et al., 2007), similarly aged children in a recent study by McGuigan and Robertson (2015), adopted an efficient strategy after the experiment was declared officially over (despite the majority having over-imitated during the experiment). Thus, more research is needed to shed light onto children's strategies outside of the laboratory and experimental context.

At this point it is hard to draw conclusions about the impact of specific social demands on OI across studies because, as reviewed above (see also supplementary material), studies differ considerably regarding experimental procedures (e.g., number and nature of demonstrations), materials (i.e., apparatuses) and coding (e.g., the level of detail of action copying required for being coded as OI). A picture that seems to emerge is that the presence of an audience during action performance and the way an action is introduced communicatively by an experimenter may have a substantial impact on imitation strategy.

Furthermore, in most studies (though not all: Whiten et al., 2016), a playful atmosphere and social desirability effects may induce higher OI rates than would be expected in everyday situations. We discuss in more detail the influences of different social and contextual factors in the following sections.

The role of causal reasoning in interaction with social motivations for over-imitation

Our definition of OI emphasizes that the imitated actions have to be perceivably unnecessary to achieve the goal of the action sequence, e.g., the retrieval of a reward. If this is not the case, e.g., because the mechanics of the task are opaque, imitation of any intentional action is a rational strategy and can be considered observational learning about object functions rather than OI. For instance, in one of the conditions of the study by Horner and Whiten (2005) an opaque box was used such that the irrelevance of some of the actions was not immediately clear. Thus, when children (and likewise chimpanzees) replicated those actions, this would not be considered OI. However, it can be difficult to tell whether individual actions within an action sequence serve a function or not, especially when the action sequence and involved objects are novel to the perceiver, as is usually the case in OI studies. Even if removing a bolt attached to the outside of a transparent container looks as if it cannot possibly affect what happens to the reward inside, is it not conceivable that children with experience of devices such as remote-controllers believe it may have a useful effect?

Asking children to justify their behavior is one way to explore this possibility. Kenward et al. (2011) asked 5-year-old children whether they would perform unnecessary actions they had just observed to retrieve a reward and if so why. Many of those children who stated that they would perform an unnecessary action claimed that they did not know why they would do this, whereas children were well able to explain the function of the necessary action. Many participants were uncertain as to whether the irrelevant action would be

necessary to retrieve the reward. This finding speaks against the idea that children generally think that all modeled actions actually have an effect. However, as the authors point out there might be a dissociation between what children are thinking and what they can verbally express.

Some researchers have speculated that children in OI studies are essentially misled about which actions are relevant to achieve the given goal (Lyons et al., 2011; Lyons et al., 2007). Lyons and colleagues suggested that children automatically encode intentional actions they observe as causally relevant (*Automatic Causal Encoding* account). Gardiner, Greif, and Bjorklund (2011) similarly propose that children use the intentionality of observed actions to infer causation. As one could argue that in everyday life most intentional actions serve a function, it would be an efficient way to learn from others to copy all they do in a deliberate manner. This is essentially what Whiten, Horner, and Marshall-Pescini (2005) proposed in suggesting that the phenomenon later termed OI might reflect a 'rule of thumb' strategy (i.e. usually functional but sometimes misfiring), to acquire useful techniques in a highly causally opaque world. The phenomenon of OI, as revealed in the experimenter-contrived situation of an OI study, would then essentially be a rare mistake that occurs when a child happens to observe a purposely non-functional action, including cases contrived by experimenters.

In fact, children do not imitate irrelevant actions that are marked as accidental or unintentional (Gardiner et al., 2011; Lyons et al., 2011). It is less clear, however, whether children actually interpret intentionally performed irrelevant actions as causally relevant or whether they imitate them regardless of their irrelevance being obvious to them. In order to shed light on this question it is necessary to create conditions in which it is absolutely clear that the modeled irrelevant actions serve no function in achieving the given goal. This can be achieved, for instance, through modeling causally unnecessary actions after the functional

goal of the action sequence has already been achieved (Nielsen, Kapitany, & Elkins, 2015) or when these actions are demonstrated in the absence of a goal (Nielsen, Tomaselli, & Kapitány, 2018). Children copied unnecessary actions in these studies at high frequencies, supporting the notion that children knew that these actions were unconnected to any tangible goal, but they reproduced them nonetheless because they interpreted these actions as ritualistic or normative.

In other cases, disconnecting unnecessary actions clearly from the action sequence's goal did result in reduced OI rates, however. In one study, 5-year-olds children observed irrelevant actions that were performed on a second container that did not contain a reward (Lyons et al., 2007). While in one condition this container was directly connected to the reward container through a bridge, in the other condition this connection was broken. The idea was that any action on the unconnected container would violate the "contact principle", i.e. the rule that a mechanical effect cannot be achieved without direct contact (Spelke, 1990). So, if children imitated out of a desire to affiliate with the experimenter or adhere to social rules, they should do so even if it is mechanically impossible for them to achieve an effect on the reward. If, however, children's causal understanding plays a role and they are misled about the task's functional mechanisms when observing an intentional irrelevant action, the violation of a fundamental physical rule may actually impede OI. In fact, children imitated irrelevant actions that were performed on the second container only when it was physically connected to the container with the reward. Children imitated actions significantly less frequently in the unconnected-container condition in which their performance of irrelevant actions was at baseline level.

This result is difficult to explain from the perspective of social motivations alone. Why would children not interpret actions performed on the unconnected container as socially

relevant behaviors? Or if they did, why would they consequently not imitate them? It is possible that children did not question the relevance of actions performed on the connected container, displaying a form of blanket copying. Actions performed on the unconnected container, however, were clearly unnecessary and might have required a certain level of social pressure and/or a high level of affiliative motivation to trigger imitation. It is important to note that children in this study were left alone during the test phase and explicitly discouraged from performing any "silly and extra" actions. Thus, social pressure to imitate was minimized. This is in contrast to studies by Watson-Jones, Legare, Whitehouse, and Clegg (2014), Clay and Tennie (2017), and Clegg and Legare (2016b) in which children imitated actions physically unconnected to the goal/reward, but in which the normative pressure was likely increased through the presence of the experimenter during test and, in some conditions, normative language. Thus, when modeled actions are at odds with children's causal understanding of the task mechanics, social motivations and pressures seem to play a particularly important role, pointing at interesting interactions between different cognitive mechanisms affecting children's behavior.

Several other findings speak against the notion that children do not imitate irrelevant actions when they can be sure that they are not required to achieve the goal. Notable examples are studies in which children did copy irrelevant actions after having observed other people retrieve a reward without any of these actions. For instance, in a study by Nielsen and Blank (2011) children first observed two adults retrieve a reward, one of whom did perform unnecessary actions and the other one did not. Then, one of the adults left the room and the other one stayed and handed the reward container over to the child. Intriguingly, children in this case adjusted their behavior according to what the person handing over the container had demonstrated. They performed unnecessary actions when the adult who had modeled these

actions stayed and they omitted these actions when the person who had modeled them left. Thus, in some cases children over-imitated, even though they had just observed someone succeed in the task without unnecessary actions. However, in stark contrast to the above-mentioned study by Lyons and colleagues, social pressure was significantly higher as the adult actually stayed in the room when children manipulated the container.

In a study by Hoehl, Zettersten, Schleihauf, Grätz, and Pauen (2014) 5-year-old children also observed two different ways to retrieve a reward, but social pressure to imitate was reduced. Children were alone in the room during test and they were explicitly told that they could get the reward however they wished. When they first saw a communicative adult retrieve a reward through a series of unnecessary and (one) necessary actions, they over-imitated as in previous research. When a second communicative adult subsequently showed them the efficient way to retrieve the reward, children readily switched strategies and omitted extra actions. Intriguingly though, children kept performing those unnecessary actions in the second phase of the experiment if the efficient model was uncommunicative. Thus, even though they were alone and encouraged to perform whatever actions they wished, children over-imitated after just having seen that those actions were not actually required to attain the reward. This finding is hard to reconcile with the idea of automatic causal encoding unless we assume that children's distorted causal beliefs are very robust and cannot easily be corrected through further observations of someone else succeeding in the task by using only relevant actions.

Another interesting observation in this study was that different kinds of actions were not imitated at equal frequencies. The least frequently imitated actions were those that were not performed on the reward container (clapping and tapping a tool on the hand) whereas actions performed directly on the container were copied at a higher rate (pushing a lever at the

top of the box and pushing a button on the side of the box with the tool) (see also Taniguchi & Sanefuji, 2017). Thus, as in the study by Lyons et al. (2007) children largely omitted actions that could not possibly cause any mechanical effect on the reward due to violation of the contact principle in the absence of social pressure. Again, it should be noted that children have been observed to imitate such actions in studies with a higher likelihood of normative pressure, such as when the experimenter remains present during test (Clay & Tennie, 2017; Watson-Jones et al., 2014).

In sum, several studies show that under some circumstances children continue to imitate visibly causally unnecessary actions even if they have seen others succeed in the task without performing them. They may do so even when they are alone during the test phase. Importantly, even when alone during test, children might have a strong motivation to comply with behavioral norms and affiliate with the model by being more similar through adopting the models' actions. Retention of socially acquired causally irrelevant actions in spite of knowledge of an efficient strategy as shown in Hoehl et al. (2014) speaks to the relevance of social motivations even in the absence of immediate normative pressure rather than distorted causal reasoning. On the other hand, children do not imitate all actions equally: in particular those actions that cannot mechanically affect the reward are often omitted when social pressure is kept low during test. This puts into question interpretations based purely on social motivations.

Results from other studies also emphasize the importance of both causal reasoning and social motivations contributing to the phenomenon of OI. Wood, Kendal, and Flynn (2013) tested the effect of prior experience on OI in 5-year-old children. In a first phase, children received either a social demonstration of the task by a puppet or had the opportunity to personally explore the reward container. When children were later shown alternative ways to

solve the task, including irrelevant actions, children in the social demonstration condition often incorporated inefficient actions in their repertoire and tended to switch between solutions over several response trials. In contrast, children with personally acquired experience with the task were less likely to copy socially demonstrated irrelevant actions. Thus, self-acquired experience and presumably resultant understanding of the causal mechanisms seemed to make children less susceptible to socially learning an inefficient task solution when compared to children who had initially received a social demonstration (although see Nielsen & Tomaselli, 2010).

Schleihauf et al. (2018) manipulated children's insight into the causal mechanisms of the task. If distorted causal reasoning underlies OI, children should show less imitation of irrelevant actions with increasing task transparency, because they should be less easily confused. In contrast, if social motives underlie OI behavior, increasing task transparency should not decrease OI, because obviously irrelevant actions should be interpreted as social norms or game rules. First, Schleihauf and colleagues tested whether the visibility of the reward affected 5-year-olds' imitation of irrelevant actions. Even though the irrelevant actions that were performed by an adult model had no effect on the reward that was constantly visible, and even though children were left alone in the room, they over-imitated when it was their turn to retrieve a reward. In accordance with this, Marsh, Ropar, and Hamilton (2014) reported OI in 5- to 8-year-old children in tasks with very simple and familiar objects requiring minimal causal reasoning demands. Interestingly, OI increased with age in this study, and children who imitated an irrelevant action were subsequently more likely to rate it as "silly" and not sensible. Thus, the more obviously causally irrelevant an action is, the more likely children seem to interpret it as a behavioral norm or game rule and consequently over-imitate (see also Froese & Leavens, 2014; Nielsen et al., 2018).

In further conditions, Schleihauf and colleagues (2018) tested whether children would also switch from a socially acquired efficient solution in order to perform socially demonstrated unnecessary actions. When children were first shown how to retrieve the reward using only the relevant action, their execution of irrelevant actions dropped to zero and, thus, below baseline level. After subsequent demonstration of an action sequence including unnecessary actions by a second model, some children incorporated some of the irrelevant actions into their repertoire, but overall performance of irrelevant actions stayed at baseline level. Thus, children's insights into the mechanisms of the task can substantially reduce OI. This overall pattern of results is in line with the suggestion by Over and Carpenter (2012) that both learning goals and social goals may drive children's behavior in imitation tasks. Depending on the task context one type of goal might be emphasized at the expense of the other. For instance, when children are first shown or personally discover an efficient strategy to retrieve a reward, this might lead to an emphasis on learning goals in the experimental setting. Thus, children are less inclined to later copy actions that they already know are unnecessary to attain the reward. If on the other hand, children are first shown action sequences that contain obviously irrelevant actions, this might lead to the assumption that the way the reward is retrieved is actually relevant, thus activating social goals like the motivation to conform to behavior norms and to affiliate with others.

To sum up this section, children's confusion about the causal mechanisms within a task cannot fully account for the phenomenon of OI, since there are instances when children copy unnecessary actions even though they clearly "know better" and even state that the imitated action is "silly". On the other hand, it cannot be denied that causal reasoning can play a crucial role. In several studies, actions that could not possibly have a mechanical effect on the reward were copied at a considerably lower frequency than actions that might have an

effect on the reward, such as those performed on the reward container directly. Also, personal experience with relevant actions leading to success at the task reduces children's inclination to incorporate unnecessary actions into their repertoire of action strategies. It seems that the relative impact of social motivations vs. learning goals (e.g., to retrieve the reward in the most efficient manner) depends on contextual factors such as which strategy is presented first and the extent of social pressure children might experience. Next, we more closely examine the decidedly social functions of OI, in particular OI as normative action parsing and the affiliative motives that might often drive the behavior.

Over-imitation as normative action parsing

As discussed in the previous section, it is now generally acknowledged that probably not one single mechanism is responsible for OI but rather that it is a multifaceted phenomenon driven by a variety of underlying motivations and serving more than one function according to context. One of the suggested mechanisms of relevance is normative action parsing. While it had been established before that imitation and norm learning are tightly linked to human culture (e.g., Tomasello, Carpenter, Call, Behne, & Moll, 2005), Kenward and colleagues (2011) were the first to explicitly relate normativity to the phenomenon of OI. They suggested that OI might be a consequence of perceiving the demonstrated actions as prescriptive norms and demonstrated that 3- and 5-year-old children indeed seem to hold normative beliefs about causally unnecessary actions without being able to explicitly attribute them to a specific domain (e.g., conventional or practical/prudential normativity). When asked about which course of action they intend to follow before it was their turn at the task, the majority of children reported that they intended to perform both necessary and unnecessary actions. When asked why they would perform the actions, children frequently explained that a causally necessary action was indeed necessary due to causal

reasons whereas they expressed uncertainty as to why the causally unnecessary actions should be performed.

Following up on this idea, several studies have provided compelling evidence that such normative beliefs about causally unnecessary actions refer to other than causal normative demands (Kenward, 2012; Keupp, Behne, & Rakoczy, 2013). Norms guide actions by setting standards of appropriate behavior that are mutually expected from participants in the norm. Normative phenomena are different from mere behavioral regularities in that they entail normative force (one 'ought' to adhere) and the possibility of error. This means that within the scope of a given norm, people who have committed to the norm experience deviations from the behavioral standard as norm violations, which deserve to be sanctioned. In OI scenarios, this becomes evident in the context of children's spontaneous third-party criticism of agents when these agents (often even just puppets) omit causally unnecessary actions. Such protests may continue even after the goal of an instrumental action sequence has been successfully achieved.

Subsequent elaborations of the normative account of OI focused on action parsing processes that might underlie the phenomenon and its normative interpretation. Children from around 10 months of age can discern the structure of intentional actions as comprising meaningful units (Baldwin, Baird, Saylor, & Clark, 2001) and from around 2-3 years of age they are sensitive to the conventionality and normative structure of actions (Diesendruck & Markson, 2011; Rakoczy & Schmidt, 2013). This then allows children to form different representations of observed actions depending on which goal results as the hierarchically most important in the underlying action parsing process. We already know from previous studies that prior intentions, new information and the actual presence/absence of a goal can alter children's goal interpretations (Bekkering, Wohlschlager, & Gattis, 2000; Carpenter, Call, &

Tomasello, 2005; Southgate, Chevallier, & Csibra, 2009) with sometimes the means of bringing about a goal and sometimes the attainment of the goal itself being the hierarchically most important goal. An instructive example is that children will imitate a specific movement style to transport a toy animal into its designated house when they have prior information that the house is the animal's home, i.e., they pay specific attention to the movement style because it is new information and thus assume it is being provided for a relevant reason. If this information was not provided prior to action demonstration, children will more often not copy the action style but transport the animal in any which way to the house, i.e., they assume the relevant information is that the animal ends up in its house (Southgate et al., 2009).

OI scenarios usually have the following abstract structure: a model performs a causally unnecessary action A (e.g., tapping on a box with a stick), a causally necessary action B (e.g., opening the door of the box), and this results in an effect E or attainment of a goal (e.g., the reward is accessible). According to Keupp and colleagues (Keupp et al., 2013; Keupp, Behne, Zachow, Kasbohm, & Rakoczy, 2015), this A-B-E sequence can be parsed and interpreted in different ways depending on various situational parameters, which results in flexible occurrence of OI depending on context-relative rational action interpretation.

When children's rational action parsing leads them to determine that "bringing about E" is what this is about, then they are not (and nobody else is) bound to bring about the effect E by the same means as the model did (they are, however, bound to choose a course of action that will ultimately bring about E, otherwise they violate instrumental normativity, i.e. according to the determined goal to bring about E they must choose an appropriate means to this end). If, however, "A-B-E" has been determined as what the activity is about, then children are (and everybody else is) bound to bring about the effect by performing both actions A and B.

Some recent findings provide support for this account of OI as a consequence of rational, normative action interpretation. Firstly, children over-imitate more frequently in conventional than instrumental contexts (Herrmann, Legare, Harris, & Whitehouse, 2013; Keupp et al., 2016; Keupp et al., 2015; Watson-Jones et al., 2014). Secondly, Keupp et al. (2015) showed that children have different representations of a demonstrated action available and can choose which one to act upon as a function of the context of action production. Finally, children's responses to a co-player who omits causally unnecessary actions or does things differently indicate that they interpret what they have seen in generic normative terms. They criticize puppets for omitting causally unnecessary actions, especially when actions had been marked as conventional activities in various ways (verbal labelling: Keupp et al., 2013, 2015, 2016; start-/end-state equivalency: Watson-Jones et al., 2014) and label such actions as "incorrect" (Keupp et al., 2013).

Note that this account does not specify the nature of the relationship between A and E and is not restricted to conventionally related action sequences. Sometimes A-B-E is conventionally connected and conventional normativity dictates that A ought to be performed. But it is equally possible that, for example, A-B-E happens to be a model's preferred way to bring about E and then it is an affiliative motive that dictates that A ought to be performed. This rational normative action account also leaves room for the possibility that sometimes it is not appropriate to perform A. This is the case when, for example, action A bears negative consequences in the context of action performance. Keupp et al. (2016) recently showed that children over-imitated less frequently in conditions in which the performance of action A resulted in the loss of a valuable item of the experimenter. This was the case for instrumental as well as conventional conditions. That is, while conventional normativity dictated performance of action A in non-costly contexts (more OI in conventional than instrumental

condition), the introduction of a conflicting normative demand (namely, one ought not to cause harm to others) changed the pattern of children's own OI as well as their third-party critique as a response to a puppet's omission or performance of action A. This leads to many interesting questions regarding how children (and adults) integrate the various rational considerations and their interactions that we are usually faced with in real life. Future research could focus on, for example, how patterns of action parsing might change with age, the role of pedagogical cues in situations with conflicting rational demands or when personal goals or preferences meet broader social demands.

Rituals as a special case of normative actions. Other readings of what could be subsumed under the broad term "normative accounts" focus specifically on the distinction between ritual and instrumental actions. Proponents of the ritual account propose that rituals are a subset of conventional behavior with distinctly social functions (Legare et al., 2015) and stress the importance of rituals for cultural learning and evolution. "Much cultural learning in human societies is motivated by affiliative goals, resulting in the acquisition of social conventions rather than instrumental behavior" (Herrmann et al., 2013, p. 537) (see also Kapitany & Nielsen, 2015; Legare & Nielsen, 2015; Nielsen, Kapitany, & Elkins, 2015). Ritualized actions are defined as being deliberate, often costly actions that are socially transmitted with the effect of signaling commitment and binding people together within groups (Rossano, 2012). Herrmann et al. (2013) propose that "[…] the psychological systems supporting the learning of instrumental skills vs. learning cultural conventions are facilitated by the use of two cognitive stances (i.e., interpretive modes). The first is an instrumental stance – seeking out a rationale for actions based on physical causation. The second is a ritual stance – seeking out a rationale for actions based on cultural convention" (p. 537). Of crucial relevance for the stance children (and adults) seek out are contextual cues such as the

presence of certain ritual-typical features (for example, repetition, redundancy, action performance is more important than the outcome, low variability, see Legare & Souza, 2012; Rossano, 2012) or causal opacity (i.e., a physical causal rationale for the action is unavailable, Kapitany & Nielsen, 2015). These are also features that characterize OI scenarios in experimental settings. It is important to note that the causal opacity as defined by Herrmann et al. (2013) does not refer to opacity in the sense of not being able to perceive the inner workings (i.e., causal mechanics) of objects, such as a puzzle box being made of opaque rather than see-through material. The absence of a physical causal rationale rather refers to the in-principle not knowable physical-causal rationale of actions that are causally transparent in the first sense. For example, if I understand that action A (e.g., tapping on the table with a stick) will not mechanically cause an effect E (e.g., making a reward available in a box on the table), then the physical-causal rationale for performing action A is absent (or opaque). As Watson-Jones et al. (2014) argue, this is also the case when effects are completely absent. Following the predictions of the ritual account, Watson-Jones et al. (2014) introduced instrumental and conventional actions by manipulating whether action performance resulted in a change of the end state of the involved objects (instrumental) or not (conventional). In the latter case, no physical-causal rationale is discernible, thus, prompting a conventional stance towards the activity. Preschoolers expressed higher imitative fidelity in conventional compared to instrumental conditions.

Another feature of rituals is their inflexibility, that is, everybody who performs a ritual must do it in the same way. The ritual account predicts that seeing several people performing an action in the same way will serve as a cue to take a ritual stance towards this behavior and result in high fidelity copying. Several studies have provided support for this prediction (Herrmann et al., 2013; McGuigan & Robertson, 2015).

We mention the ritual account separately to acknowledge that it was developed against (and is embedded in) the background of culture-specific behaviors and cross-cultural psychology. However, in conclusion, the patterns of results in studies testing the ritual account are compatible with (and probably based on) rational normative action parsing. That is, the "ritual stance" is taken when conventional normative demands are assigned to the observed behavior. In the absence of ritual/conventional cues, a behavioral response can take different forms and often manifests in less faithful re-enactment of the observed actions.

Many of the findings that are compatible with normative accounts of OI fit nicely with the idea of two functions of imitation: sometimes imitation serves a social function, for example to communicate an affiliative attitude towards the model or follow a convention, and sometimes it serves an instrumental function, for example to learn how to operate a novel tool (Over & Carpenter, 2012; Uzgiris, 1981). From an evolutionary perspective, the ability to parse actions and assign different functions to their sub-elements is very useful as it enables us to acquire skills that go beyond what we can learn individually. This is the case, for example, in complex action sequences where the effect of performing a certain action element is not directly perceivable but is of crucial importance for later steps and the final goal (Gergely & Csibra, 2006). OI can clearly serve a social function such as conforming to group behaviors and following culturally important conventions.

Relation between normative accounts and affiliative motives. One may wonder in what way normative accounts might differ from the idea that what drives children's (and probably adults') imitation of irrelevant actions is a motive to affiliate with the model. Indeed, recently Gellén and Buttelmann (2017) and Gellén and Buttelmann (2018) presented 14-, 18,-24-, and 36-month-olds with an identical imitation task and found the selectivity of 14-month-olds' imitative responses (i.e., imitation of freely performed actions and omission of modeled

actions forced by physical constraints) disappeared within the second year of life. Interestingly, older children's high levels of imitation independent of the circumstances the model was facing were accompanied by children's looks at the model while or briefly after the execution of the imitative act. The interpretation is that children imitated in order to affiliate with the model, and looked at her to ensure that she was paying attention to the child's actions (Gellén & Buttelmann, 2018).

While many of the findings that are compatible with normative accounts also fit into the framework of an affiliative function of imitation, recent findings of selective OI and, more importantly, corrective interventions challenge the notion that a desire for affiliation with the model is sufficient to explain the phenomenon. An affiliative motive alone cannot explain selective OI in instrumental vs. conventional conditions or in costly vs. non-costly conditions (Keupp et al., 2016). Moreover a desire to affiliate with the model does not naturally entail that children should also protest against a third party who omits the causally unnecessary action in her action performance, that they do so at different rates in some conditions (more so when an action sequence is framed conventionally than instrumentally) and that they explicitly label such a course of action as "wrong" (Kenward 2012; Keupp et al, 2013, 2015, 2016). Affiliation accounts cannot explain the occurrence of third party critiques without some generalizing amendments: first, children would have to assume that the model wants everybody to do it her way and second, children feel it is their responsibility to see to that. The second point means that the children believe that the performance of the unnecessary action is held to be normative (i.e., it is something that ought to be done) – otherwise they would have no reason to assume that the demonstrator would approve of its enforcement in third parties (Kenward, 2012).

Characteristics of the model: children consider adult models as teachers

Children are able to learn from other people through observation but also through direct instruction. One reason for children's OI may be that they consider adult models as teachers and expect them to show them "how things are done". According to the theory of *natural pedagogy* children are particularly inclined to acquire generic cultural knowledge when being directly addressed by an adult, e.g., through eye contact (Csibra & Gergely, 2009). For instance, 14-month-old infants are more likely to copy a novel and rather inefficient action (turning on a touch-sensitive light with the head instead of the hand even though the hands are available) when the action is presented in a communicative way as opposed to through incidental observation (Kiraly et al., 2013, though there were other differences between conditions as well, notably the distance between model and infant). According to the authors, when the adult's reason for using an inefficient means to achieve the goal of lighting up the lamp is opaque, infants encode the communicatively presented novel action as relevant information and reproduce it accordingly.

Gergely and Csibra (2006) argue that many actions that can be observed in human culture are cognitively opaque, either because complex artifacts are being used or because these actions constitute social behavioral norms. In this view, children will imitate actions without any obvious function in terms of achieving the given goal because they expect communicative adults to convey culturally relevant information. With regard to actions involving artifacts this information may concern the function of the artifact (which might be otherwise opaque) or the specific culturally shaped mode of using this artifact relating to social norms. For example, whether a particular functional action was demonstrated pedagogically or not affected which particular actions children chose to later demonstrate to naïve others (Vredenburgh, Kushnir, & Casasola, 2015). In most OI studies (although not all: Whiten et al., 2016) the model did communicate with the children before or while showing

them a particular action sequence. Thus, OI might be construed as a behavior arising from pedagogical interaction in the sense of the natural pedagogy account. However, a few studies directly manipulated the adult model's communicativeness during the demonstration and found that children's OI did not depend on communication taking place.

For example, Nielsen, Moore, and Mohamedally (2012) showed that 4-year-olds copy causally irrelevant actions even when these are not directly taught to them, but to a second adult. It did not matter whether the adult "teacher" or the adult "student" stayed in the room when it was the child's turn, but participants were never left alone with the reward box in this study. Thus, children do not seem to rely on direct engagement from the potential "teacher". However, ostensive communicative signals were present in all conditions in this study, potentially suggesting the transmission of culturally important information. Therefore, it is also important to look at situations in which the demonstration lacks clear signals of communicative intentions.

Hoehl et al. (2014) conducted a series of experiments with 5-year-old children to clarify whether OI occurs also in the complete absence of communication. In the first phase of each experiment children were presented with a series of actions, including several irrelevant actions, to retrieve a token from a puzzle box. Then it was their turn to try and retrieve a token. In the second phase children were presented with the most efficient way to retrieve the token by a second adult experimenter and afterwards had the opportunity to get a second token themselves. When it was their turn to manipulate the box, children were always alone in the room. Whether the adult experimenters were communicative or not was experimentally manipulated. Communicative models had previously engaged with the children in a warm-up game and directly addressed them when showing them how to retrieve a token from the box.

Uncommunicative ("no-contact") models, in contrast, were completely unfamiliar to the children and never addressed them directly through speech or eye contact.

Contrary to predictions based on the natural pedagogy account, children imitated causally irrelevant actions at a similar frequency in the first phases of all experiments, irrespective of whether the model addressed them directly or not. This is surprising given the stark difference between the models' behaviors in this study. Thus, this finding speaks to children's eagerness to imitate others even when only incidentally observing actions that are clearly not necessary to achieve the goal. However, communication was found to play a role in the second phase of the experiments. When children had acquired an inefficient strategy through direct instruction by the communicative experimenter, they continued to perform the nonfunctional actions even in the second phase of the experiment after observing an uncommunicative experimenter performing the efficient action only. When the second experimenter showed them the efficient action in a communicative manner, in contrast, children switched to the efficient strategy irrespective of whether the first experimenter had been communicative or not. Thus, it seems that although communication is not necessary for OI to occur, it will help children to abandon it for a more efficient strategy. In line with the results of this study, Whiten et al. (2016) reported that adults readily imitate causally irrelevant actions, even in a real-life context, from an unfamiliar confederate without direct social interaction or instruction.

Other factors that may influence whether children perceive another person as a potential teacher, apart from direct communication, are the age and assumed expertise of the model. Wood, Kendal, and Flynn (2012) showed 5-year-old children videos of an adult or a child professing either knowledge or ignorance of the task at hand. The respective model retrieved a reward using both causally relevant and irrelevant actions. Children produced

more of the irrelevant actions when these were presented by an adult as opposed to a child model. Interestingly, self-proclaimed expertise in the task had no significant effect on participants' copying behavior. Thus, children were biased to learn from adults in this study irrespective of the models' self-proclaimed knowledge status. However, children's tendency to copy adults more than same-aged peers seems to depend on the specific task and context. In a study by Wood et al. (2016), 4- to 6-year-olds were as likely to copy irrelevant actions after viewing a child as after viewing an adult model (although the number of copied irrelevancies after viewing a child was higher). The authors suggest that in this study the context was more playful and the reward box was more obviously a toy (and labeled as such) compared to the Wood et al. (2012) study. This potentially prompted children to rely as well on their peer's modeled actions as on the adult's. Thus, there seems to be no ubiquitous bias for children to copy either peers or adults in OI tasks, and self-proclaimed expertise seems to have little effect. Still, the status of an adult as a teacher (specifically the child's actual class teacher or head teacher) seems to affect OI in 5-year-old children (McGuigan, 2013).

To sum up, children and adults imitate causally irrelevant actions readily even when they are not demonstrated in a communicative manner. Still, communication has some effect on children's persistence to over-imitate (Hoehl et al., 2014). Depending on the nature of the task children preferentially imitate adult or peer models, but their behavior is hardly affected by the model's self-professed knowledge status. Thus, the model's communication and the children's inclination to see adults as teachers have some influence on children's over-imitative behavior, but they do not seem to be necessary for OI to occur.

Conclusions on cognitive and motivational factors

Considering the empirical evidence reviewed in this section, a picture of OI as a rather flexible and rational behavior emerges that depends fundamentally on the motivations being

emphasized or induced by the task context. *Figure 2* illustrates the interaction between two major factors modulating OI behavior (see also Over & Carpenter, 2012): (1) the context-dependent focus on learning goals in the task at hand which can be induced, for example, by modeling the efficient way to reach the goal first (Schleihauf et al., 2018) and (2) the degree of children's motivation to comply with the model's behavior on a continuum from a lack of motivation up to social pressure being applied. In our view, a motivation to comply with assumed behavioral norms and a wish to affiliate with the model is the default for children participating in OI experiments. In some rare instances, the motivation to comply may be reduced, for example, because the task-irrelevant actions are actually harmful to someone else (Keupp et al., 2016). In this case, OI rates will be low regardless of whether instrumental learning is emphasized or not. In other studies, actual social pressure is exerted. This is the case when normative language is used or when the model is present during test (Clegg & Legare, 2016b; Keupp et al., 2013; Nielsen & Blank, 2011) or, presumably, when the task is introduced as a (competitive) game in which irrelevant actions may be interpreted as implicit game rules (Lyons et al., 2011). When social pressure is exerted, a high rate of OI as well as an increased tendency to imitate actions that cannot possibly mechanically affect the goal (e.g., actions without contact to the reward container) can be expected, regardless of the extent to which learning goals are activated.

- Insert Figure 2 here -

Although we assume that a fundamental motivation to comply and affiliate is present even in the absence of immediate social pressure, there is of course some variance which might explain why certain models induce higher rates of OI than others (Schleihauf et al., submitted; Wood et al., 2016). In cases, in which there is social motivation to comply (or, there is no reason not to comply), but no social pressure is exerted, the dissociation between

social goals and learning goals (Over & Carpenter, 2012) becomes most relevant. If learning goals are emphasized in these cases, OI rates drop and actions that are not plausibly related to attaining the goal are mostly omitted. If learning goals are not emphasized, for example because the context is playful, relatively high rates of OI can be expected even in the absence of social pressure.

Most, if not all, of the findings on OI behavior reviewed in this section are in line with this model. It also leads to a range of testable hypotheses. For instance, OI rates should be low, regardless of the situational context, when the model is someone not liked by the observer or someone belonging to a social out-group (Krieger, Buttelmann, & Aschersleben, 2018). Furthermore, increasing social pressure should lead to imitation of irrelevant actions performed on an apparatus unconnected with the reward container in tasks such as the one used by Lyons et al. (2011). Finally, individual differences in OI performance might be related to variances in individuals' social motivations. This factor will be addressed in the following section.

Characteristics of the imitator

After discussing cognitive and motivational factors underlying and modulating OI behavior depending on the specific context, we will now focus on individual differences and the factors that might explain variance in OI behavior across individuals. We start with a review of findings on OI in children with autism spectrum disorder. Then we will discuss the potential impact of cultural background by reviewing research conducted in non-Western societies before discussing age-related changes in OI within and across cultures.

Children with autism spectrum disorder

While imitation emerges early in typically developing children (TD) and is closely linked to social-communicative motivation, imitation deficits are a central characteristic of developmental disorders, such as autism spectrum disorders (ASD) (Williams, Whiten, & Singh, 2004). Differences between TD and ASD children's imitative behaviors have been found in children as young as 2 years of age (Charman et al., 1997).

Comparing imitation in TD and ASD children is important for at least two main reasons: First, finding out about the specific nature of the imitation deficit will help to inform therapeutic interventions. For example, target-oriented imitation training can facilitate positive social interactions in and beyond training and experimental settings (Heimann et al., 2006; Ingersoll, Walton, Carlsen, & Hamlin, 2013; Nadel et al., 2000). Second, relating comorbid deficits in certain clinical patterns, such as ASD, with imitation, can inform us about causes and consequences of imitation behaviors (i.e., which factors drive imitation patterns, which cognitive functions depend on imitation or its enabling mechanisms). This seems to be an important puzzle piece to understand the complexity of human social fabrics.

Various findings indicate that the imitation deficit in ASD patients is not the consequence of a general deficit in motor abilities or general disability to match own actions with others. It seems more likely that a difference in overall social motivation drives differences in imitative behavior in TD and ASD individuals. As Van Etten and Carver (2015) point out, imitation might serve a different function in ASD and TD individuals. Thus, while the social function might be impaired in ASD children, the causal and learning function might be in place. Interestingly, in her meta-analysis, Edwards (2014) found that while imitation was impaired in ASD children, emulation (i.e., re-enacting goal achievement) was not.

Recent research indicates that the ASD imitation deficit is not universal but depends on the type of modeled action and demonstration situation. As reviewed in Van Etten and

Carver (2015), ASD children i) are more impaired regarding the imitation of body movements and gestures as compared to object-directed actions (although see Edwards, 2014, who found no difference in her meta-analysis), ii) imitate less in spontaneous than elicited imitation situations whereas TD children show no difference (Ingersoll, 2008), and iii) are often able to imitate when adequately rewarded (Ingersoll, Schreibman, & Tran, 2003).

The OI paradigm seems to be an ideal test case to explore the impairment of socially motivated imitation where actions clearly serve no causal-functional purpose. A recent study (Vivanti, Hocking, Fanning, & Dissanayake, 2017) supports the notion that ASD children's difficulties in imitation seem to be rooted in a fundamental difference of attention to the relevant social cues, specifically a lack of interest regarding social reasons for unexpected behavior. Vivanti and colleagues found that ASD preschoolers were less likely to imitate causally irrelevant actions (OI) and seemed less surprised when a demonstrator performed such causally irrelevant actions (e.g., no increase in attention to the demonstrator's face), as compared to chronological age-matched TD children. Similarly, Gonsiorowski, Williamson, and Robins (2016) found decreased imitation of causally opaque actions and attention to the demonstration in very young ASD-risk children (prior to formal diagnosis and interventions) compared to a matched control group.

Earlier studies on ASD children's OI have provided mixed findings: for example, Nielsen and Hudry (2010) and Nielsen, Slaughter, and Dissanayake (2013) found no difference in OI between ASD and control groups, whereas Marsh, Pearson, Ropar, and Hamilton (2013) found a reduced OI rate in their ASD test group. More recent reviews (Edwards, 2014; Van Etten & Carver, 2015) pointed out that characteristics of the tested samples and experimental procedures might explain some of the differences between studies. For example, higher-functioning groups of ASD participants generally showed less imitation

impairment than lower-functioning groups. Further, ASD participants were less likely to imitate when social and learning aspects were clearly separated in demonstrated actions (e.g., by using familiar actions and objects) (e.g., Marsh et al., 2013).

As of yet, the direction of the relation between imitation deficits and other social and cognitive impairments is unclear. Still, comparing TD and ASD participants in imitation and OI studies will help to pinpoint the nature of the deficits and to seek out those features that are best suited to support individuals with ASD via optimal interventions and training procedures. The current picture of specific imitation deficits in individuals with ASD stresses the role of social motivations for imitation, including OI.

Cross-cultural studies

Given the robustness of occurrence in a wide range of studies and the importance attributed to OI in the context of cultural evolution (Legare & Nielsen, 2015), we would expect it to be a universally human phenomenon. Unfortunately, OI research suffers from the same WEIRD (Western, Educated, Industrialized, Rich, and Democratic; Henrich, Heine, & Norenzayan, 2010) sampling bias as other prominent areas of cognitive-developmental research (Nielsen, Haun, Kartner, & Legare, 2017). In addition, cross-cultural studies on OI are still sparse.

So far, all studies on OI across cultural contexts have found positive results to some extent. Preschoolers from WEIRD cultural contexts (for instance, Horner & Whiten, 2005; Lyons et al., 2007), from South African bushman communities and Australian Aborigines (Nielsen, Mushin, Tomaselli, & Whiten, 2014; Nielsen & Tomaselli, 2010), from Japan (Taniguchi & Sanefuji, 2017), from Vanuatu (Clegg & Legare, 2016a), and Chinese American children (Corriveau et al., 2017) were reported to over-imitate. The factors that

influence the extent and onset of this imitation strategy might vary slightly across cultures, however. Clegg and Legare (2016a) found differences in OI between Ni-Vanuatu and US children after an instrumentally framed action demonstration, with Ni-Vanuatu children expressing higher rates of OI. Berl and Hewlett (2015) found that 4- to 7-year-olds from hunter-gatherer communities in the Central African Republic showed almost no OI, although adults from the same community did over-imitate.

Hewlett, Berl, and Roulette (2016) suggested that different developmental patterns of OI might emerge as a function of societal structures (egalitarian vs. hierarchical) and caregiving practices. Different parenting practices have indeed been found to be related to cultural differences in several domains. For example, Kärtner, Keller, Chaudhary, and Yovsi (2012) found that cultural differences regarding mirror self-recognition were best explained by differences in parents' valuing development of autonomy in children. Differences in early helping behavior between Indian and German toddlers were found to co-occur with cultural differences in socialization goals and practices (Giner Torréns & Kärtner, 2017). Similarly, differences in parenting styles might explain cultural differences in the propensity to over-imitate. Recently, Clegg, Wen, and Legare (2017) found that US parents value conformity differently compared to Ni-Vanuatu parents, with Ni-Vanuatu parents judging conforming behavior to be intelligent and 'good behavior' to a larger extent (however, see Wen, Clegg, & Legare, 2018, for different findings of children's and adolescents' evaluations of (non-) conforming learners). This might show in the social cues and feedback they provide for their children, that may indicate if imitation and conformity are desired. Cultural differences in this respect may explain differences in OI between Ni-Vanuatu and US children. Children from both cultural contexts imitated at high rates in conventional contexts, but Ni-Vanuatu children

showed more imitative conformity in instrumental contexts than did US children (Clegg & Legare, 2016a).

Over-imitation in different age groups

The task of elucidating the relationship between observer age and the occurrence of OI is necessarily a complex one as a consequence of cross-study variation in the type of task employed and the nature of the irrelevant actions modeled, as well as differences in the context in which such tasks are presented (see Table 1 and supplementary material). An additional layer of complexity arises when we consider that similarly-aged observers have been shown to differ in the extent to which they over-imitate, most notably as a consequence of being raised within different cultural environments (Berl & Hewlett, 2015), or as a result of a developmental disorder (Marsh et al., 2013). In the following section, we outline the developmental patterns evident in typically developing populations with a particular, although not exclusive, focus on the artifact domain. Our aim is not to provide an exhaustive discussion of all age differences witnessed across the many OI studies conducted; instead, we attempt to distil broad developmental patterns from the more classical OI literature, leaving important discussions of the way in which observer age interacts with more specific features of the task presented (e.g., verbal instructions, model characteristics, see earlier sections) for another occasion.

In order to detail age-related changes in OI it is first useful to consider whether developmental patterns are evident when identical, or close variations of a task, are presented to differently aged observers in directly comparable contexts. The task that has been employed most frequently, and across a variety of different age groups (spanning infancy to adulthood), is the transparent variant of the 'glass ceiling box' (see *Figure 1*, e.g., Whiten & Horner, 2005; McGuigan, Whiten, Flynn, & Horner, 2007; Lyons et al., 2007; McGuigan,

Makinson, & Whiten, 2011). In its 'traditional' format the GCB is presented within a dyadic context, in which a single adult model provides a live (or on occasion televised) demonstration for an observing individual, whilst providing limited verbal instructions. The developmental pattern revealed, counter to any expectations that children would 'grow out of' OI with greater cognitive maturity, is one in which the causally irrelevant actions are reproduced more accurately as the age of the observer increases, with 23-month-olds reproducing almost no causally irrelevant actions (McGuigan & Whiten, 2009), and the fidelity of adult observers approaching ceiling (McGuigan et al., 2011). However, the increasing level of OI does not share a straightforward linear relationship with observer age, most notably as a consequence of a dramatic upwards shift in OI (~45%) evident between late infancy and the preschool period. The authors attribute this shift to a greater focus on the model's actions, and an increased capacity to infer the intentions of the model (McGuigan & Whiten, 2009). Subsequent to this large shift in imitative fidelity we see a period of more gradual change, in which the rate of OI remains high, but evidences small increments across 3 to 6 years (Lyons et al., 2007; Moraru et al., 2016); at which point children are reproducing irrelevancies at almost equivalent levels to their highly imitative adult counterparts.

Importantly, subsequent studies have shown that the pattern of high, and increasing, levels of OI is not restricted to the GCB, with age-related increases in OI occurring across a variety of differently structured transparent puzzle boxes (Gardiner, 2014; Keupp et al., 2013; Marsh et al., 2014), and their opaque equivalents (Gardiner, 2014; McGuigan & Whiten, 2009). Similarly, age-related increases in OI have been witnessed in this age period using tasks other than puzzle boxes (e.g., for body-part imitation see Gellén & Buttelmann, 2018). For example, a suite of studies employing gesture-based OI tasks (e.g., model presses fists together before interacting with an object) have shown that older children (5-6 years) are

more imitative than their preschool counterparts (3-4 years), particularly when gestures are modeled within a conventional, as opposed to an instrumental, context (Clay, Over, & Tennie, 2018; Clegg & Legare, 2016b; Legare et al., 2015; Watson-Jones et al., 2014). Taken together the results of studies from the artifact as well as the body-part imitation domain paint a consistent picture of age-related increases in OI, with no study evidencing an age-related decrease in the reproduction of causal irrelevancies.

However, the results of studies conducted outside of these domains suggest that the relationship between observer age and the degree of OI witnessed may not be a straightforward one. In stark contrast to the age-related increase in OI witnessed with novel artifacts, Freier et al. (2015) found that OI decreased significantly from 3 to 5 years when irrelevant actions were modeled within the context of a familiar action sequence (such as making sandwich). Interestingly, the tendency to over-imitate was almost completely eradicated in both age groups when action planning was externally supported; a pattern of performance that differs sharply from that witnessed with traditional puzzle boxes where OI is notoriously difficult to prevent (Lyons et al., 2011; Lyons et al., 2007). Freier et al. (2015) propose that the developmental pattern observed resulted from the younger, 3-year-old, children being less able than their older counterparts to relate sub-actions to outcomes within the overarching goal of the task. Such an account suggests that OI within natural event sequences results, not from an active attempt to copy the causally irrelevant actions as in traditional OI tasks, but from a failure to organize the sequence of observed actions in a meaningful way. Whatever the exact source of the age-related decrease in OI witnessed in the familiar event context, direct comparisons to performance in classic tasks such as the GCB are difficult, and somewhat premature, primarily as a consequence of the very different way that the causally irrelevant actions are presented in relation to the principal goal of the task.

The developmental patterns described above were extracted from data collected from individuals raised in WEIRD cultures, leaving open the question of whether or not the same developmental timeline would be witnessed in non-WEIRD populations. Intriguingly, studies conducted with non-WEIRD participants have revealed an OI timeline that shows both similarities and differences to that of their WEIRD counterparts. With respect to cross-cultural similarities, participants from non-WEIRD cultures show an increase in the tendency to reproduce causally irrelevant actions as they age (Nielsen & Tomaselli, 2010), with Aka adults over-imitating at higher levels than Aka children, and at equivalent levels to adults from WEIRD cultures (Berl & Hewlett, 2015). However, cultural variation exists in the age at which children begin to over-imitate, with Aka children (4-7 years) demonstrating levels of OI that are: i) comparable to those produced by 23- and 30-month-old WEIRD children, and ii) significantly reduced in comparison to those displayed by same aged children from both WEIRD and non-WEIRD cultures (Ngandu) (Berl & Hewlett, 2015). It therefore appears that OI does not emerge universally in early childhood; rather, the specific developmental patterns witnessed are a consequence of a complex interplay between ontogenetic and cultural influences, worthy of further dissection.

In sum, for contexts where participants are presented with novel artifacts or actions to be imitated, the most pervasive developmental pattern witnessed is one in which OI increases from childhood through to adulthood (McGuigan et al., 2011; McGuigan et al., 2007). In WEIRD cultures this increase takes the shape of an, in some tasks, dramatic preschool shift followed by a series of incremental rises through to adulthood (McGuigan & Whiten, 2009), whereas OI in non-WEIRD cultures emerges either later (Aka), or at the same time (Ngandu), as in WEIRD cultures (Berl & Hewlett, 2015). Studies employing less traditional OI tasks have provided evidence that developmental patterns may vary according to the nature of the

task presented, with an age-related decrease in OI when familiar event sequences are employed. This complex variation in the nature of the developmental patterns witnessed warrants further, more detailed, examination of age-related changes in OI in future research.

Conclusions and future directions

In this review, we have offered an overview of the last decade of research on over-imitation and different accounts regarding the underlying mechanisms. We also focused on characteristics of the task, context and the imitator, as well as other factors leading to divergent findings across studies.

In the first part, including electronic supplementary material, we identified differences in procedures, which we showed to have a (sometimes) strong influence on rates of OI and interpretations. The social situation can also have substantial effects on OI rates. Whilst any one study is usually consistent across conditions regarding whether the imitator is alone when tested or an experimenter is present, differences in social context can lead to different behaviors across studies and interact with other factors, such as perceivable causality of actions. Recent findings suggest that the sex of model and imitator, and the format of action demonstration (live vs. video) can affect OI rates and interact with other factors. Finally, characteristics of the experimental situation, such as playfulness or the study context in general, may bias findings towards more OI and should be considered when we interpret results and connect OI with its ultimate and proximate functions.

We also addressed the question of how OI can be adequately defined. We have tried to distill, in our suggestion for defining OI, what it has essentially been meant to capture in this young field of research. We acknowledge that focusing our review on studies that incorporate "extra" unnecessary actions may exclude some studies that conceptually can be thought to

measure the same phenomenon, such as studies which operationalized OI via alternative options to act, one of which is less efficient than the other. However, we believe that clarity is gained by specifying some core boundaries in what qualifies as an instance of OI; for example, that OI should be restricted to the action domain and not be extended to the vocal domain (Subiaul, Winters, Krumpak, & Core, 2016). Word learning and communication are so intrinsically conventional that any "transparency" of what might constitute an irrelevant aspect to copy must be intrinsically fuzzy or nonexistent.

In the second part, we reviewed underlying cognitive processes as suggested by different accounts of OI and explored the foundations of a unifying theoretical framework. The suggested reasoning processes (causal, affiliative, and normative) all capture important parts of the phenomenon and none can explain all instances of OI by itself. From a young age, children include causal, normative and social reasoning in their rational action parsing and goal inferences. An important task ahead is thus to delineate the processes that are most likely activated by different situational cues. Importantly, there are substantial effects of age and culture on OI behavior. We reviewed existing findings but clearly more research is needed to address these factors more systematically. For example, we know of no study which examined OI across the lifespan including older adults – does OI simply increase ever more or eventually becomes more selective? Different age groups might also have a different perception of the causal transparency of a task; thus, it should be instructive to explore different tasks on the continuum of causal transparency and measure the effect on OI. An interesting way to manipulate the degree of causal transparency (and so far, rarely used in OI studies), could also be to provide statistical information, from which causal irrelevance of certain actions can be inferred (e.g., Buchsbaum, Gopnik, Griffiths, & Shafto, 2011). More cross-cultural studies are needed to assess the interaction of OI rates with interactive styles

and what is considered appropriate behavior in different cultures and study groups (e.g., pedagogical cues might differ depending on whether natural models emphasize the importance of performing certain actions to different degrees).

What is also missing is research regarding when a "copy all/refine later" strategy (Whiten et al., 2005) potentially comes to bear. Only few studies have looked at more than a couple of repetition trials per participant, whereas in the real world, we likely stick to a successful strategy rather longer until we begin to consider refining it. Another open question is whether OI is always deliberately performed. Perhaps it often is, or comes to be routinized as, a form of 'automatic' behavior copying based on rapid unconscious assessment of situational demands and risks – in this case, understanding all about the intentional structure of means and goals of the model is not necessary on all occasions. This would be different from an automatic causal encoding account, however, because parsing the actions as causally irrelevant is part of the assessment. Future research could explore this by assessing older participants' (e.g., school aged children or adults) reasoning and conscious processing of information during OI studies, perhaps through verbal measures.

OI is a crucial adaptation to life in our artifact-rich and conventionally opaque human culture(s) and related to other cognitive-processes and aspects of human psychology such as elevated interest in social information, conformity (Whiten, in press) and preparedness to accept others as teachers. We have endeavored to provide a usefully comprehensive review on the burgeoning field of over-imitation research and the plethora of procedural approaches that have evolved over the first ten years since the term was coined. Against the background of the current state of the literature, OI should be conceptualized as a flexible and, in fact, normally highly functional phenomenon.

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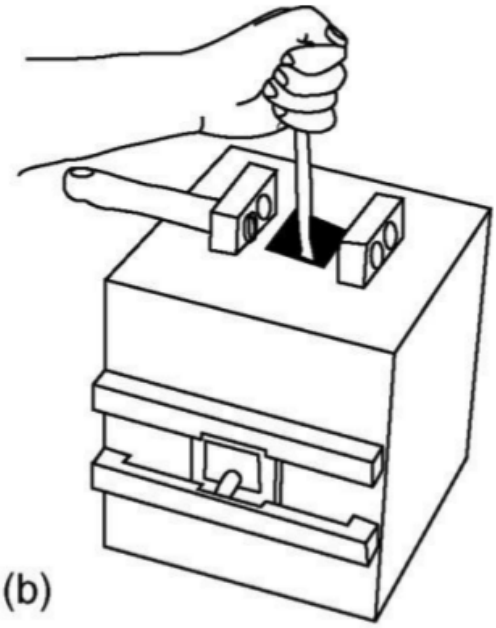
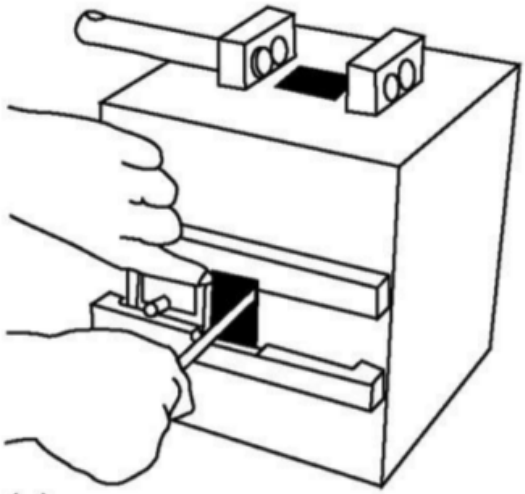
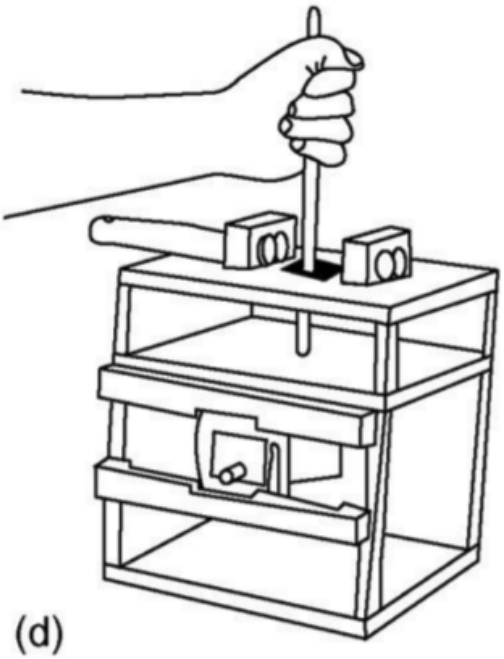
(a)



(b)



(c)



(d)

Figure *1*. Opaque and transparent puzzle boxes as used by Horner and Whiten (2005) and subsequent replications and extensions: (a) adult model demonstrating a causally unnecessary action on the transparent box; (b) model probing in top of opaque box; (c) extraction of reward from the opaque box; and (d) model probing in top of transparent box, where it can be seen that this action is ineffectual, merely hitting a barrier, a feature of the task that resulted in it being named the "glass ceiling box" (GCB). After Whiten (2005).

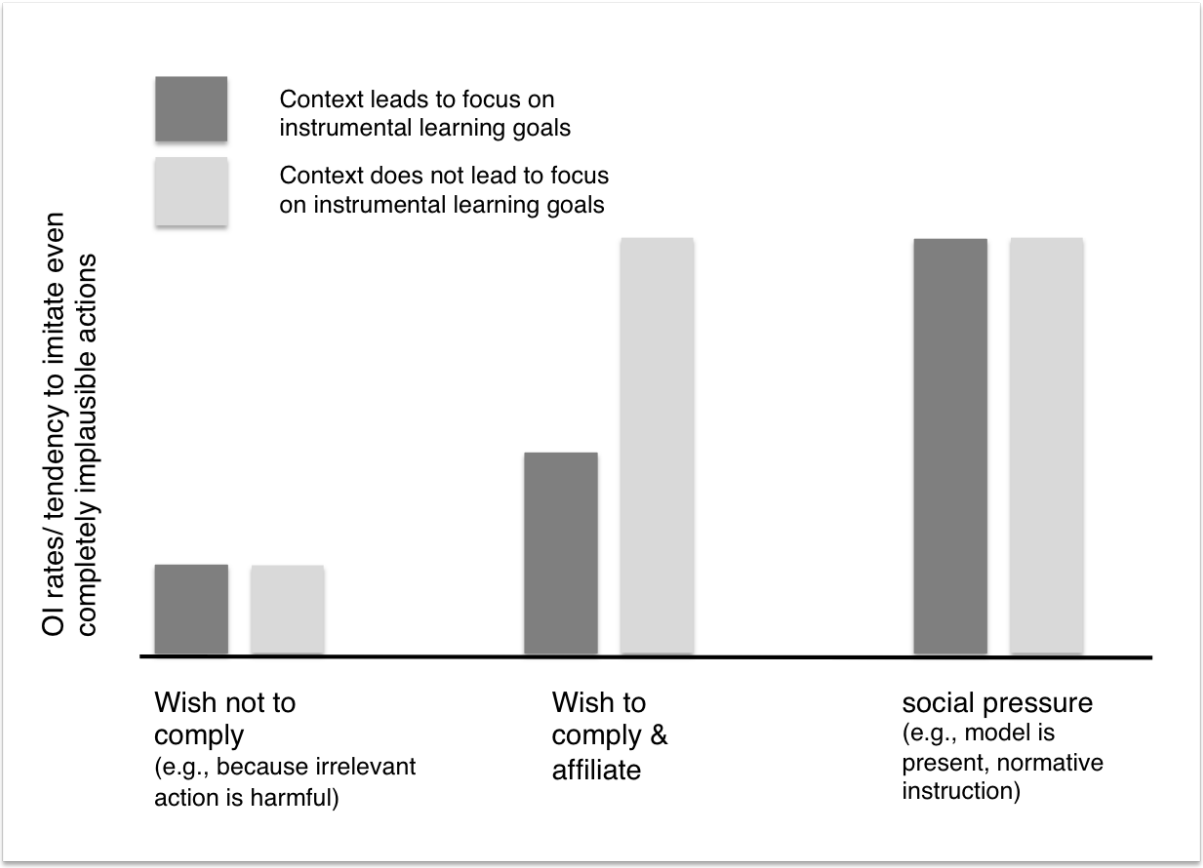


Figure 2. Illustration of the hypothesized interaction between the degree of social motivation/ social pressure and the focus on instrumental learning goals in the given context on OI rates. Actual scores illustrated are notional.

Supplement 2: Detailed review of methods and procedures used in OI research

By now a great variety of tasks has been designed to investigate imitation of irrelevant actions. What all these tasks have in common is that participants observe at least one model performing irrelevant and relevant actions on an object and are subsequently given a chance to operate on the object themselves. However, reported tasks differ in many aspects, such as their complexity, whether tools are needed to perform irrelevant or relevant actions, their transparency or the outcomes which are achieved. Certain aspects of the task and context may systematically affect the behavior and consequently lead to diverging conclusions. Therefore, a systematic overview is warranted.

Here, we offer an overview of the main experimental approaches that have been used and discuss the possible implications of diverging operationalization of OI across different studies and laboratories. We focus on variations in experimental approaches that may perhaps unnecessarily interfere with comparability between studies, whereas in the main article we focus on systematic manipulations of variables to explore their effects on OI. The purpose of this supplementary section is to (a) provide an overview on different procedures used in the literature as a source of information for researchers designing OI tasks and (b) to discuss possible implications of differences in procedures across studies when contradictory results were reported. Therefore, results of the cited studies are only discussed in this section when they illuminate effects of different procedures. We hope this overview helps guide critical decisions on study designs and also sensitizes researchers to "hidden factors" that should at least be reported and discussed, if not manipulated or counterbalanced, in studies on OI.

1. Apparatus and types of irrelevant actions

In the classical OI task, as introduced by Horner and Whiten (2005), participants can retrieve an object out of a "puzzle-box". The puzzle box is usually made out of wood

(Nielsen, Moore, & Mohamedally, 2012; Nielsen, Mushin, Tomaselli, & Whiten, 2014), plastic (Keupp, Behne, & Rakoczy, 2013), or acrylic glass (Hoehl, Zettersten, Schleihauf, Grätz, & Pauen, 2014; Horner & Whiten, 2005; Lyons, Young, & Keil, 2007), can be either transparent or opaque and at least one functionally relevant action is required to open the box.

The objects that need to be retrieved from puzzle-boxes are usually either rewards (Hoehl et al., 2014; Horner & Whiten, 2005) or objects which are needed to fulfill another task, e.g. toy jewels, which need to be cleaned (Kenward, 2012) or puzzle pieces, which are needed to complete a puzzle (Keupp, Behne, Zachow, Kasbohm, & Rakoczy, 2015). In the original study by Horner and Whiten (2005), a puzzle box made of polycarbonate ('Lexan' in the USA) was used (see *Figure 1* in the main manuscript). On the top of the box was a square hole that was covered by a bolt, which could be slid aside to expose a hole. On the front face of the box was a square hole connected to a sloping opaque tube housed inside the box. This hole was covered by a flap. A reward was placed at the bottom of the opaque tube and could be retrieved by opening the flap and inserting an aluminum tool. The irrelevant actions demonstrated were removing the top bolt and inserting the tool in the top hole. Insertion of the tool in the top hole resulted only in hitting a barrier that prevented physical contact between the tool and the reward tube. Only the number of tool insertions into the top irrelevant hole was used as a measure for OI. This was done because tool insertions could be clearly identified and quantified. That type of task was used in several later studies (McGuigan, Makinson, & Whiten, 2011; Wood, Kendal, & Flynn, 2012).

Other studies use transparent puzzle boxes with different designs, on which irrelevant and relevant actions are performed (Gardiner, 2014; Hoehl et al., 2014; Marsh, Pearson, Ropar, & Hamilton, 2013; Nielsen, Mushin, Tomaselli, & Whiten, 2016). For example, Hoehl et al. (2014) used a puzzle box with an attached lever and a button, both of which had no

functions. As irrelevant actions the demonstrator clapped her hands, then pushed the lever back and forth, then tapped a rod on the palm of her hand three times, then pushed the button with the rod. Subsequently the demonstrator performed the only relevant action: she lifted a flap that covered an opening to a tube and removed a marble from this tube by using the magnetic rod. The irrelevant actions were varied regarding their relation to the puzzle box and the rod. Interestingly, children most frequently imitated the actions that were performed on the box. Corresponding to this pattern of results, a recent study showed that it makes a significant difference what types of irrelevant actions are demonstrated, such as whether the demonstrated actions involve a tool (e.g. tapping with a tool vs. one's hand on the puzzle box) and whether they are performed on the apparatus or the demonstrator's own body (e.g. tapping with the rod on the puzzle box vs. in the palm of the hand) (Taniguchi & Sanefuji, 2017). Children over-imitated the action toward the apparatus and the action with the tool more than the action toward an actor's own body and the action without the tool. Notably, some other studies do report imitation of actions without contact to the puzzle box (Clay & Tennie, 2017) or actions directed toward the body (Clegg & Legare, 2016). Some inconsistencies in results might stem from other aspects that were different between the studies. For example, in contrast to Hoehl et al. (2014), in Clay and Tennie (2017) and Clegg and Legare (2015) the experimenters stayed in the room during children's imitation. This illustrates that seemingly small differences in procedures can lead to vastly different results and interpretations.

Beside the transparent puzzle boxes, several studies investigated OI using opaque puzzle boxes. For example, Nielsen, Kapitany, and Elkins (2015) used several wooden boxes on which both irrelevant and "causally related" (i.e., relevant but not the most efficient) actions were performed. One of the boxes could simply be opened by turning a switch. As the

irrelevant action, a stick was used to tap on the top of the box three times, then used to turn the switch (causally related action). If wooden boxes are used, the irrelevant actions are usually performed on the outer surface of the box (mostly tapping on the box), to make their irrelevance visible. However, in times of technologies such as touchscreens and voice command, it cannot be excluded that children infer that the tapping has causal relevance. The potential effects of new technologies resulting in the expansion of boundaries of causal principles (e.g., the contact principle stating that objects can be manipulated or moved only through direct contact) should be kept in mind when designing OI tasks but have not received much attention in OI research thus far (apart from a few cross-cultural studies discussed below).

How researchers try to ensure that the irrelevance of the demonstrated actions is perceivable varies significantly between studies. Some studies present irrelevant actions on the outer surface of a puzzle box (e.g, Nielsen et al., 2015), others use transparent puzzle boxes (McGuigan, Whiten, Flynn, & Horner, 2007), sometimes even with transparent reward locations (Schleihauf, Graetz, Pauen, & Hoehl, 2018). We can also find studies in which the irrelevant actions are demonstrated after the relevant action was already performed (e.g. the puzzle box was already opened, Nielsen et al., 2015) or a more efficient strategy was demonstrated earlier (Schleihauf et al., 2018).

Sometimes, gestures are demonstrated as irrelevant actions (Watson-Jones, Legare, Whitehouse, & Clegg, 2014). In a study by Watson-Jones et al. (2014) a demonstrator modeled tapping colored building bricks on top of each other and pressed her fists together in between. Here, the authors demonstrated that adding an instrumental action at the end of the demonstrated action sequence (i.e., opening a box and putting an object into it) led to lower imitative fidelity scores than skipping that instrumental action at the end (i.e., opening and

closing the box without putting anything in). In one case the focus of the demonstration was shifted to the movement of an object from one location to another (without any further need of that object), whereas in the other case the focus of the demonstration was shifted to the action sequence itself. The authors concluded that start- and end-state equivalency cues expectations of social conventionality, whereas an altered end-state cues expectations of an instrumental goal. This demonstrates how minimal changes in the procedure effect the outcome.

Especially in the animal social learning literature, it is claimed that imitation as an underlying mechanism can only be attributed when certain alternative explanations such as object movement re-enactment or goal emulation can be excluded (Whiten, Horner, Litchfield, & Marshall-Pescini, 2004). That is, as soon as a tool (e.g., a stick) is used or any part of an apparatus moves visibly, it might be the movement of the object or the changed state of the apparatus that participants re-create ("emulation") rather than "imitating" the whole action (sequence), where actions are further specified to be bodily actions. Thus, these authors might claim that copying an intransitive action such as clapping constitutes true imitation while replicating the tapping of a tool on the reward container can be explained with alternative mechanisms. Consequently, some researchers have proposed the term "over-emulation" in such contexts (McGuigan & Whiten, 2009). This may well affect children's OI and needs to be considered when designing tasks.

2. Action Goal

Whereas the initial OI studies were largely focused on the goal of retrieving a reward from a puzzle box (inspired by Horner & Whiten, 2005), more recent studies expanded the contexts to other types of action goals, such as changing the state of certain materials (Keupp et al., 2015), producing a simple effect such as a light or sound (Keupp et al., 2013; Over &

Carpenter, 2009), a handicraft (Clegg & Legare, 2016), a brick tower or a paper fan (Marsh, Ropar, & Hamilton, 2014), or preparing a sandwich (Freier, Cooper, & Mareschal, 2015).

In the study by Keupp et al. (2013), for example, the demonstrated relevant actions were to remove the barriers from a marble slide, to allow the marble to roll down and reach the Xylophone bars at the end of the slide. The demonstrated irrelevant action was turning a clock hand on a completely disconnected box beforehand. In a study by Clegg and Legare (2016) a model demonstrated to children how she made a necklace. The relevant actions were stringing the beads on a thread. The irrelevant actions consisted of touching the forehead with the beads before stringing them onto the thread. So far there is one study on OI using the floating object task (Nielsen, 2013). Here the children were presented with a clear long tube that contained a small blue plastic monkey at its base, which could float but not be reached from the top of the tube. A bottle of water and two measuring cups in different sizes were available. In different conditions, models either directly used the bottle to pour water into the tube or they used one of the measuring cups to do so.

A relatively new development is the expansion of the OI concept to the vocal or linguistic domain (Bannard, Klinger, & Tomasello, 2013; Subiaul, Winters, Krumpak, & Core, 2016). For example, Subiaul et al. (2016) found that preschoolers adopted a model's unusual pronunciation in a word naming task and defined this vocal imitation as an instance of OI outside the artifact domain. As such findings do not meet our criteria for OI we will not discuss them further.

Taken together, the demonstrated action sequences in OI tasks can be separated into actions, which are necessary to produce the designated effect (relevant actions) and actions, which are not necessary to produce the designated effect (irrelevant actions), but may well have other effects (e.g., sounds). The tasks can be separated into those that involve retrieving

a reward from a (transparent or opaque) puzzle box and those that involve changing the state of provided material or producing something. Given the existing literature we do not have reason to assume that fundamentally different processes are involved in OI depending on the nature of the action goal (i.e., reward retrieval vs. something else).

2. Baseline

In some studies, the participant's imitation rate of irrelevant actions is compared to that of a control group that did not receive a demonstration but could - in the case of the classical puzzle box tasks - interact with the apparatus (Hoehl et al., 2014; Lyons et al., 2007; Schleihauf et al., 2018). This is done to ensure that the performance of irrelevant actions is not due to the puzzle box being too complex for children to understand on their own (Lyons et al., 2007) and/ or to establish the spontaneous production of the irrelevant actions due to attractive appearances or affordances of certain features of the puzzle box (e.g., the lever in Hoehl et al., 2014). A baseline of figuring out the functioning of an experimental apparatus can be useful to argue that the causal workings are potentially perceivable and understandable for children at the tested age.

Whether OI in an experimental condition is compared to a baseline or to another condition can have a substantial effect on the interpretation of results. For instance, Schleihauf et al. (2018) found a significant difference in OI behavior between two conditions. However, the condition, in which more OI behavior was observed, did not differ significantly from a control group without a demonstration. Thus, the authors concluded that OI was not reliably elicited in either of the two conditions.

3. Demonstrations of irrelevant actions

Children's OI rates may also be influenced by the demonstration format. While many studies present a live demonstration (Buchsbaum, Gopnik, Griffiths, & Shafto, 2011; Clegg &

Legare, 2016; Flynn & Smith, 2012; Hoehl et al., 2014; Horner & Whiten, 2005; Keupp et al., 2013; Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons et al., 2007; Nielsen, Slaughter, & Dissanayake, 2013; Schleihauf et al., 2018) others show the model demonstrating the action sequence on video (Chudek, Baron, & Birch, 2016; Herrmann, Legare, Harris, & Whitehouse, 2013; Legare, Wen, Herrmann, & Whitehouse, 2015; McGuigan, 2013; McGuigan et al., 2011; Watson-Jones et al., 2014; Wood et al., 2012).

Two studies investigated the effect of presentation format systematically: McGuigan et al. (2007) found that 5-year-olds over-imitate with similar rates no matter if they observe a live or a video demonstration. In contrast, 3-year-olds did not perform more irrelevant actions than children in a control condition when they saw a video demonstration, but when they saw a live demonstration their OI rates were similar to those of the 5-year-olds. Marsh et al. (2014) found that children's tendency to over-imitate dropped around 50 percent if they saw a video demonstration instead of a live demonstration. That was the case for 5- to-6-year-olds as well as for 7- to 8-year-olds. Even if these results are not completely consistent it seems that imitation rates in general are higher if children observe live demonstrations.

Studies on OI also vary regarding the number of demonstrations, which are performed before the test trial. In the original study by Horner and Whiten (2005), children saw three demonstrations before the first test trial, one more demo before the second, and one more before the third test trial. Other studies vary from three (e.g. McGuigan et al., 2007), over two (Keupp et al., 2013; Nielsen et al., 2015), to only one demonstration of irrelevant and relevant actions (Gardiner, 2014; Hoehl et al., 2014; Schleihauf et al., 2018). Due to different tasks and coding systems it is hard to systematically compare how the number of demonstrations influences children's OI. From research on deferred imitation in 12- to 21-month-old infants it is known that a video deficit effect could be overcome by doubling the

number of demonstrations (Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007). Therefore, multiple demonstrations of irrelevant actions could potentially increase OI. It is possible, that multiple demonstrations also change children's interpretation of a behavior. If a specific way to solve a task is shown multiple times, children's focus might be shifted away from the goal of the task towards the means of how to solve the task. This might be especially relevant when children recognize (e.g. due to the transparency of the puzzle box) that the demonstrated actions are obviously not necessary to achieve the instrumental goal.

4. Different instructions and different contexts

In the original study by Horner and Whiten (2005) children were given limited verbal instructions, but in other studies instructions have been given before and/or after the demonstrations and sometimes even during demonstration.

The instructions given prior to demonstration are mostly as neutral as possible, like "See the [animal]? I'm going to get the [animal] out." (Marsh et al., 2014) or "Watch what happens because I'm going to let you have a go in a minute (McGuigan et al., 2007). Lyons et al. (2007) even prompted the children to look out for unnecessary actions ("I want you to watch really carefully, because when I open this [puzzle object], I might do something that's silly and extra."). However, we also find instructions, which might trigger a normative or conventional context, because the experimenter is telling the child that he/she will *teach* him/her *how* to get the box open (Nielsen et al., 2015) or *how* the toy works and *how* to get the reward out (Ronfard, Was, & Harris, 2016). In some studies the OI task is introduced as a game, which also could create a normative context (Hoehl et al., 2014; Keupp et al., 2013; Schleihauf et al., 2018).

Several experiments, which manipulated the verbal instructions to create either a conventional / action-oriented framing or an instrumental / goal-oriented framing (Moraru,

Gomez, & McGuigan, 2016) demonstrate that caution needs to be exerted when deciding how to verbally introduce the imitation task *prior* to demonstration. Very minimal changes in the introduction of an OI task had effects on children's OI rates (Moraru et al., 2016). When the experimenter introduced the demonstration phase by ''I will show you how to get the toy out" (conventional condition), children over-imitated to a higher degree than when the experimenter introduced the demonstration phase with ''I will show you one way to get the toy out" (instrumental condition).

The use of instrumental vs. conventional verbal cues has been investigated in several OI studies. However, the results are not completely consistent. For example, Keupp et al. (2013) and Keupp et al. (2016) tried to create a conventional context by making up a novel word describing the sequence of actions that were performed (prior demonstration: "Now I'm going to show you something else - now I'm going to dax", after demonstration: "Now you can have a go and dax"). In the condition where an instrumental context should be created the effect of the actions was emphasized (prior demonstration: "Now I'm going to show you something - now I'm going to ring the bells", after demonstration: ''Now you can have a go and ring the bells"). However, while this experimental manipulation did not influence children's OI in the Keupp et al. (2013) study, in Keupp et al. (2016) they over-imitated more in the conventional than in the instrumental condition. Clegg and Legare (2016) used more salient cues for creating a conventional versus instrumental context (conventional: "I always do it this way. Everyone always does it this way. Let's watch what I am doing. Everyone always does it this way"; instrumental: "I am going to make a necklace. Let's watch what I am doing. I am going to make a necklace"). In that study, children in the conventional condition had higher imitation scores than children in instrumental condition.

Instructions given after the demonstration, shortly before the test trial, can also be divided into neutral ("Now it's your turn.", e.g. Gardiner, 2014; McGuigan et al., 2007; "If you want to, you can get the turtle while I'm gone. You can get it out however you want.'', Lyons et al., 2007; 2011), conventional / action-oriented ("Now you can have a go and dax", Keupp et al., 2013), and instrumental / goal-oriented (''Now you can have a go and ring the bells", Keupp et al., 2013). There also are instructions which try to motivate children to skip irrelevant actions ("Can you get the [duck] out', do it as quickly as you can", Marsh et al., 2014 "Remember, don't do anything silly and extra, okay? Only do the things you have to do", Lyons et al., 2007).

Moraru et al. (2016) showed that it also matters which kind of *post*-demonstration instructions are used. When the experimenter instructed the children with ''Now it's your turn", children had the highest OI rates. When the experimenter instructed the children with ''Now it's your turn. You can get the toy out however you want" the OI rates were slightly lower. And when the instructions also included a motivation to skip irrelevant actions (''I want you to know that some of the things I did when I got the toy out were silly. I did not need to do them to get the toy out. So, I want you to try your best and not do those things. Now it is your turn") children's OI rates were lowest.

The use of verbal comments during the demonstration has been tested less often. Most OI studies use verbal comments during the demonstration phase, but there are a few exceptions. Ronfard et al. (2016) narrated the irrelevant actions during demonstration, but did not experimentally manipulate this across conditions. Gardiner, Greif, and Bjorklund (2011) experimentally manipulated the verbally expressed intentionality of the model. The model accompanied every action with either "there" (intentional) or "whoops" (accidental). The

children were less likely to replicate causally unnecessary actions when they were cued as accidental than when they were cued as intentional.

Even though the instructions given prior, during, and after the demonstration influence participants' tendency to over-imitate (Keupp et al., 2013; Legare et al., 2015; Moraru et al., 2016), it has been shown that both children and adults tend to over-imitate even when no instructions are given at all and when the participants are not even aware of taking part in an experiment (Whiten et al., 2016).

5. Presence of experimenters

A major inconsistency across OI studies is the presence of an experimenter or the model during the testing phase. In most studies using video demonstrations, video model and live experimenter are different people. In these studies, it is often found that the experimenter stays in the room during the testing phase (Chudek et al., 2016; DiYanni, Corriveau, Kurkul, Nasrini, & Nini, 2015; Legare et al., 2015). Sometimes also in studies with live demonstrations, model and experimenter are different people, which allows for the demonstrator to leave the room during the testing phase, while the experimenter stays with the child (Nielsen et al., 2015). However, in many studies using live demonstrations, the model and the experimenter are the same person. Here, we find different approaches to how testing phases are structured. In some studies, the experimenter just stays in the room with the child (Clegg & Legare, 2016; Herrmann et al., 2013) or the experimenter stays in the room, but turns away from the participant pretending to be busy (Keupp et al., 2013; McGuigan & Burgess, 2017). Other studies aimed to reduce any tendency to copy the experimenter through social conformity or other pressures, so the experimenter left the room during the testing phase (Hoehl et al., 2014; Lyons et al., 2007).

There are also a few studies that manipulated who was present during the testing phase. Nielsen and Blank (2011) devised a paradigm in which 4-year-old children watched two adult models perform a puzzle box task. In one condition, both models performed the task using the same inefficient technique, whereas in two other conditions one model acted efficiently and the other acted inefficiently. On completion of the two demonstrations, either the efficient or inefficient model left the testing room, leaving the children to perform the task in the presence of the remaining model. Children were more likely to omit the irrelevant actions when the efficient model was present than when the inefficient model was present. McGuigan and Robertson (2015) used a similar manipulation, but with child and puppet models. OI rate was generally low irrespective of condition and model presence.

To our knowledge there is only one OI study that experimentally manipulated whether the model is absent or present during testing phase. Participants were younger than in the majority of OI studies; being only 18 months old (Kupan et al., 2017). The authors manipulated communicative cues and model presence during the demonstration phase. Infants tended to copy the communicatively demonstrated way to reach the goal. This choice behavior was not influenced by the later presence or absence of the demonstrator. The non-communicative demonstration, however, did not elicit a particular learning outcome. Therefore, in this situation, infants' choice behavior was affected by the demonstrator's presence or absence. Infants developed an individual solution if the demonstrator was absent. If the demonstrator was present, they were more likely to reproduce the observed manipulation, which the authors interpreted as a tendency to communicate with or conform to the actions of the demonstrator.

In most studies, it is reported if the model or the experimenter stays in the room during testing phase. However, only a few studies report if the children's caregivers were in the room

during testing (e.g. Kupan et al., 2017), if they waited behind an occluder and therefore were not visible (e.g. Corriveau et al., 2017), or if they waited in a separate room (e.g. Schleihauf et al., 2018). In many OI studies there is no information about parents' location during the study or especially during the testing phase. However, it is plausible that the presence of an adult – an authority – may influence children's imitative behavior, irrespectively if the adult is an experimenter or a parent.

6. Model's characteristics

Certain characteristics of a model, such as status, prestige, success, age, expertise and familiarity influence children's tendency to imitate irrelevant actions (see Price, Wood, & Whiten, 2017, for a review). This research is addressed in more detail in the main manuscript in the sections on the underlying cognitive mechanisms of OI. Here, the focus is on aspects of the model that might vary across studies without necessarily being deliberately manipulated and that might nonetheless have an effect on the results.

In the OI literature, puppets are often used as a target of potential normative protest (Kenward, 2012; Keupp et al., 2013). Typically, the inefficient task demonstration is performed by a human model before the puppet comes along and performs the task in a different, more efficient way. Such studies show that the children often protest verbally against the puppet's more efficient technique and continue to over-imitate the human model in subsequent trials, despite having viewed the puppet's more efficient solution. However, in a few studies, puppets were also used as models (McGuigan & Robertson, 2015; Wood, Kendal, & Flynn, 2013). When children were presented with irrelevant action demonstrations by either a group of peer or puppet models, levels of OI in the peer model conditions were higher than those witnessed with the puppet models (McGuigan & Robertson, 2015).

The question of whether observing a same-gender versus different-gender model affects OI has received little attention so far. Dunham, Baron, and Carey (2011) found that both male and female participants showed a robust preference for their gender in-group on measures like explicit attitude, resource allocation and behavioral attribution. Therefore, the gender of the model could play a role also in children's OI. Some authors take this possibility into account by counterbalancing the gender of models and children in their OI experiments (Hoehl et al., 2014; Schleihauf et al., 2018). A recent study showed that female children in particular are affected by the model's gender: Five-year-old girls were less prone to imitate irrelevant actions modeled by a male adult versus a female and readily switched to an efficient solution, whereas boys were not affected by the model's gender (Schleihauf, Pauen, & Hoehl, submitted).

Furthermore, the behavior of the majority has an effect on children's imitation of irrelevant actions (McGuigan & Burgess, 2017; McGuigan & Robertson, 2015). If a group of models performed irrelevant actions and a single person performed an efficient demonstration children's tendency to copy irrelevant actions was higher than if they witnessed an equal number of inefficient and efficient models. If the group demonstrating the inefficient actions consisted of 3-, 5-, 8-, 11- or 13-year-olds, the same-aged or 13-year-old models elicited the highest OI rates in the 5-year-old participants (McGuigan & Burgess, 2017). Furthermore, three peer models demonstrating inefficient actions elicited higher OI rates than did two models or only one model demonstrating inefficient actions. Interestingly, this pattern of performance did not extend to puppet models who induced far less OI (McGuigan & Robertson, 2015).

Taken together, some characteristics of the model were shown to affect OI: number of different models observed, gender in relation to the child's gender, age of the model, and whether a puppet or human demonstrates the actions.

7. Coding

In OI studies, superfluous, additional actions are demonstrated that do not contribute to reaching a perceivable goal. Thus, participants observe separate irrelevant and relevant actions demonstrated by a model. Most of these studies use minimal criteria to code OI (as soon as a participant reproduces a target action at least once within a trial it is coded as OI; e.g. Hoehl et al., 2014; Keupp et al., 2016; Schleihauf et al., 2018). Others differentiate between different levels of imitation fidelity, depending on whether target actions are imitated more or less often than demonstrated (McGuigan et al., 2011; Nielsen et al., 2013). In the following, we list commonly used coding systems and discuss their impact on interpretations of study results.

7.1. OI scores taking number and repetitions of performed actions into account

7.1.1 Proportional OI scores

The puzzle box task introduced by Horner and Whiten (2005) was used in several other studies (e.g. McGuigan et al., 2011; Wood et al., 2012). However, the studies vary regarding how many and which irrelevant actions are coded. In the original study, only the number of tool insertions into the top irrelevant hole of the puzzle box was used as a measure of OI while removal of the bolts was ignored. The proportion of irrelevant actions in each condition was determined by calculating the number of tool insertions into the top irrelevant hole, as a percentage of total tool insertions. McGuigan and colleagues (McGuigan et al., 2011; McGuigan et al., 2007) used the same coding strategy but also calculated an 'irrelevant tool insertion score' which could range from 0, indicating only relevant tool insertions, to 1,

indicating only irrelevant tool insertions (i.e., into the top hole). In these studies, exact reproduction of the model would generate a score of 0.75 (since 3 irrelevant tool insertions were demonstrated, divided by 4 tool insertions in total). This coding strategy allows for participants who perform even more tool insertions than demonstrated to receive a higher score, thus making it possible to track whether children displayed irrelevant actions even more often than demonstrated. Vivanti, Hocking, Fanning, and Dissanayake (2017) also used an OI proportion score. However, they calculated the proportion of causally irrelevant actions out of the total opportunities (i.e., the 3 demonstrated superfluous actions presented in the videos), not out of the total number of performed irrelevant actions. A slightly different kind of coding was used by McGuigan (2013) as she also took into account if an action was performed more often than demonstrated.

7.1.2 Total frequency OI scores

In several studies by Nielsen and colleagues (Nielsen et al., 2014; Nielsen et al., 2013) the authors coded how frequently an irrelevant action was performed. Since the irrelevant action was demonstrated three times an OI score of 3 stood for perfect imitation. If a child repeated one specific irrelevant action, this type of coding would result in a very high OI score. Therefore, Nielsen and colleagues decided to search for and exclude outliers. Nielsen et al. (2014) used puzzle boxes similar to that of Horner and Whiten (2005) and scored for three different irrelevant actions, whereby one irrelevant action (i.e., inserting a stick into the top compartment, demonstrated with three repetitions) could be performed more than once. Here, the absolute frequency with which the stick was inserted into the top compartment was coded and not whether the three insertions modeled were followed perfectly.

7.2 OI scores taking number and repetitions of performed actions into account, with the demonstration score as maximum

In a more recent study by McGuigan and Burgess (2017) an OI score was calculated by totaling the number of irrelevant actions that matched those demonstrated by the inefficient model (i.e., two bolt removals and three irrelevant tool taps against the second ceiling). The minimum score a participant could receive was 0, indicating that no causally irrelevant actions were performed. A maximum score of 5 indicated that all elements of the inefficient sequence were reproduced (i.e., the participant performed 2 bolt removals and 3 taps). Here, it was not taken into account if the participant repeated a specific action more often than demonstrated, but it was recorded if the participant performed less repetitions than demonstrated. The same coding system was also used in studies by Wood et al. (2012) and Moraru et al. (2016), who also used the original Horner and Whiten puzzle box.

7.3 Binary Coding for each demonstrated irrelevant action

Besides the studies taking into account the repetitions of a performed irrelevant action, several other studies use binary coding. Here it is coded whether or not a specific irrelevant action is performed at least once. Usually the participant is awarded a score of 1 for each irrational action completed and a score of 0 otherwise (e.g., Hoehl et al., 2014; Keupp et al., 2013). Binary coding records the number of different irrelevant actions that matched those demonstrated by the model. However, there is variation in what is counted as one action in different studies using the same over-imitation task. Whiten et al. (2016) condensed the scoring to record only the removal of both bolts (together) and the triple tapping as two irrelevant actions (resulting in an irrelevant action score of 2, 1 or 0). Chudek et al. (2016) argued that the demonstrated actions are not independent; for example, if the children did not remove both bolts, they were unable to insert the tool into the top hole. Therefore, they decided to use a single binary coding for the removal of the bolts, which they thought to be the most salient, most obviously causally superfluous step.

7.4 Coding partially performed irrelevant actions

Gardiner and colleagues calculated action scores that reflected the degree to which participants manipulated the respective moving parts of the testing apparatus (Gardiner, 2014; Gardiner et al., 2011). Therefore, they used a scale related to the precision with which children's manipulations replicated the experimenter's actions.

7.5 Comparison of different coding systems

To our knowledge, there is only one study so far which combined different coding strategies. Berl and Hewlett (2015) used and analyzed all the following measures: a) the total number of irrelevant actions performed, b) an irrelevant imitation score (= number of insertions into top irrelevant hole/ total number of insertions on the top irrelevant and front relevant hole with 0 = all ins. relevant; 1 = all ins. irrelevant), 3) an irrelevance quotient (= total number of irrelevant actions/ total number of irrelevant + relevant actions (full proportion of irrelevant actions), and 4) a fidelity quotient (= longest string of actions performed in the same order as the demonstration/ maximum possible fidelity score). Considering their results, the authors suggested that a proportional measure may be more informative than the raw count data. The irrelevancy quotient had the advantage of being comparable across studies with differing methodologies. To facilitate comparisons between studies, it is would be helpful if future OI studies included and reported such different, varied, coding systems. A meta-analysis would be helpful to address the question if different coding systems lead to systematically different findings. Unfortunately, however, the current state of the art of OI research impedes such an endeavor because differences in coding systems are confounded with other methodological differences.

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Table SI 1

Overview of over-imitation studies from 2005 – 2017. Included are studies, which meet the over-imitation criteria as defined in the main manuscript.

Authors (year)	Age (sample size)	Task description	Design & Conditions	Results
Horner & Whiten (2005). Causal knowledge and imitation/emulation switching in chimpanzees (Pan troglodytes) and children (Homo sapiens).	**Exp. 1-3**: 2 – 6 years old chimpanzees (n = 12, 4 in each group) **Exp. 4:** 3 – 4 years old children (n = 16, 4 in each group)	**The task: Exp. 1, 4**: retrieve reward from opaque or clear puzzle box; **Exp. 2,3**: pull correct rake to retrieve reward **Irrelevant actions:** directed to top of box: tapping bolt with tool, removing top bolt, inserting tool into top hole **Relevant actions:** directed at front of box: pushing/dragging bolt with tool and lifting/sliding door (Method 1/2; two-action-design); inserting tool to retrieve reward **Demonstration specifics:** Subjects (chimpanzees in Exp.1/children in Exp. 4) observed a human demonstrator use a tool to retrieve the reward (food/sticker). The sequence of procedure was: three Demos > Trial 1 > Demo > Trial 2 > Demo > Trial 3. Testing was repeated later in the alternative condition. One/two weeks later, the chimpanzees had to select one of two rakes to pull towards them: only one was physically connected to the reward (**Exp. 2**) or to a box that contained a barrier preventing access to the reward (**Exp. 3**).	**Design:** between-groups design Dependent variables: reproduction of (ir)relevant actions (emulation or imitation); used method; first tool choice (Exp. 2,3) Independent variables: Availability of causal information **Conditions:** there were four groups in Exp. 1 and 4: - Group A: demonstration of method 1; first three trials with opaque, then three trials with clear box - Group B: method 2; opaque box first - Group C: method 1; clear box first - Group D: method 2; clear box first Exp. 2, 3: position of food reward and side of correct choice was randomized.	Chimpanzees who interacted first with the opaque box (group A, B) tended to imitate both relevant and irrelevant actions but switched to a more emulative approach when presented with the clear box. The ones who interacted with clear box first also used emulation and continued to do so when presented with the opaque box. Exp. 2 and 3 revealed that chimpanzees were able to select the correct tool/box. Both chimpanzees and children used the observed method significantly more than the alternative. In contrast to chimpanzees, children tended to imitate both irrelevant and relevant actions, regardless of the transparency of the box.
Lyons, Young, & Keil (2007). The hidden structure of overimitation	Exp. 1 *(A & B)*: 3 – 5 years (n = 63) Exp. 2 (A & B): 3 – 5 years (n = 29)	**The task:** retrieving a toy from different puzzle objects (box, cage, dome, Igloo) **Irrelevant actions:** box: push bolt/pull bolt; cage: side handle/top handle; dome: pull handle/pull ball (Experiment 1 A & B and Experiment 2 A); **Relevant action:** box: remove plug/slide frame; cage: unscrew cap/remove spindle; dome: rotate arm/flip up arm **Demonstration specifics:** Exp. 1A: First there was a training phase, where children watched the experimenter retrieving a toy (dinosaur) from 8 different transparent containers using a sequence of relevant and irrelevant actions. After each retrieval the child was asked which actions were necessary for retrieval and which actions were silly. The participant received corrective feedback. In the test phase the experimenter and the child sat in front of a novel transparent puzzle object containing a toy (turtle). The experimenter retrieved the toy using a sequence of relevant and visibly irrelevant actions. Then he left the room and suggested retrieving the toy to the child while he was gone. Each child was tested with two out of three puzzle objects.	**Design:** within-subjects design (Exp. 1); mixed design (Exp. 2) Independent Variables: presence of experimenter, information about the irrelevance of actions Dependent Variable: imitation of irrelevant actions **Conditions:** Exp. 1A: The participant was requested to retrieve the toy while the experimenter was absent. Exp. 1B: The participant was told that the Experiment was over and his/her help was needed; time pressure; experimenter was present but busy. Exp. 2A: The participant was directly warned of performing irrelevant actions; experimenter was absent Exp. 2B: The two halves of the puzzle object (Igloo) were either connected or disconnected (violation of the contact principle)	Over-imitation persists in all variations of situation except in Exp. 2B (contact principle violated), including encouragement not to overimitate. Exp. 1A: Children in both age groups who scored the highest on training—and thus received the most praise for identifying irrelevant actions as silly and unnecessary—were just as likely to overimitate as participants who found training more difficult. Exp.1B: For two of the three puzzle objects frequency of over-imitation did not decline from Exp. 1A levels. Exp. 2A: Children continued to overimitate as frequently as they did in Exp. 1A. Exp.2B:

		Exp. 1B: Afterwards the child was told that the Experiment was over and given a prize. The experimenter told the child that he was worried if the assistant had put the toy turtles back in the puzzle objects. He explained that he was in a rush and asked the child to help by checking whether the turtles were back in the puzzle objects. Exp. 2A: The training phase was the same as in Experiment 1 (A). Then the child was tested with either the puzzle box or the dome object. The experimenter told the child explicitly that he had done and was going to do silly extra actions that hadn't helped to get the dinosaur and firmly instructed the child to ignore any silly actions and to do only what was necessary to retrieve the turtle. Then he left the room and it was the child's turn. Exp. 2B (2B was always presented before 2A): The training phase was the same as in Exp. 1A. For the testing phase a new puzzle object consisting of two spatially separated halves and a removable connector was used. The child watched the experimenter retrieve a toy turtle by performing an irrelevant action at one of its halves a relevant action on the other. One half of the children saw the object's halves joined by the connector, the other half without connector. After the demonstration it was the child's turn.		Over-imitation was much more frequent for the connected form of the Igloo than for the disconnected form.
McGuigan, Whiten, Flynn, & Horner (2007). Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children	3 years (n = 48) 5 years (n = 48)	**The task:** retrieve reward from transparent or opaque Glass Ceiling Box **Irrelevant actions:** eleven actions directed to the top of the box: tap end of two bolts three times, remove both bolts (using drag or push technique), tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box (using slide or lift technique) and insert stick tool inside **Demonstration specifics:** Children observed either three live or three video demonstrations of the task with either the opaque or the transparent box. Each demonstration comprised an action sequence containing both causally irrelevant and casually relevant elements, with the causally irrelevant actions always occurring first. Following three task demonstrations the children completed their first test trial, using the same box viewed in the demonstration phase. The experimenter then provided two additional demonstrations interspersed with two more test trials (demo > demo > demo > trial 1 > demo > trial 2 > demo > trial 3). *No-model Control Conditions:* Participants interacted with	**Design:** Between-subjects design with box transparency, task presentation, and observer age as factors **Dependent variables:** proportion of irrelevant taps performed, fidelity to method of defense removal witnessed, time until reward retrieval Independent variables: box transparency (transparent or opaque), task presentation (live or video), and observer age (3 or 5 years) **Conditions:** Children in each age group were allocated to one of three conditions (live, video, or no demonstration). Within all three conditions each child interacted with either the transparent or the opaque box. In the two demonstration conditions the children viewed one of two different two-action techniques for removing the defenses (push bolts-lift door or drag bolts-slide door).	Children performed an equivalent number of causally irrelevant actions with the transparent and opaque boxes. There were significant effects of both age group and condition, as well as a significant interaction between these factors. Live demonstration: Both 3- and 5-year-olds overimitated even in causally transparent condition. Video demonstration: 3-year-olds did not imitate causally irrelevant actions; 5-year-olds did.

		either the transparent or the opaque box without having first viewed a model.		
Brugger, Lariviere, Mumme, & Bushnell (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences	Exp. 1: 15 months (n = 42) Exp. 2: 14 – 16 months (n = 21)	**The task:** flower box (Exp. 1 & Exp. 2): open the box and see the flowers inside, ramp (Exp.1): roll a ball down the tube, rake (Exp. 1): obtain an out-of-reach toy; tape player (Exp. 2): make the music play; rattle (Exp. 2): generate noise; battery-operated toy dog (Exp. 2): make the dog bark **Irrelevant actions:** flower box: undo the latch (even though it does not hold the lid shut); open a Velcro latch on a wooden block next to the flower box; patting the head with the hand; ramp: remove the uphill presented cardboard barrier; remove a barrier on a separate smaller tube; patting the head; rake: push in a plastic tray (even though the pit trap is not on the same side of the box as the toy), close a trap in a smaller separate box, pat your head; tape player with two plastic tubes fastened to one side: take the rod out of one tube and place it into the other **Relevant actions:** undo the latch and open the lid of the flower box; ramp: remove the downhill presented cardboard barrier and place a ball in a hole at one end; rake: push in a plastic tray to close a pit trap and pull on a paddle; tape player: press the start button; rattle: assemble the two barrel halves and snap the two halves together; toy dog: flip a toggle switch and press a button **Demonstration specifics:** Exp. 1: After a warm-up phase, the experimenter and the infant on the parent's lap sat at a table while an assistant set the objects between the infant and the experimenter. E drew the infant's attention to the toy addressing the infant and making eye contact. E demonstrated the two-action sequence in a slow fashion twice. Then it was the child's turn. After the child's trial, the toy was removed, and the assistant brought out the materials for the next trial. The second and third trial followed the same procedure as for the first trial. Exp. 2: The procedure was similar to that of Exp. 1. With each toy, E demonstrated the appropriate two-action sequence and effect in a slow manner and offered the toy to the infant. For toys presented in the socially cued conditions, demonstrations were given as in Exp. 1. In the not cued condition, E did not solicit the infant's attention	**Design:** within-subjects design (Exp. 1 & Exp. 2) Independent Variables: necessity of the first action was manipulated (Exp. 1 and Exp. 2) and the first action was socially cued or not (Exp. 2) Dependent Variables: imitation of target actions 1 and 2 (Exp. 1 & Exp. 2) **Conditions:** Exp. 1: All three tasks consisted of two actions (A and B) each; the necessity of the first action (A) was varied for each toy. Necessary condition: first action had to be executed in order for the second action to then yield the effect Unnecessary condition: the first action was not integral to generating the result Off-object condition: first action was not integral to producing the effect, nor was it performed on the object where the effect occurred (remote version: first action was performed on a separate object; body version: first action was performed on the experimenter's body) Exp. 2: Each infant participated in four trials, each with a different novel toy. Two actions (A and B) towards the toy yielded in an effect. The nature of the first action (A) was manipulated. Socially cued and necessary: E solicited the infant's attention before the first action and the first action was necessary. Not cued and necessary: E didn't solicit the infant's attention before the first action and the first action was necessary. Socially cued and unnecessary: : E solicited the infant's attention before the first action and the first action was unnecessary Not cued and unnecessary: E didn't solicit the infant's attention before the first action and the first action was unnecessary.	Exp. 1: There was a significant effect indicating that action A was performed with different frequencies across the three conditions and a significant effect indicating that infants performed the action A first with different frequencies across conditions. Infants were more likely to do action A in the necessary cond. than in any of the other conditions. Exp. 2: Action A was not performed with different frequencies across the four trials. There was a significant effect indicating that infants performed action A first with different frequencies across the four trials. Over all four trials infants were more likely to perform action A on the socially cued trials compared to those that were not cued. Additionally, infants were also more likely to perform action A first on the socially cued trials. Over all four trials, although infants were not more likely to perform action A in general on the necessary trials, they were more likely to perform action A as their first action on those trials as compared to the unnecessary ones.

		before the first action.		
Flynn (2008). Investigating children as cultural magnets: do young children transmit redundant information along diffusion chains?	2 years (n = 40; thereof 16 in control cond.) 3 years (n = 40; thereof 16 in control cond.)	**The task:** retrieval of a sticker with a tool from an opaque or transparent glass-ceiling box **Irrelevant actions:** drag or push the bolts on the top of the box; tap on the glass ceiling **Relevant actions:** open door (either by sliding or lifting) and insert a tool to pull the reward out **Demonstration specifics:** In the diffusion chains the first child watched the experimenter either push or drag the bolts from the top hole of the box, tap the tool on the glass ceiling below three times, lift or slide the door away, insert the tool and remove the reward. E performed five irrelevant actions. Having witnessed two demonstrations, the child was allowed to have a turn. The first child received feedback until she/he had incorporated all of the elements demonstrated by the experimenter. Then the second child was brought in and told to wait while the first child had two attempts, then it would be his/her turn. The second child hat two solo attempts before becoming a demonstrator for the next child in the chain. This procedure continued to the final child, who had only two attempts. In the no-model condition, the child was presented with the box and the tool and was told that it was her/his turn and given general encouragement.	**Design:** diffusion chain; between-subjects design Independent Variables: demonstrated method (drag/push bolts and lift/slide door), opaque or transparent box Dependent Variables: removal of the bolts (used method), tapping of the box (how many times), door opening (used method), successful removal of the sticker **Conditions:** Experimental conditions: 6 children in each chain; five irrelevant tasks were demonstrated to the first child in each chain. • 2-year-old transparent box chain • 2-year-old opaque box chain • 3-year old transparent box chain • 3-year old opaque box chain Control conditions: 8 children in each chain No-model opaque box: one chain of 2-year-olds and one chain of 3-year-olds No-model transparent box: one chain of 2-year-olds and one chain of 3-year-olds	Children in the diffusion chains were significantly more successful at retrieving the reward than children in the no-model control conditions. Children in the first position made significantly more irrelevant actions than children in the following positions. Children in the first position did not differ significantly in the number of irrelevant actions made from children in the second position, and children in the second position did not differ to children at any other position. Significantly more children imitated the method that they had witnessed used to open the door than children who used an alternative method. It was found that children showed fidelity to the method used to perform a relevant action both within dyads and across groups.
McGuigan & Whiten (2009). Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds.	23 months (n = 24) and 30 months (n = 24)	**The task:** retrieve reward from transparent or opaque Glass Ceiling Box **Irrelevant actions:** eight actions directed to the top of the box: tap end of two bolts three times, remove both bolts (using drag or push technique), tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box (using slide or lift technique) and insert stick tool inside **Demonstration specifics:** Children watched a model (E) retrieve a reward from either a transparent or opaque puzzle box using both causally irrelevant and causally irrelevant actions. On completion of the child's first trial (which followed either 1 or 3 prior demonstrations), E provided further two-task demonstrations interspersed with Trials 2 and 3.	**Design:** between subjects design with box transparency and observer age as factors **Dependent variables:** proportion of irrelevant taps performed, fidelity to method of defense removal witnessed, efficiency of task completion, approach adopted (imitation, emulation, or mixed) **Independent variables:** box transparency (transparent or opaque) and observer age (23 or 30 months) **Conditions:** - Opaque box model condition (push bolts-lift door or drag bolts-slide door) - Transparent box model condition (push bolts-lift door or drag bolts-slide door) - No-model control condition	More children were successful in reward retrieval in the model than in the no model control condition (both ages). 23-month-olds were more likely to adopt an emulative approach than 30-month-olds. Comparisons with 3- and 5-year-olds from a previous study (McGuigan et al., 2007) showed a clear pattern of rising fidelity with age. While at 23 and 30 months, irrelevant tool insertions in model conditions were uncommon, 42-month-olds performed greater proportions of irrelevant tool insertions, rising even further at 66 months. Older children were more likely to adopt an imitative approach than 23- and 30-months-olds.
Nielsen & Tomaselli (2010). Overimitation in Kalahari Bushmen Children and the	**Exp. 1:** 2 - 6 years (n = 32; 16 children from industrialized city	**The task:** retrieve toy from three opaque boxes (accompanied by different objects) **Irrelevant actions:** placing stick on top of box and moving it in circular motion three times/ tapping top of box three	**Design:** between-groups design Dependent variables: reproducing irrelevant action score (0-3) and using object to open box score (0-3) Independent variables: demonstration, familiarity of model (in	In both experiments, children in the demonstration conditions produced irrelevant and unnecessary actions significantly more than children in no-

Origins of Human Cultural Cognition.	Brisbane and 16 from remote Bushman community in South Africa) **Exp. 2:** 2 - 13 years (n = 62 children living in !Xun and Khwe clans)	times with mallet/ wiping stick three times across box **Causally related but inefficient actions:** lifting up stick and pushing it onto the knob to open door/ placing and moving mallet against switch to release lid/ using stick to poke dowels out of their chambers to open box **Relevant actions**: opening box by hand: pulling know to open trap door/ sliding a switch from left to right/ removing two dowels from tubes **Demonstration specifics:** E demonstrated first an irrelevant action and then an action that was causally related to opening the box but was unnecessarily complicated. This sequence was repeated twice. Then it was the child's turn. If the child successfully opened the box, the whole procedure was repeated for the next box. **Exp. 2:** same procedure except for changes in the in the baseline condition and variation of familiarity of the demonstrating model across conditions.	Exp. 2) **Conditions:** Children were assigned to one of two conditions: demonstration vs. baseline (no-demonstration). In **Exp. 2,** the familiarity of the demonstrator was also varied (community member vs. visitor). Baseline condition in Exp. 2 was split into two phases: first children could explore the box without seeing any demonstration before (no demonstration phase), then they watched a model perform the target action and could interact with the box again (post-demonstration phase).	demonstration conditions/phases. Children in demonstration conditions overimitated at similar rates regardless of their cultural environment. In **Exp. 2**, children in the demonstration group overimitated at similar rates, regardless of having watched a visitor or community member as demonstrator. Younger children produced fewer OI actions than older children. Children in the baseline condition (Exp. 2) overimitated only after the demonstration. Children copied irrelevant actions at equivalent rates, irrespective of whether they had a prior opportunity to explore the boxes or not.

McGuigan & Graham (2010). Cultural transmission of irrelevant tool actions in diffusion chains of 3- and 5-year-old children	3 – 5 years (n = 64) 32 in 4 diffusion chains; 32 in a no-model control condition	**The task:** retrieve reward from transparent or opaque Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts (using drag or push technique), tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box (using slide or lift technique) and insert stick tool inside **Demonstration specifics:** The first participant (X) in each chain was pre-trained to perform the action sequence by E. Once the seed had mastered the action sequence they demonstrated for the next individual in the chain (A), who subsequently demonstrated for B and so on along the chain.	**Design:** diffusion chain vs. no model control condition Dependent variables: number of irrelevant actions performed, fidelity of transmission of two-action method of bolt and door removal, Independent variables: box transparency (opaque or transparent), observer age (3 or 5 years) **Conditions:** varied according to box transparency and two-action method used Four experimental chains: - Transparent box chain (drag bolts-slide door) - Opaque box chain (drag bolts –slide door) - Transparent box chain (push bolts-lift door) - Opaque box chain (push bolts-lift door) Two “no model” control conditions: - Opaque box condition - Transparent box condition	Irrelevant actions: In the chain of 5-year-olds presented with the transparent box only the first child performed any of the irrelevant actions, the subsequent 7 children performed relevant actions only. In contrast, in the opaque box chain all 8 of the 5-year-olds performed irrelevant actions (number of bolt removals decreased along the chain). In the 3-year-old chains all children performed irrelevant actions, regardless of box transparency. In the two no-model control conditions very few irrelevant actions were witnessed. Transmission of the two-action method: 3-year-olds transmitted the technique used to open the bolt defense with high levels of fidelity. In the 5-year-old chains children always performed the same technique as the “expert child”. No significant differences were recorded in the fidelity of transmission of the door mechanisms. In the no model control conditions children of both ages showed no consistent technique for bolt removal. There was no predominant approach for door defense removal among 3-year-olds, 5-year-olds preferred to lift the door.

Kenward, Karlsson, & Persson (2011). Over-imitation is better explained by norm learning than by distorted causal learning.	**Exp. 1 and 2:** 4 years (n = 32) **Exp. 3:** 5 years (n = 46)	**The task:** retrieve two different object types (marbles, rectangles) from transparent box **Irrelevant actions: Exp. 1, 2**: inserting stick into dial and turning it to make paddle rotate; **Exp. 3**: acting on side of box not containing marbles (simple box) / pulling handle attached to mechanism with no marbles (complex box) **Relevant actions: Exp. 1,2**: Inserting stick into front hole on left/right side; **Exp. 3**: inserting stick into hole/moving handle **Demonstration specifics:** E first demonstrated reward retrieval twice for each object (ABAB order) and asked children to bring it to their parents. Unnecessary actions were paired with retrieval of only one of the object types. After 4 demonstrations, parents told their child that they liked one of the objects and wanted more of those and then waited for the child to retrieve an object. Next, children were asked to retrieve another object (previously paired with unnecessary action) together with E for **Exp. 2**. E either used a stick to unnecessarily turn the dial himself before passing it to the child or passed it without turning. In **Exp. 3,** E demonstrated reward retrieval three times, always preceding the necessary with the un-necessary action. Children were asked to verbally explain their actions before performing them.	**Design:** mixed Dependent variables: retrieval of (requested) object, unnecessary action performed (y/n); self-reported justifications of intended actions Independent variable: Context of unnecessary action was varied **Conditions:** children were allocated to one of two conditions: **Exp. 1:** marbles vs. rectangles were paired with unnecessary action **Exp. 2:** E himself turned the dial with stick before passing stick to children (i.e. performed unnecessary action) vs. E passes stick without turning it **Exp. 3:** simple vs. complex apparatus (contained two independent mechanical mechanisms)	**Exp. 1**: Results indicated that children associated unnecessary actions specifically with a goal (retrieval) and not generally with the box: Each of the 16 children who were requested to retrieve the object paired with the unnecessary action preceded retrieval with the unnecessary action, whereas only 3 of 16 asked to retrieve the other object did so. **Exp. 2**: None of the 16 children for whom E first performed the unnecessary action, did so themselves. Of the other 16, 13 performed it too, indicating that children had a flexible declarative belief that the dial should be turned before retrieval. **Exp. 3:** Regarding necessary actions, children often explained they intended to perform them because they were needed to retrieve the marbles (causal impact). For unnecessary actions, they often could not explain why they would perform them.
Nielsen & Blank (2011). Imitation in Young Children: When who gets copied is more important than what gets copied	4 – 5 years (n = 36)	**The task:** retrieval of a toy from an opaque box using an object (wooden mallet and orange-colored stick) **Irrelevant actions:** circular swiping on top of the lid from right to left three times; tap the right side three times **Relevant actions:** push horizontally from right to left; rotate anti-clockwise **Demonstration specifics:** All children were tested sitting opposite two experimenters and next to the parent. They saw at least one experimenter opening the box using causally irrelevant actions. E1 placed the box in front of the child and performed three causally irrelevant actions three times. Then the causally relevant action was performed, which opened the box so the toy could be retrieved. This sequence was repeated twice. The actions	**Design:** between-subjects design Independent Variables: presence of irrelevant, efficient or both experimenters Dependent Variables: frequency of the reproduced causally irrelevant actions; whether the object was used to open the box **Conditions:** *Both-adults-irrelevant-condition:* both experimenters modeled the same causally irrelevant actions and one of them left the room afterwards *Irrelevant-adult-stays-condition:* one experimenter modeled the causally irrelevant actions, the second modeled the causally relevant actions; the experimenter who had modeled the irrelevant actions remained in the room *Efficient-adult stays-condition:* one experimenter modeled the	Children produced the irrelevant actions at a significantly lower rate when given the apparatus by the efficient adult than when given the apparatus by the adult who used the irrelevant actions during demonstration. Remarkably, despite having been shown the redundant nature of the irrelevant actions by the now-departed efficient adult, children in the irrelevant-adult-stays condition produced the unnecessary actions at a rate similar to that of children who saw

		of E2 were determined by condition. E2 modeled a further three times either the same causally irrelevant actions as E1 or only causally relevant actions depending on condition. The condition also determined which experimenter left the room afterwards. Then the remaining experimenter told the child that it was his/her turn.	causally irrelevant actions, the second modeled the causally relevant actions; the experimenter who had modeled the relevant actions remained in the room.	the irrelevant actions modeled by both adults. Thus, as predicted, 4- to 5-year-old children overimitated by faithfully copying irrelevant actions modeled by an adult only when that adult was still present to witness the exchange.
Yu & Kushnir (2011). It's all about the game: Infants' action strategies during imitation are influenced by their prior expectations.	2 years (n = 36, 12 for each prime game)	**The task:** retrieving puzzle piece from toy **Irrelevant actions:** action A (first action) in Unnecessary condition (e.g. unhooking latch when it was not connected to door) **Relevant actions:** action A in Necessary condition (e.g. unhooking latch when it was connected to door); action B (second action; e.g. opening door) was always necessary **Demonstration specifics:** After a familiarization session, infants played one of three prime games. Then children played 8 trials of the imitation game. In each imitation game trial, E took one of five toys (box, ramp, rake, two version of birdhouses) and performed three actions (action A, action B, retrieving piece). Then it was the infant's turn.	**Design:** 3 (game; between-subjects) x 2 (conditions; within-subjects) design Dependent variables: retrieval of piece, retrieval time, action strategy (performing action "A+B"= faithful imitation; "B only"= emulation; "other") Independent variable: prior expectations (prime games) **Conditions:** Infants were randomly assigned to one of the prime games: - Copy-me: mimicking four hand gestures of E - Find-the-piece: Finding and putting pieces in a puzzle together with E (= shared goal) - Drawing: Non-interactive (Control) Then they played 4 trials in each condition of the imitation game: - necessary (Action A necessary for retrieval) and unnecessary condition (Action A unnecessary)	Infants who played Copy-me imitated more faithfully than the other groups. Infants who played Find-the-piece were more likely to avoid unnecessary actions and instead only copy necessary ones. Infants playing the control game were generally less likely to imitate and did not show preferences for any strategy. No significant differences were found in action strategy across the three games context in the Necessary condition, indicating that different action strategies were probably due to infants' different social inferences about the prime game (copying actions vs. sharing goals).
McGuigan, Makinson, & Whiten (2011). From over-imitation to supercopying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children.	Children: 3 years (n = 24) and 5 years (n = 24) Adults: 42 years (n = 24)	**The task:** retrieve reward from transparent Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts (using drag or push technique), tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box (using slide or lift technique) and insert stick tool inside **Demonstration specifics:** Participants saw a video of either a child or adult model demonstrating the task five times (using both causally relevant and causally irrelevant actions). The child's attempts were interspersed with the demonstrations in the following way: Demos 1-3 > Trial-1 > Demo-4 > Trial-2 > Demo-5 > Trial-3). **The task:** retrieve reward from transparent and opaque Glass Ceiling Boxes	**Design:** between-subjects design with model age and observer age as factors Dependent variables: proportion of irrelevant taps performed, fidelity to the two-action method of bolt and door defense removal witnessed Independent variables: model age (adult or child model), observer age (3 years, 5 years, or adults) **Conditions:** Participants of each age group were allocated to one of two conditions: - 30-year-old adult model (using either push lift or drag slide method of defense removal) - 5-year-old child model (using either push lift or drag slide method of defense removal)	Results showed an increase in OI from 3 years to adulthood: Adults performed significantly more irrelevant tool insertions than both 5- and 3-year olds. Significantly more causally irrelevant actions were performed in the adult model condition than in the child model condition in all three age groups.
Lyons, Damrosch, Lin, Macris, & Keil (2011). The scope and limits of overimitation in the transmission of artefact culture	Exp. 1 & Exp. 2: 4 – 5 years (n = 92; n = 64 in experimental condition, n = 28 in baseline	**The task:** retrieving a toy from a transparent puzzle box **Irrelevant actions:** monkey box: remove bolt and tap; prize box: swing arm (noisy bell) **Relevant actions:** monkey box: open door and retrieve toy on ribbon; prize box: open lid, retrieve prize **Demonstration specifics:** Exp. 1: In the training phase the	**Design:** mixed-design (Exp. 1 & 2); between-subjects design (Exp. 3) Independent Variables: competitive or non-competitive context (Exp. 1) or real life competitive context (Exp. 2) or intentional irrelevant actions/accidental irrelevant actions (Exp. 3) Dependent Variables: imitation rate of irrelevant actions	Over-imitation decreases slightly in competitive phase, but remains fairly robust (> 60%). Over-imitation continues even when irrelevant actions endanger treat in "real-world" situation.

	condition) Exp. 3: 3 – 5 years (n = 27)	participant watched an experimenter removing toy dinosaurs from eight transparent containers using sequences of relevant and irrelevant actions. For the first four items the child was asked to identify the unnecessary actions, for the last four items the child was invited to try to retrieve the toy faster than the experimenter. Children who didn't identify the unnecessary actions or copied them were corrected. In the *non-competitive phase* the child was introduced to a novel puzzle box (monkey box) consisting of two symmetrical halves separated by an opaque divider. The child watched the experimenter retrieving a toy turtle from the box using irrelevant and necessary actions. The experimenter invited the child to retrieve the toy while he was gone. In the *competitive phase* the experimenter returned and introduced Felix, an orangutan puppet, which was operated by a hidden second experimenter. The experimenter put one toy into the box and told the child that there was going to be a race between the child and Felix. Whoever opened their side of the box fastest would retrieve the toy and win. Before each race (up to three consecutive races) a cardboard barrier was fitted over the box, hence the child couldn't see Felix who skipped all the irrelevant actions. Exp. 2: After Exp. 1 E introduced a novel box containing prizes to the child. E retrieved a prize for the child using a series of relevant and irrelevant actions, whereas a bell attached to the irrelevant mechanism jingled every time an irrelevant action was performed. Then E handed the child the prize, Felix re-emerged, took the prize and disappeared. E explained to the child, that the bell must have awoken Felix and that he would leave the room so that the child could retrieve another prize quietly. Exp. 3: The training phase was the same as in Exp. 1. Then the child observed E performing several irrelevant actions (waving a wand) until finally completing the irrelevant sequence by striking the bolt's wing (monkey box) or hitting a rod (prize box). Afterwards he applied the relevant actions to open the object. For each puzzle object half of the participants saw the irrelevant actions marked as accidental (gestures of the experimenter while talking on the phone) while the other half saw them as intentional. Afterwards E left the room and it was the child's turn.	**Conditions:** Exp. 1 & Exp. 2: Non-competitive phase: retrieval of a toy while the experimenter was absent. Competitive phase: retrieval of a toy in a competitive race against a puppet monkey Baseline Condition: opening of the box independently Real world competitive condition (Experiment 2): irrelevant actions cause noisy bell ringing, which would lead to the danger of the prize being stolen Exp. 3: Intentional condition: Irrelevant actions were performed in a meaningful manner. Unintentional condition: Irrelevant actions were marked as accidental.	Over-imitation does not occur when irrelevant actions carried out non-intentionally by the demonstrator.
Simpson & Riggs (2011). Three- and 4-	Exp. 1: 3 – 4 years (n =	**The task:** open a transparent puzzle box **Irrelevant action:** open top aperture	**Design:** between-subjects design (Exp. 1 & Exp. 2) Exp. 1:	Exp. 1: Actions: Children made the irrelevant

year-olds encode modeled actions in two ways leading to immediate imitation and delayed emulation	90) Exp. 2: 3 – 4 years (n = 80)	**Relevant action:** open front aperture and remove block **Demonstration specifics:** Exp. 1: The two experimenters and the child sat side by side at a small table. E1 asked the child to watch carefully while removing a block from the apparatus performing both relevant and irrelevant actions. This demonstration was presented three times. In the test phase of the short-term condition, E1 said that it was the child's turn. Both experimenters coded the child's action. Each child received three test trials. In the long-term condition E1 said that the child would have a turn tomorrow. The test phase took place five to eight days later. The experimenter than simply said that it was the child's turn. In the control condition the children watched the box and the tool being placed on the table and told that it was their turn. Exp. 2: The procedure was the same as in experiment 1, except that only data from one test trial were collected and, in the reverse conditions, the relevant action was modeled before the irrelevant action.	Independent Variables: test interval (short-term, long-term, control) Dependent Variables: frequency of making the irrelevant and relevant actions and frequency of imitation and emulation Exp. 2: Independent Variables: test interval (short-term, long-term) and standard or reverse demonstration Dependent Variables: frequency of making the irrelevant and relevant actions and frequency of imitation and emulation **Conditions:** Exp. 1: Short-term condition: test phase took place directly after the demonstration phase Long-term condition: test phase took place five to eight days after the demonstration. Control condition: children could immediately interact with the box without any prior demonstration Exp. 2: Standard short-term condition: performance of the irrelevant action followed by the relevant action; test phase immediately after demonstration phase Standard long-term condition: performance of the irrelevant action followed by the relevant action; test phase after a delay Reverse short-term condition: performance of the relevant action followed by the irrelevant; test phase immediately after demonstration phase Reverse long-term condition: performance of the relevant action followed by the irrelevant; test phase after a delay	action significantly more often in the short-term condition than the long-term condition, but the control and long-term conditions did not differ. Children made the relevant action considerably more often in the long-term condition. Type of coding: Children imitated more often in the short-term than the long-term condition. Children emulated more often in the long-term condition than the short-term condition. Exp. 2: Actions: The majority of children made the irrelevant action in the short-term condition, but this declined in the long-term condition. Most of the children made the relevant action in all conditions. For the irrelevant action, there was an effect of test interval but no effect of action order or interaction. For the relevant actions, there was no main effects. Type of copying: For imitation, there was an effect of testing interval but no effect of action order or interaction. For emulation, there was an effect of testing interval but no effect of action order.
McGuigan, Gladstone, & Cook (2012). Is the cultural transmission of irrelevant tool actions in adult humans (homo sapiens) best explained as the result of an evolved conformist bias?	Exp. 1: 17 – 53 years (n = 84) Exp. 2A & 2B: 18 – 36 years (n = 31)	**The task:** retrieve reward from transparent Glass Ceiling Boxes **Irrelevant actions:** five actions directed to the top of the box: remove two bolts, tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box and insert stick tool inside **Demonstration specifics:** Exp. 1: Adult participants were presented with two task demonstrations in which they viewed two adult models retrieve a reward from inside a puzzle box. The reward was either retrieved from the box using only causally relevant actions (efficient approach) or was retrieved after the model had performed five causally irrelevant actions (inefficient approach). The participants observed either two inefficient models, or one efficient model and one inefficient model, before being allowed to attempt the task in the presence of one,	**Design:** between-subjects design (Exp. 1); mixed design (Exp. 2A & 2B) Independent Variables: strategy demonstrated (efficient or inefficient), model presence (present or not present, Exp. 1 & 2A), task context (experimental or non-experimental, Exp. 2B) Dependent Variable: number of irrelevant actions performed **Conditions:** Exp. 1 Inefficient strategy conditions: each of two models performed a task demonstration containing irrelevant actions; one (cond. 1), neither (cond. 2), or both (cond. 3) models were present during the participant's attempt Mixed strategy conditions: one model performed a demonstration containing irrelevant actions, the other model performed the task without irrelevant actions; the efficient (cond.4), the inefficient (cond. 5), neither (cond. 6), or both (cond. 7) models were present during the participant's attempt	Exp. 1: There was no significant effect of model presence in the inefficient strategy conditions with participants performing a large number of irrelevant actions irrespective of the presence of model(s) during testing. There was no significant effect of model presence in each of the mixed strategy conditions with participants performing very few irrelevant actions irrespective of whether the model(s) were present. Exp. 2A: There was no sign. difference in the number of irrelevant actions performed between conditions. Across Exp. 1 and 2A: The presence of

		neither or both models. Exp. 2A: Depending on condition the participants saw either one model performing three inefficient demonstrations and one model performing one efficient demonstration (majority strategy condition), or three models performing inefficient demonstrations and the fourth model performing the efficient demonstration (majority model condition), before being allowed to attempt the task. Exp. 2B: On completion of Experiment 2A as a test for the influence of the experimental context, the participants completed a 'post experiment' trial in which they were asked to check if the reward was in the box to be used by the next participant.	Exp. 2A: Majority strategy condition: one model performed three inefficient demonstrations, the other model performed one efficient demonstration Majority model condition: three models performed inefficient demonstrations, the fourth model performed the efficient demonstration Exp. 2B: Post experiment trial: after the experimental trials were complete each participant was asked to check if the reward was inside the box for the next participant.	an inefficient strategy majority resulted in high levels of OI, whereas the presence of an efficient strategy only prevented the occurrence of OI. Exp. 2B: Participants performed significantly fewer irrelevant actions in the post experiment trial than the experimental trials.
Nielsen, Cucchiaro, & Mohamedally (2012). When transmission of culture is child's play.	4 – 5 years (n = 42 from Brisbane, Australia and n = 42 from Colombo, Sri Lanka)	**The task:** retrieve toy from one of two opaque puzzle boxes accompanied by different objects **Disconnected irrelevant action:** neither touching nor opening box: sliding object on the ground surrounding/ behind the box three times **Connected irrelevant action:** touching but not opening box: sliding object across the lid of the box three times/ tapping object three times across the top of the box **Relevant action:** placing object to switch on the front of the box to open it **Demonstration specifics:** Children first watched an adult demonstrate one of two sequences of causally irrelevant disconnected and irrelevant but connected actions; followed by the relevant action. Then it was the child's turn. Next, children were given a second attempt while another child sat next to them to observe. The 2nd child then in turn could show the 3rd child in the chain.	**Design:** between-groups, diffusion chain design Dependent variable: score (frequency of produced disconnected and connected irrelevant actions; whether or not box was opened) Independent variable: initial adult demonstration **Conditions:** there were three experimental conditions: - Playful demonstration with looks and smiles; use of playful objects (toy car and cow) - Functional demonstration in deliberate, structured manner with ostensive communicative cues; use of functional objects (stick and key) - No-model control condition There were 10 chains of 3 children for each of the four experimental conditions and 8 chains of 3 children for the control condition.	When the adult initially modeled irrelevant actions in a playful way, they were retained down to the 3rd child in the diffusion chain at higher rates than when actions were shown in a functionally oriented way. Children in the 2nd position of the chain in the Control condition produced significantly fewer actions than children in the Playful or Functional condition. For children in the 3rd position, those in the Playful condition produced significantly more actions than in the other conditions. There were no significant differences in responses of the Brisbane and Colombo children.
McGuigan (2012). The Role of Transmission Biases in the Cultural Diffusion of Irrelevant Actions.	18 – 25 years (n = 44); 32 in 4 experimental chains, 12 in a no-model control group)	**The task:** retrieve reward from transparent or opaque Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts (using drag or push technique), tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box (using slide or lift technique) and insert stick tool inside **Demonstration specifics:** The first participant (X) in each chain was pre-trained to perform the action sequence by E. Once the seed had mastered the action sequence they demonstrated for the next individual in the chain (A), who subsequently demonstrated for B and so on along the chain.	**Design:** diffusion chain vs. no-model control condition Dependent variables: number of irrelevant actions performed, fidelity of transmission of two-action method of bolt and door removal, speed of task completion Independent variable: box transparency (opaque or transparent) **Conditions:** varied according to box transparency and two-action method used Four experimental chains: - Transparent box chain (drag bolts-slide door) - Opaque box chain (drag bolts –slide door) - Transparent box chain (push bolts-lift door) - Opaque box chain (push bolts-lift door) Two "no model" control conditions:	Adults in transparent box chains performed significantly fewer irrelevant actions than those in opaque box chains. However, irrelevant actions were evident within each chain suggesting that causally irrelevant tool actions can survive within groups of adults. Female observers were more likely to overimitate their model than male observers. The bolt removal technique was transmitted with an extremely high level of fidelity in opaque chains, and with slightly lower levels of fidelity in

<table>
<tr><td></td><td></td><td></td><td>- Opaque box condition
- Transparent box condition</td><td>transparent chains. The technique used to remove the door defense showed low levels of fidelity.
In the control conditions few irrelevant actions were performed with either box, and there was no difference in the technique used to open the door defense with either box.</td></tr>
<tr><td>Wood, Kendal, & Flynn (2012). Context-dependent model-based biases in cultural transmission: children's imitation is affected by model age over model knowledge state.</td><td>5 years (n = 96, 85 for experimental conditions and 11 in control group)</td><td>The task: retrieve reward (sticker) from transparent Glass Ceiling Box
Irrelevant actions: poking/dragging with tool to remove bolt defense (leads to empty compartment with glass ceiling), inserting tool into hole, tapping glass ceiling three times
Relevant actions: sliding/lifting door to reveal opening at the front of box, inserting tool (two-action task)
Demonstration specifics: Children watched a video introduction twice in which a model walks into room and professes (lack of) knowledge about task completion. Next, they watched one of two video demonstrations twice of extracting the reward, using either method 1 (poke-bolts-then-slide-door) or method 2 (drag-bolts-then-lift-door). Then, children could interact with the box (T1). Next, children watched the video demonstration a third time and were given another trial (T2).</td><td>Design: 2x2 between-groups design
Dependent variables: successful removal of sticker, used method, number of irrelevant actions copied
Independent variable: type of model
+ within-groups variable of trial number (T1 vs T2)
Conditions: children were randomly allocated to one of four conditions pertaining to the model's characteristics:
<table><tr><th></th><th>Adult model</th><th>Peer model</th></tr><tr><td>Task-knowledgeable model</td><td>Adult professing knowledge</td><td>5-year old professing knowledge</td></tr><tr><td>Task-ignorant model</td><td>Adult professing ignorance</td><td>5-year-old professing ignorance</td></tr></table>+ no-model control (no demonstration video)</td><td>Children who observed a demonstration performed significantly more irrelevant action at T1 than children in the no-model control group. Children imitated relevant action regardless of model's age and knowledge state. They imitated more irrelevant actions produced by an adult model than a peer model. Children who witnessed an ignorant model tended to produce fewer irrelevant actions than children who witnessed a knowledgeable model. Overall, children produced significantly more irrelevant actions at T2 than at T1.</td></tr>
<tr><td>Kenward, (2012). Over-imitating preschoolers believe unnecessary actions are normative and enforce their performance by a third party</td><td>3 years (n = 24)
5 years (n = 24)</td><td>The task: retrieval and replacement of jewels from two transparent boxes (push box and hook box) using a tool (stick/hook); Color-sorting (conventional) and washing jewels (instrumental)
Irrelevant actions: turn a dial connected to a paddle on top of the box; knock jewels on the side of the box before replacement (push box); shake the hook in a plastic loop on the side of the box; transfer the jewels with a piece of white cardboard to the box's upper surface before replacement (hook box)
Relevant actions: insert a stick in a hole in the front of the box to push out jewels; replace jewels through the front hole (push box); hook jewels out of the box with a special hook; push jewels into the box opening (hook box)
Demonstration specifics: First in the warm-up phase one of the experimenters introduced three instrumental tasks, which the child and the puppet (operated by E2) were encouraged to perform. The puppet made basic instrumental mistakes on the first and third tasks and E1</td><td>Design: mixed design
Independent Variables: omitted or performed unnecessary actions by a puppet, mistakes made in conventional or instrumental tasks by a puppet
Dependent Variables: child's responses during the puppets turn
Conditions: It was varied if the puppet performed or omitted the unnecessary action in the over-imitation task and if the puppet made mistakes in both instrumental tasks or in both conventional tasks.
Order of Tasks
<table><tr><th>Task Box</th><th>Order</th><th>Description</th><th>Type</th></tr><tr><td>Push box</td><td>1</td><td>Pushing jewels out</td><td>Over-imitation</td></tr><tr><td></td><td>2</td><td>Polishing jewels</td><td>Instrumental</td></tr><tr><td></td><td>3</td><td>Color-sorting jewels</td><td>Conventional</td></tr><tr><td></td><td>4</td><td>Replacing jewels</td><td>Over-imitation</td></tr><tr><td>Hook box</td><td>5</td><td>Hooking jewels out</td><td>Over-imitation</td></tr><tr><td></td><td>6</td><td>Color-sorting jewels</td><td>Conventional</td></tr></table></td><td>Across task types, the proportion of tasks with normative protest was greater when the puppet deviated from the demonstration than when it conformed. Task type and its interaction with puppet conformity/deviation were also significant predictors. For each task type individually, normative protest occurred in a greater proportion of tasks in which the puppet deviated from the demonstration. Although normative protest against the puppet's omission of the unnecessary action occurred in a relatively low proportion of tasks, the majority of children made at least one protest against omission of the unnecessary action in the more liberal protest category that also included non-normative protest. The</td></tr>
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		encouraged the child to help the puppet. After the warm-up phase E1 instructed the child and the puppet for each task to watch her while she dealt with the jewels. Then it was the child's turn while E1 turned her back and busied herself. Afterwards, E1 asked the puppet to have a turn. This procedure was the same for all 8 tasks. Demonstration of the over-imitation task always included the unnecessary action. For every participant the puppet omitted the unnecessary action in three over-imitation tasks but performed it in one. For each participant, the puppet either made mistakes in both instrumental tasks and not in the conventional tasks, or vice versa.	7 8	Washing jewels Replacing jewels	Instrumental Over-imitation	puppet's deviation from the demonstration elicited normative protest in a greater proportion of instrumental tasks than over-imitation and in a greater proportion of instrumental tasks than conventional tasks. There was no difference between conventional and over-imitation tasks in this respect. In over-imitation tasks in which the puppet omitted the unnecessary action, the frequency of normative protests was positively correlated with the proportion of jewel retrievals/replacements children conducted using the unnecessary action.
Flynn & Smith (2012). Investigating the Mechanisms of Cultural Acquisition: How Pervasive is Overimitation in Adults?	**Exp. 1**: 25 - 60 years (n = 60, 10 for each condition) **Exp. 2**: 18 – 39 years (n = 32) **Exp. 3**: 18 – 29 years (n = 32) **Exp. 4**: 18 – 21 years (n = 32)	**The task:** retrieve reward (sticker) from glass ceiling puzzle box (opaque or transparent) **Irrelevant actions:** actions directed to top of the box: removing two bolts, tapping three times **Relevant actions:** lifting (or sliding, in Exp. 2-4) front door, inserting tool **Demonstration specifics:** For **Exp. 1**, adults first watched irrelevant actions performed live by E, then the causally relevant actions and the reward retrieval. Then it was the participant's turn. The whole procedure was repeated a second time. Same procedure in **Exp. 2,** but only one trial. To manipulate social pressure, presence/absence of E was varied. For all participants, time pressures were added ("go as quickly as you can") as a potential motivator to eliminate irrelevant actions. **Exp. 3** was similar to in experimenter-present condition of Exp. 2. A competition for a monetary reward was added. **Exp. 4** was similar to Exp. 3. Identity of demonstrator was manipulated so that participants watched a demonstration by a supposedly "fellow participant".	**Design:** mixed Dependent variable: performance score (y/n: Removal of bolts, tapping, reward removal) Independent variables: Evaluation/social/times pressure, identity of model **Conditions:** **Exp. 1:** 4 observational learning conditions with variations regarding box (first demonstration on opaque vs. transparent box); irrelevant tapping repetitions (one vs. three); 2 no demonstration control conditions with transparent vs. opaque box **Exp. 2:** two-action design was introduced (lifting vs. sliding method for each half of participants of each condition), 4 conditions with variations regarding social pressure (E present vs. absent); box (opaque vs. transparent) **Exp. 3 and 4:** two-action design, 2 conditions: opaque vs. transparent box	Adults in **Exp. 1** reproduced irrelevant actions for both transparent and opaque box first conditions. They tended towards exact imitation (number of taps produced significantly differed between groups who witnessed 1 vs 3 taps). In **Exp. 2** participants overimitated at similar rates, irrespective of whether E was present or not. In both **Exp. 2 and 3,** there was no significant difference in level of imitation according to box type. With the introduction of a monetary incentive (**Exp. 3 and 4**), the rate of OI was significantly lower than in Exp. 1. In **Exp. 4,** participants presented with the transparent box were significantly less likely to overimitate than participants presented with the opaque box.
Nielsen, Moore, & Mohamedally (2012). Young children overimitate in third-party contexts	Exp. 1: 4 years old (n = 48) Exp. 2: 4 years (n = 36)	**The task:** retrieve a toy from an opaque box (3 different boxes, each accompanied by a different object) **Irrelevant actions:** blue box: place stick on top of box and wipe around in a circular motion; switch box: tap mallet on top of box; artificial fruit: wipe stick along box from back to front **Relevant actions:** blue box: hold stick on top of knob, push down and open front of box; switch box: using mallet, push switch from left to right to open box;	**Design:** between-subjects design Independent Variables: presence of teacher or student and exploration or no exploration phase Dependent Variables: reproducing the irrelevant action; using the object to open the box; opening the box **Conditions:** Exp. 1: It was varied which experimenter (student or teacher) remained in the room and if there was a exploration phase prior to demonstration phase	Exp. 1: Irrelevant actions were produced at similar high rates by children in the Prior Experience – Teacher Stays, Prior Experience –Student Stays, No Experience – Teacher Stays, and No Experience – Student Stays conditions. They similarly produced the causally related actions at comparable rates

artificial fruit: using stick, push out dowels toward front until they fall onto top of table
Demonstration specifics: Exp. 1: In condition 1 both the child and the parent sat at a table with all three opaque boxes and associated objects. E1 simply suggested that they could be played with. E1 (the "teacher") and E2 (the "student") occupied themselves during this exploration phase. In the demonstration phase the teacher told the student to watch and opened the first box performing one irrelevant and one causally relevant action with a tool (the box could have been more easily opened by hand). Once the toy was retrieved, the box was reset and placed next to the tool that was used. Then the student left the room and the teacher asked the child to show what to do. After the child's turn, the student returned, and the procedure was repeated for the remaining two boxes. Cond. 2 was identical to Cond. 1 except that the teacher left the room and the student remained to ask the child what to do with the box. Cond. 3 was identical to Cond. 1 except there was no exploration phase. In Cond. 4 there was no exploration phase and the student remained in the room.
Exp. 2: The test apparatuses were the same as in Exp. 1 except for an additional basket of toys placed on a play mat. The child was asked to sit on the play mat and the caregiver next to him/her. The caregiver was requested not to give any directions to the child. E2 sat on the floor, read a book and encouraged the child to play. In Cond. 1 E1 entered the room, looked at neither the child nor E2, and said she forgot to show how to use the box. She sat on the floor and demonstrated the irrelevant and relevant actions without looking at anyone. E2 didn't look up from her book. Once the box was open, E1 shut it and repeated the procedure. After the second demonstration E1 slid the box to E2 and requested her to have a turn, but E2 rejected, so E1 slid the box to the child and encouraged the child to have a turn. E1 left the room during the child's turn. This procedure was repeated for the other two boxes. Cond. 2 was similar to Cond. 1 except that the demonstration was aimed directly at E2, meaning E1 addressed E2 directly and they looked at each other. In Cond. 3 E1 the demonstration was directly aimed at the child and she directly pushed the box to the child after the demonstration.

Condition 1: Prior Experience – Teacher stays
Condition 2: Prior Experience –Student stays
Condition 3: No Experience – Teacher stays
Condition 4: No Experience – Student stays

Exp. 2:
It was varied if the target actions were modeled for the participant or another person.

Condition 1 – Solitary Third Party: The demonstration was neither aimed at the child nor E2. The child had a turn after E2 rejected.

Condition 2 – Social Third Party: The demonstration was aimed at E2. The child had a turn after E2 rejected.

Condition 3 – Direct Modeling: The demonstration was aimed directly at the child. The child had a turn directly after demonstration.

across conditions and succeeded in opening the boxes at comparable rates.

Exp. 2:
Regardless of condition, children produced the irrelevant actions on the majority of opportunities. They also produced the causally related actions and succeeded in opening the boxes at comparable rates across conditions. Thus, children's inclination to overimitate remained strong regardless of whether or not the target actions were clearly modeled for them or another person and even in circumstances where they were otherwise engaged with a set of novel toys.

McGuigan (2013). The influence of model status on the tendency of young children to over-imitate.	5 years (n = 41)	**The task:** retrieve reward from transparent Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts, tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box and insert stick tool inside **Demonstration specifics:** Children watched an adult model of varying status and familiarity retrieve the reward from the box (3x) using both causally irrelevant and causally relevant actions. The box was then reset, and the child allowed an attempt.	**Design:** between subjects design with model status and model familiarity as factors Dependent variables: Number of irrelevant and relevant actions performed Independent variables: model status (high or low) and familiarity (familiar or unfamiliar) **Conditions:** Four model conditions collapsed into two status dimensions: - High status: familiar (class teacher) and unfamiliar (principal teacher) - Low status: familiar (experimenter) and unfamiliar (stranger)	Children reproduced more irrelevant actions after viewing high status models in comparison to low status models. Children performed more irrelevant actions in the head teacher condition than in both the familiar and unfamiliar model conditions. There was no significant difference between conditions in the occurrence of relevant actions.
Nielsen (2013). Young children's imitative and innovative behaviour on the floating object task	4 years (n = 36)	**The task:** pouring water into a transparent tube to retrieve a toy. **Irrelevant actions:** pour the water into a small or large cup first, before pouring it into the tube. **Relevant action:** pour water into the tube. **Demonstration specifics:** A tube apparatus with a monkey inside, a bottle of water and two empty cups (one large, one small) were set at a table. The child sitting at the table was asked by the experimenter to retrieve the monkey. If the child used the water to retrieve the toy, the session terminated. If the child didn't attempt to use the water, she/he was allocated to one of the three following conditions: *Bottle demonstration:* The experimenter took the bottle and poured some water into the tube, so much that the monkey floated, but could not yet be retrieved. Then it was the child's turn. *Small cup demonstration:* Instead of pouring the water directly into the tube, the experimenter poured it into the small cup first and then into the tube. This was repeated three times. Then it was the child's turn. *Large cup demonstration*: Same procedure as in the small cup condition, except that the cup was larger.	**Design:** between-subjects design Independent Variables: bottle, small cup or large cup demonstration Dependent Variables: attempt to retrieve the toy, attempt to retrieve the toy using the water, attempt to retrieve the toy using the water as demonstrated, successful retrieval of the toy **Conditions:** If the child didn't use water to retrieve the toy spontaneously (pre-demonstrational), it was allocated to one of the following conditions. Cond. 1 – bottle demonstration Cond. 2 – small cup demonstration Cond. 3 – large cup demonstration	Pre-demonstration: 5 out of 36 (14%) children retrieved the monkey initially by pouring water into tube (3 using cups) Cond. 1: 6 out of 10 successful retrieval Cond. 2: 7 out of 10 successful retrieval, 6 using cup as shown Cond. 3: 8 out of 11 successful retrieval, 7 using cup as shown 19 out of 31 (61%) were successful in the post-demonstration conditions, significantly more than in the pre-demonstration (14%, $p<0.5$); There was no difference in successful retrieval rates across the three conditions.

Keupp, Behne, & Rakoczy (2013). Why do children overimitate? Normativity is crucial	3 years (n = 48) 5 years (n = 47)	**The task:** retrieving a marble and putting it into a tube (game 1); pushing out the lowest marble (2); clearing the way for a marble (3) **Irrelevant actions:** tapping on the lid of a physically disconnected box (1); brushing the lid of a physically disconnected box with a paintbrush (2); turning the clock hand of physically disconnected box (3) **Relevant actions:** opening the box and taking out a marble (1); inserting a stick into the box to push out the lowest marble (2); lifting four barriers to clear the way for a marble (3) **Demonstration specifics:** First there was a warm-up phase to familiarize the child with the main experimenter (E1) and a puppet (operated by E2) by playing different games. In the test phase the child participated in three games. In the *method condition* E1 presented the game's effect prior to the demonstration. First E1 stressed the following actions by naming it (e.g. daxing) and then E1 demonstrated a full action sequence of relevant and irrelevant actions twice. Then it was the child's turn while E1 looked away. Afterwards the puppet appeared and played the game twice (1x omitting & 1x performing irrelevant actions). E1 asked the child about the correctness of puppet's actions after each turn. Then it was the child's turn again. In the *goal condition* the procedure was the same as in the method condition except that there was no prior demonstration of the game's effect and E1 labeled the following action by its effect (e.g. ringing the bell).	**Design:** between-subjects design Dependent Variables: performance of the irrelevant action or an approximation of it; protest category (normative, imperative, hints); explicit judgment of the correctness of the puppet's actions Independent Variables: (no) prior demonstration of the effect & labelling of effect/method **Conditions:** Method condition: prior demonstration of the game's effect & labelling of the method Goal condition: no prior demonstration of the game's effect & labelling of the effect.	Results show high over-imitation scores throughout all conditions and trials (even after seeing the efficient strategy). Children spontaneously protested against the third party specifically when she omitted the irrelevant action but did not when she did overimitate, and children protested against omitting the irrelevant action more in the method condition than in the goal condition. 84% of the protests contained normative language.
Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis (2013). Selective and faithful imitation at 12 and 15 months.	12 and 15 months (n= 37, longitudinal)	**The task:** retrieve reward from four toys (two wooden boxes, two toy trucks) **Irrelevant actions:** first action in unnecessary condition: pulling Velcro strap from half of the box without lid on it/ removing glass cover from animal in back of the truck **Relevant actions:** both actions in necessary condition: pulling Velcro strap to open lid/ removing glass cover from a toy animal to push it in the front seat in order to make music play **Demonstration specifics:** There were four test phases with two demonstrations of each condition. E took the first toy and modeled a two-step sequence twice. Then it was the child's turn to play with the toy (response period). The whole procedure was then repeated for the second toy.	**Design:** longitudinal within-subjects design Dependent variable: (focused on first action) - selective imitation (copying the first action more often in the necessary than in the unnecessary condition) - faithful imitation (copying both necessary and unnecessary first actions) Surgency/Extraversion was assessed to evaluate infants' social motivation (Early Childhood Behavior Questionnaire ECBQ), completed by mothers. Independent variable: causal context was varied **Conditions:** Depending on the condition, the first action was either irrelevant vs. causally necessary for the second action.	Infants were more likely to copy first actions in the necessary condition compared to the unnecessary condition, both at 15 and 12 months. From 12 to 15 months, selective imitation decreased while faithful imitation increased. For the necessary condition, no effect of age was found. High-surgency (extrovert) infants were more likely to copy first actions (faithful imitation) than low-surgency infants.

Nielsen, Slaughter, & Dissanayake (2013). Object-Directed Imitation in Children With High-Functioning Autism: Testing the Social Motivation Hypothesis.	4 – 8 years [n = 34, 16 children with high-functioning autism (HFA); 18 typically developing (TD) children]	**The task:** reveal toy from three opaque boxes (OI task); interact with toy (teddy bear/ cup/ slide rule; synchronic imitation task) **Irrelevant actions:** swiping stick across box in circular motion three times/pressing mallet onto box three times, using steel plate like a stamp/wiping spanner three times across box **Causally related but unnecessary actions:** placing stick into hole in the back and pushing drawer out/ pushing steel plate against switch and active mechanism to release the lid/pushing spanner onto handle to open door **Relevant/efficient action:** opening box by hand **Demonstration specifics:** In the OI task, children were presented a box accompanied by a different object. E first demonstrated an irrelevant action with the object, then opened the box with the object by using a causally related but unnecessary action. This demonstration was repeated three times, then it was the child's turn. This was repeated for all boxes. For the synchronic imitation task, E demonstrated two actions with a toy. Then it was the child's turn to "do whatever they want" with a second, identical object. This was repeated for the other two objects.	**Design:** between-groups design Dependent variables: frequency of repetition of causally irrelevant action (imitation score), imitation of causally relevant action, opening of box in over-imitation task + Synchronic imitation duration and score Order of tasks, presentation order of boxes and objects was counterbalanced across children.	HFA children opened boxes and produced the causally related actions at similarly high levels to the TD children. Both groups of children showed close to perfect imitation of the irrelevant actions and spent almost identical amounts of time copying the experimenter in the synchronic imitation task.
Marsh, Pearson, Ropar, & Hamilton (2013). Children with autism do not overimitate.	4 – 13 years [n = 31 children with Autism spectrum conditions (ASC), n = 30 typically developing (TD) children matching in verbal mental age; 30 TD children matching in chronological age]	**The task:** retrieve toy from a box or build a simple object **Irrelevant actions:** tapping top of box twice/ sliding box along table/ stroke top of box twice or turn block in hand/tapping paper on table twice **Relevant actions:** unclipping fastenings/removing elastic band from box and removing lid /pull box towards self or place block 1 on table and place block 2 and 3 on top/ gather up paper and fold it **Demonstration specifics:** There was one warm-up (not containing unnecessary actions) and five experimental trials in which a demonstrator showed two necessary and one unnecessary actions on the box/object. E meanwhile interacted with the child and gave instructions. Then children were asked to get/make the toy as quickly as possible. Finally, there was a rationality discrimination task (watching demonstrator complete individual actions from each sequence and rating action as sensible/silly).	**Design:** between-groups design Dependent variables: over-imitation score (0-5), goal achievement and rationality discrimination score Independent variable: eye contact **Conditions:** timing of eye contact (Demonstrator stopping the demonstration and looking directly at child) was varied to explore the ostensive signals in OI	Children with ASC copied unnecessary actions at a significantly lower rate than both groups of TD children. TD children were better at discriminating action rationality than the ASC group. However, OI seemed to be independent of a child's ability to discriminate the necessity of an action. Eye contact did not influence OI in either TD or ASC children.
Hoehl, Zettersten, Schleihauf, Grätz, & Pauen (2014). The role of social interaction and pedagogical cues	5 – 5 ½ (n = 99; 28 in each experimental condition)	**The task**: Extract a magnetic golden marble from a puzzle box with a magnetic rod **Irrelevant/inefficient action(s):** Clapping, tapping the rod on the palm of the hand three times and counting simultaneously to three, pushing a	**Design**: between/within/mixed Variables: independent & dependent variables … **Conditions**: It was varied how communicative the models acted with the child. One baseline condition and three experimental conditions were conducted:	Children imitated irrelevant actions both when they were modeled by a communicative and when they were modeled by a no-contact model. Children stopped using the previously

for eliciting and reducing overimitation in preschoolers		lever back and forth, pushing a button which was connected to the side of the puzzle box **Relevant actions:** Opening the flap covering the tube, inserting the magnetic rod and extracting the marble **Demonstration specifics**: First children observed one model using an inefficient strategy to extract a token from a puzzle box. Then they were asked to extract a token. Second, they observed another model using an efficient strategy. Then it was their turn again	<table><tr><th></th><th>Phase 1: Inefficient model</th><th>Phase 2: Efficient model</th></tr><tr><td>Cond. 1</td><td>Communicative</td><td>No contact</td></tr><tr><td>Cond. 2</td><td>No contact</td><td>Communicative</td></tr><tr><td>Cond. 3</td><td>Communicative</td><td>Communicative</td></tr></table>	learned irrelevant actions only when they were subsequently shown the more efficient way to achieve the goal by a communicative model. Communication lead to adaption of imitative behavior but did not affect eliciting over-imitation.
Gardiner (2014). Beyond irrelevant actions: Understanding the role of intentionality in children's imitation of relevant actions	Exp. 1: 3 – 5 years old (n = 58) 3 years old (n = 18) 4 years (n = 21) 5 years (n = 19) Exp. 2: 3 – 5 years (n = 58) 3 years (n = 18) 4 years (n = 20) 5 years (n = 20) (none of the children of Exp. 2 took part in the Exp. 1)	**The task:** Three actions to retrieve a toy from (6 different) transparent (Experiment 1) or opaque (Experiment 2) apparatuses. All children participated in all 6 (2 of them were control conditions) conditions. **Irrelevant action:** Imitating the first action when its relevancy was removed. **Relevant action:** Imitating relevant actions **Demonstration specifics:** Exp. 1: The experimenter placed an apparatus (transparent) in front of the child and showed 3 actions to retrieve the toy out of the box. The first action was marked as intentional ("There!") or accidental ("Whoops!") while the second and third actions where always marked as intentional. For the child's turn, an assistant reset the apparatus behind the barrier and made the first action irrelevant or left it relevant. Then it was the child's turn. Exp. 2: E presented a toy and told the child, that it was going to be placed in an (opaque) box. After the assistant placed the toy in the box, the demonstrator placed the box in front of the child and pointed out that the toy was now in the box. Then the procedure continued as in Experiment 1.	**Design:** Within-subjects design Dependent variables: retrieval of the toy, number of performed manipulations, degree to which the respective moving parts were manipulated Independent variables: intentionality of the demonstrator, relevancy of the actions **Conditions:** 4 demonstration conditions and 2 control conditions <table><tr><th>Demonstration: Intentionality of first action</th><th>Child's turn: Relevancy of first action</th><th>Condition</th><th>Consistency of intentionality and causality</th></tr><tr><td>Intentional</td><td>Relevant</td><td>Intentional Relevancy Retained</td><td>Consistent</td></tr><tr><td></td><td>Irrelevant</td><td>Intentional Relevancy Removed</td><td>Inconsistent</td></tr><tr><td>Accidental</td><td>Relevant</td><td>Accidental Relevancy Retained</td><td>Inconsistent</td></tr><tr><td></td><td>Irrelevant</td><td>Accidental Relevancy Removed</td><td>Consistent</td></tr><tr><td>No demonstration</td><td>Relevant</td><td>Control Relevancy Retained</td><td>n/a</td></tr><tr><td></td><td>Irrelevant</td><td>Control Relevancy Removed</td><td>n/a</td></tr></table>	Exp. 1: Children in the control conditions were significantly less successful in removing the toy from the box and performed significantly more manipulations than children in the experimental conditions. Main effects of relevancy (children had higher first action scores when relevancy was retained) Exp. 2: Significant differences between the Relevancy Retained conditions and between the Relevancy Removed Conditions. Children performed significantly more manipulations in the control conditions. Main effects for intentionality (children had lower scores when demonstration. of the first action was accidental than when demonstration was intentional). Children had lower scores when relevancy was removed than when relevancy was retained. When demonstration of the first action was intentional, relevancy retained, and relevancy removed scores were not significantly different.
Nielsen, Kapitány, & Elkins (2014). The perpetuation of ritualistic actions as revealed by young children's transmission of normative behavior	Exp. 1: 4 years (n = 42, 14 in each condition) Exp. 2: 4 years (n = 44)	**The task:** removing a toy from an opaque box by using tools **Irrelevant actions:** touching or tapping the box with a tool **Relevant action:** pushing the lid up with or without a tool **Demonstration specifics:** Exp. 1: *Helping – Demonstrator absent:* E1 opened a box and removed a toy, played with it, put it back into the box and left the room. E2 entered, took out the toy, played	**Design:** between-subjects design (Exp. 1 & Exp. 2) Dependent variables: selection of the tool, copying the arbitrary action, copying the causally-related action Independent variables: demonstrator absent or present or direct demonstration **Conditions:** Exp. 1: three experimental conditions; 2 trials per condition Helping – demonstrator absent Helping – demonstrator present Direct demonstration	Exp. 1: Tool choice: No differences across conditions, most children followed E's choice. Arbitrary actions: Similar amounts of arbitrary actions in all conditions Causally-related actions: More actions in direct demonstration than in demonstrator absent or demonstrator present conditions.

		with it (or let the child play with it), and put it in a different box. Before E2 left the room, she showed the child twice how to open the new box by using one of two present tools and performing both an arbitrary and a causally-related action. E2 left the room and E1 entered, asking for her toy. Then it was the child's turn to open the box and retrieve the toy. For the second trial E1 exchanged both boxes for new ones and the procedure continued identical to trial 1. *Helping – Demonstrator present*: The condition was identical to the Helping – Demonstrator Absent condition, except that E2 didn't leave the room but stayed in a corner and put headphones on. *Direct Demonstration:* The Condition was identical to the Helping – Demonstrator Absent condition, except that after the opening demonstration, E2 slid the box and the tools over to the child and prompted him/her to open the box before E1 returned. Exp. 2: *Arbitrary actions displaced – helping condition*: Identical to Helping – demonstrator-absent condition of Exp.1, except the arbitrary actions were performed after the box had been opened. *Arbitrary-actions-displaced-demonstration condition:* Same as direct demonstration condition, except that the arbitrary actions were performed after the box had been opened with the causally-related action. *Direct-demonstration condition*: Identical to Exp.1	Exp. 2: three experimental conditions Arbitrary-actions-displaced-helping Arbitrary-actions-displaced-demonstration Direct demonstration	Exp. 2: Tool choice: No differenced across conditions Tool Choice & causally-related actions: No differences Arbitrary Actions: More arbitrary actions in the direct demonstration condition compared to arbitrary-actions-displaced-helping condition; arbitrary-actions-displaced-demonstration condition lies in between with no significant differences to either condition. No differences between production of arbitrary actions in demonstrator-absent condition Exp.1 and arbitrary-actions-displaced condition Exp.2 (same demonstration, only action sequence differed).
Watson-Jones, Legare, Whitehouse, & Clegg (2014). Task-specific effects of ostracism on imitative fidelity in early childhood	3 – 6 years (n = 96) 3 – 4 years (n = 48) 5 – 6 years (n = 48)	**The task:** tapping wooden cubes on a peg of a pegboard, using a tool to slide open the lid of a box, put a pipe in the box (only in instrumental conditions) closing the box with the right hand **Irrelevant actions:** all of the actions are irrelevant in achieving a goal except for putting the pipe in a box in instrumental condition **Relevant action:** place a pipe inside the box and close it (only potential goal associated with the end-state in the instrumental conditions) **Demonstration specifics:** Depending on condition each child viewed a video prime depicting ostracism or affiliation. Next the experimenter introduced the model in the video and children watched either a single videotape of the convention (only the object set) or instrumental action sequence (object set and one novel gesture to clearly differentiate the causally meaningless element from the potentially causally meaningful). At the	**Design:** 2x2 between-subjects design Independent Variables: type of prime, same end-state or different end-state Dependent Variables: imitative behavior, explanation for behavior, **Condition:** Ostracism-convention: ostracism prime and start- and end-states were equivalent Affiliation-convention: affiliation prime and start- and end-states were equivalent Ostracism-instrumental: ostracism prime and start- and end-states were different Affiliation-instrumental: affiliation prime and start- and end-states were different Description of primes: Ostracism prime: three blue pentagons that entered the screen and appeared to interact as a group. When a fourth pentagon	Main effects of prime: children in ostracism condition had higher imitative fidelity scores (in both tasks). Main effects of task: children in the convention cond. had higher imitative fidelity scores. Main effects of age: older children had marginal higher imitative fidelity scores. Interaction effects: no significant interaction between prime and task Main effects of planned comparison: the difference between ostracism and affiliation priming was only significant within the convention condition. Children in the ostracism-convention condition imitated each element of the action sequence more than children in the other conditions.

		conclusion of the video demonstration the objects that the child had seen in the video were placed into the view of the child and the child was encouraged to have a turn. Following the imitation task, the experimenter asked the child why he/she accomplished the task in this particular way.	entered and approached the group, the group moved away from the fourth pentagon four times. Affiliation prime: Four blue pentagons entered the screen together and appeared to interact and move as a group.	Social convention explanations: Children in the ostracism-convention condition provided more and children in the affiliation-instrumental condition provided fewer explanations.
Marsh, Ropar, & Hamilton (2014). The social modulation of imitation fidelity in school-age children	5 – 8 years (n = 94) 5 years (n = 26) 6 years (n = 25) 7 years (n = 22) 8 years (n = 21)	**The task:** Retrieving an object from a transparent box or building an object (tower of blocks, paper fan); rating on a 5-point scale how silly or sensible an action was after watching a short clip (video condition) or a short demonstration (live condition). **Irrelevant actions:** Imitating action 2 (tapping the top of the box, sliding box along the table, stroking the top of the box, turning block 360°, tapping paper) of one of the 5 tasks. **Relevant actions:** Imitating actions 1 (unclipping fastenings of box, removing elastic band, pulling box, placing block 1, gathering up paper) and actions 3 (removing the lid and retrieving the duck, elephant, lion, placing blocks, folding the paper) **Demonstration specifics:** *Practice Trials:* In the first practice trial the experimenter placed three beads on a peg. Then it was the child's turn. In the second practice trial the experimenter put a doll in a pot. Then it was the child's turn. *Video Conditions:* The experimenter placed a laptop in front of the child and drew the child's attention to the laptop showing a picture of the end goal of the action. Then the movie demonstration of the task started. It was divided into 3 actions (first action was rational, second irrational, third rational). After each video, depicting one of 5 tasks, the experimenter gave the child the same apparatus shown in the video and invited the child to retrieve the object as quickly as possible. Each child watched 5 videos. Once all 5 trials were completed, the children were shown 10 short clips (5 rational and 5 irrational actions randomly presented). After each clip the child was asked to rate on a 5-point scale how sensible (experimenter pointed to a smartly dressed man) or silly (experimenter pointed to a clown) the action was. *Live Conditions:* The procedure was the same as in the video conditions besides the demonstrations, which were performed live by a third person.	**Design:** Mixed model Dependent Variables: Achievement of the goal of the action, performance of irrational actions, rationality ratings Independent Variables: Video or live demonstrations, eye contact **Conditions:** Between-subjects: Children were randomly assigned to one of two experimental conditions (live demonstration or video demonstration) that were matched for gender and age. Within-subjects: Eye contact was manipulated and counterbalanced for action (either preceding a rational or irrational action) and for trial (type of apparatus) across participants.	62% of children completed at least one irrelevant action. Main effects: Participants in live demonstration condition overimitated significantly more than those in the video demonstration. OI increased significantly with age. No main effect of eye contact preceding an irrational action is reported. Children who overimitated an action subsequently rated that action more irrational than actions that they did not overimitate. Interaction effects: A significant age by eye contact interaction was found, which was driven by an increase in over-imitation in the older children when eye contact was absent. There was a significant interaction between age and demonstration type. Older children are more likely to overimitate the live, but not the video condition. Older children reported lager rationality differences between rational and irrational actions.

Nielsen, Mushin, Whiten & Tomaselli (2014). Where Culture Takes Hold: "Overimitation" and its flexible deployment in Western, Aboriginal, and Bushmen Children.	**Exp. 1:** 3 – 6 years (n = 64 Bushman children from !Xun or Khwe clan in Platfontein, South Africa and n = 64 children from suburbs of Brisbane, Australia) **Exp. 2:** 3 – 6 years (n = 19 indigenous Australian children and n = 19 Brisbane children)	**The task:** retrieve reward from three puzzle boxes (opaque cube box/opaque slab box/clear slab box) **Irrelevant actions:** removing top dowel, pushing dowels with stick, tapping with stick into hole three times **Relevant actions:** sliding/lifting front open and using stick to retrieve reward **Demonstration specifics:** Children observed E demonstrating causally irrelevant actions with a stick on a box and then retrieving the reward. This was repeated twice, then it was the children's turn (on same vs. other box, depending on condition). **Exp. 2** followed the same procedure, except: after their first turn (Response Phase 1), the opaque box was reloaded again, and children were given a second attempt to retrieve the toy (Response Phase 2).	**Design:** mixed Dependent variable: Causally irrelevant actions score, causally related actions score, toy retrieval, time Independent variable: context of demonstration, characteristics of box **Conditions:** Children in both samples were randomly allocated to one of six experimental conditions: - demonstration (model vs. exploration/no demonstration) - transfer (other box vs. same box as in demonstration) - opacity of box (opaque vs. clear) **Exp. 2**: instead of exploration/no demonstration condition, there was an experience condition (children observed demonstration on slab box, then there were two trials of exploration on first the slab box, then the cube box)	OI rate was higher in model-same conditions than both model-transfer and exploration-transfer conditions. In model-same conditions, both groups also produced more relevant actions than in both transfer conditions. In the model-transfer condition, Brisbane children produced more irrelevant and relevant actions than Bushman children but there were no cultural differences in the model-same and exploration-transfer conditions. **Exp. 2** revealed that regardless of prior experiences, children produced irrelevant and causally related action at similar rates.
Keupp, Behne, Zachow, Kasbohm, & Rakoczy, (2014). Over-imitation is not automatic: Context sensitivity in children's overimitation and action interpretation of causally irrelevant actions	Exp. 1: 3 – 5 years (n = 32) Exp. 2: 3 – 5 years (n = 30)	**The task:** clean a marble and put it in a box (1); get a chip ball and collect it into the saving box (2); finish a puzzle (3); store objects properly (4) **Irrelevant actions:** tap on the side with a stick (1); brush the lid with a paintbrush (2); turn the clock hand (3); stroke the side of the frame with a stick (4) **Relevant actions:** put a dusty marble into the machine and clean it (1); insert a stick into a tube to push a ball out (2); open the Velcro and turn over cup (3); put an object into one of the compartments and close plastic cover (4) **Demonstration specifics:** Exp. 1: In the training phase after familiarization the experimenter (E) told the child that she would sometimes perform "extra and silly" actions. Then she opened three different transparent containers with a toy inside after performing an irrelevant action on each of them. Following each opening she asked the child about the relevance of the two actions. In the test phase the child participated in four tasks. The two conditions varied with regard to the instructions the child was given. In both conditions E introduced the activities as tasks with instrumental goals and used the only two freely accessible items to perform the effect. Then E showed what else one could do and called the activity by a novel name ("daxing") and performed an A-B-E sequence of irrelevant (A) and relevant (B) actions leading to the effect (E: the task's goal). In the exploration phase E	**Design**: 2x2 within-subjects design Dependent Variables: rate of over-imitation (Experiment 1); imperative and normative protest (Experiment 2) Independent Variables: same or different context **Conditions:** It was varied which instructions the child was given. Exp. 1: Same context condition: for instruction the child was given the game's name (Ex. 1); the puppet announced her actions mentioning the game's name (Exp. 2); Different context condition: the child was instructed to bring about the effect (Exp. 1); the puppet announced her actions mentioning the game's effect (Exp. 2)	Exp. 1: Over-imitation was significantly higher in the same context condition than in the different context condition. In 6 of the 17 cases of over-imitation in the different context condition, children explicitly stated that they were, in fact, performing the conventional activity. Exp. 2: There was more protest in the same context condition than in the different context condition and there was a higher frequency of protest (proportion of trials in which protest occurred across the three tasks and compared across conditions). There was no correlation between rate of over-imitation and protest against omission of irrelevant actions.

		pretended to be busy for 10-15s. In the test phase E instructed the child according to condition. In the same context condition E invited the child to "dax", in the different context condition E instructed the child to bring about the effect. Exp. 2: The procedure was the same as in Experiment 1, except that in the test phase the children witnessed a puppet announcing either that she would perform the same activity as the experimenter had shown (same context condition) or that she would perform a different activity (different context condition). In both conditions the puppet omitted the irrelevant actions. Children participated in three test rounds.		
Keupp, Bancken, Schillmöller, Rakozcy, & Behne, (2016). Rational over-imitation: Preschoolers consider material costs and copy causally irrelevant actions selectively	4 – 5 years (n = 57)	**The task:** 4 different tasks: ring a bell (1), ring xylophone bars (2), collect marble along a scale (3), convey marble in a collector's bag (4) **Irrelevant actions:** throw a bead into the rubbish bin (1); rip a sticker in two and put each part onto one field on the board (2); rip a sheet of paper and put each part into the box (3); "junkpress" a ball with the tool (4) **Relevant actions:** hook the red block to ropeway and let it slide down (1); use the magnetic end of a stick to lift two barriers which block a marble (2); release a marble to run through the pipes (3); navigate marble through the labyrinth (4) **Demonstration specifics:** In the *warm-up phase* E1 introduced a puppet (Lola) operated by E2 to the child. This phase was designed to encourage the child to interact with Lola and intervene when Lola made mistakes in a picture-matching game. Moreover, it ensured the child's understanding that things cannot be retrieved from boxes without a tool. In the *test phase* children participated in four games. Depending on condition the games differed with regard to available objects. In the *prior phase* E1 provided items belonging to the same object category. These items included nine high-value ones and some low-value ones. E1, puppet and child chose each three for themselves, so that only low-value items were left. Puppet and child used their items immediately, while E1 explained how much she liked her items and that she would need them later. Thus, at the end of this phase three high-value items belonging to E1 together with some low-value items (high cost cond.: two items, low cost cond.: at least five items). In the *main test phase*, the introduction of the test game varied between the two context conditions. In	**Design:** mixed design Independent Variables: value of items, conventional or instrumental context Dependent Variables: performance of an irrelevant action, uttering protest **Conditions:** *High cost condition:* the only remaining suitable items to perform the irrelevant action with were high value items belonging to E1 *Low cost condition:* availability of target items was manipulated so that the causally irrelevant action could be performed with valueless items belonging to no one *Means-oriented conventional method condition*: E1 reminded the child of the effect of the apparatus and contrasted it with a new activity *Ends-oriented instrumental goal condition:* E1 reminded the child of the effect and repeated the demonstration of the effect	Over-imitation: children reproduced irrelevant actions in more than half of the trials. Generalized linear mixed model analysis showed significant effects for cost (more over-imitation in low cost condition) and context (more over-imitation in method condition). Protest: majority of children protest at least once against omitting the irrelevant action (overall protest rate: 28%) and some against the performance of irrelevant actions (overall protest rate: 12%). Children were more likely to protest against omitting irrelevant actions in the low-cost condition and for performing the irrelevant actions in the high cost condition.

		both children saw a brief video clip of the apparatus and its effect. Then E1 brought a real version of the apparatus and performed a live demonstration either again of the effect of the apparatus (goal cond.) or she demonstrated a new activity (method cond.). For both conditions, E1 then performed the same action sequence including irrelevant and relevant actions and the effect. Specifically, E1 took one of the low-value items left over from prior phase and used it for the irrelevant action, then she performed the relevant action that produced the effect. E1 performed this demonstration twice. In the high-cost cond. there are only three high value items left, in the low-cost cond. there are three high value items and several low-value items left. Then E1 invited the child to have a go while she turned away. When the child had finished, Lola took two turns playing the game once omitting the irrelevant action and once performing it.		
Clegg & Legare (2015). Instrumental and conventional interpretations of behavior are associated with distinct outcomes in early childhood	3 – 6 years (n = 246; n = 20 in baseline condition; n = 35 in an imperative condition)	**The task:** necklace-making **Irrelevant actions:** bringing the ends of the strings together and opening it; laying the string out on the table; touching a bead to the forehead; **Relevant action:** placing beads on a string **Demonstration specifics:** All children participated in an imitation task and were randomly assigned to one of two conditions (instrumental or conventional condition). The experimenter placed a set of necklace-making materials on the table. Depending on condition the experimenter told the child one of two language cues and began to make the necklace performing relevant and causally irrelevant actions. Then it was the child's turn. After the imitation task, the experimenter asked the child to recall the specific objects used in the sequence and then asked him/her to model the behavior demonstrated for a puppet. Afterwards only the 5- and 6-year-old children participated in a problem-solving task.	**Design:** between-subjects design *Independent Variables:* outcome-oriented or convention-oriented cue *Dependent Variables:* Imitative Fidelity **Conditions:** Instrumental condition: children heard an outcome-oriented language cue (e.g. "I am going to make a necklace") Conventional condition: convention-oriented language cue (e.g. "Everyone always does it this way") Baseline condition: children were presented with the necklace-making materials without any instructions or demonstration. Imperative condition: prior to the imitation task children received directions to imitate (e.g. "I want you to do what I am going to do")	Marginally significant interaction may indicate that children display a greater distinction in imitative fidelity between the instrumental and ritual stances as they increase in age. There were higher levels of imitative fidelity in the conventional condition; imitative fidelity increased with age across both conditions. There was a higher fidelity in the imperative condition than in the conventional condition. Children had higher transmission scores in the conventional condition, transmission score also increased with age.
McGuigan & Robertson (2015). The influence of peers on the tendency of 3- and 4-year-old children to over-imitate	3 – 4 years (n = 69)	**The task:** retrieve reward from transparent Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts, tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box and insert stick tool inside **Demonstration specifics**: In *phase 1* the child saw two models (either two familiar peers or two puppets) retrieve the reward from the box using one of two approaches: (a) using only causally relevant actions	**Design:** mixed design with experimental phase as the within-participants factor and condition as the between-participants factor Independent Variables: model identity (puppet or peer); model demonstration (inefficient or efficient); approach adopted by model present during trial 1 (efficient or inefficient), task context Dependent Variable: number of irrelevant actions performed **Condition:** 6 conditions - Efficient model stays condition (mixed approach): following an inefficient and efficient task demonstration the efficient	There was a significant effect of condition for both peer and puppet models: More irrelevant actions in "both models inefficient" condition than in the "mixed approach" conditions. Greater amount of OI in peer model conditions compared to puppet model conditions (except inefficient model stays cond.) There was a significant effect of trial in

		(efficient approach), or (b) using both causally relevant and causally irrelevant actions. The child observed either two inefficient models or one efficient and one inefficient, before one of the models left the testing area. The box was then reset, and the child allowed an attempt (trial 1). In *phase 2* the child viewed (on video) a further three puppets/peers performing the task. On completion of each model's demonstration the child had an attempt (trials 2, 3, 4). Irrespective of the condition, each participant witnessed a total of five models, four of whom performed the causally irrelevant actions and one whom performed the relevant actions only. *Phase 3*. As a test for the influence of the experimental context, the children completed a 'post experiment' trial in which they were asked to check if the reward was in the box for the next participant (trial 5).	model stays during trial 1 (both peers and puppets) - Inefficient model stays condition (mixed approach): following an inefficient and efficient task demonstration the efficient model stays during trial 1 (both peer and puppet models) - Both models inefficient condition: one inefficient model remains during trial 1 (both peer and puppet models) Post experiment trial: after the experimental trials were complete each participant was asked to check if the reward was inside the box for the next participant.	3/6 conditions: increasing amount of OI across trials in inefficient peer model, efficient peer model, and efficient puppet model stays cond. (OI scores low in remaining conditions). Almost all children omitted the irrelevant actions in the post-experimental trial 5.
Freier, Cooper & Mareschal (2015). The planning and execution of natural sequential actions in the preschool years.	**Exp. 1 and 2:** 3 and 5 years (n = 60, 15 in each condition/age group)	**The task:** preparing a sandwich **Irrelevant actions:** using **distractor objects,** i.e. taking bag of sugar, filling sugar into red jar, taking a mixing bowl, scooping jam into mixing bowl, stirring it, pouring second bag of sugar into red jar, putting lid on red jar, shaking it, peeling banana, placing it next to sandwich **Relevant actions:** using **goal-relevant objects,** i.e. taking two slices of bread, placing them next to each other, opening jar of jam, selecting knife, spreading jam, combing the pieces of bread **Demonstration specifics:** Children watched a video of a woman either preparing a sandwich or wrapping a gift by using 6 goal-directed and 7 distractor sub-actions. Then children were led to a table with all objects displayed in the misleading demonstration and were asked to make a sandwich. **Exp. 2** was similar except that objects were spatially positioned (left-to-right order) according to the action sequence. Distractor objects were lined up after the last relevant object.	**Design:** 2x2 multifactorial, between-groups design Dependent variables**:** intrusion score (time spent acting on distractor objects), error rates (omissions, preservations, objects substitutions), number of objects manipulated (separate scores for relevant and distractor objects), total performance time Independent variables**:** demonstration and underlying spatial event structure (in Exp. 2) were manipulated **Conditions:** Within each age group, children were randomly assigned to one of two demonstration conditions: - Misleading demonstration of target action (woman preparing a sandwich) - Control condition: Demonstration of unrelated event (woman wrapping a gift)	In contrast to 5-year-olds, 3-year-olds performed more distractor actions but were consistently less engaged in distraction in the control condition. 5-year-olds acted generally faster (especially in the misleading condition, in both Exp. 1 and 2) and manipulated fewer objects in the misleading condition than 3-year-olds. In control condition, almost equal numbers of distractor objects were manipulated by both groups. Condition seemed to be the more influential factor than age in Exp. 1. Children in **Exp. 2** overimitated less (on any of the measures) than children in Exp. 1. A 32% decrease of OI behavior was observed in 3-year-olds in Exp. 2 compared to Exp.1.
Berl & Hewlett (2015). Cultural Variation in the Use of Overimitation by the Aka and Ngandu of the Congo Basin.	4 – 7 years (n = 29 Ngandu horticulutarlists; n = 28 Aka hunter- gatherers) and 20 – 38 years (n = 14 Aka adults). Both groups in Congo Basin rainforest,	**The task:** retrieve reward from transparent puzzle box **Irrelevant actions:** actions on the top or sides of the box: tapping left or right side of box, sliding top door, tapping barrier **Relevant action:** opening front door by sliding or lifting **Demonstration specifics:** An in-group adult male model demonstrated a sequence of actions (four irrelevant and two relevant actions) on the box which resulted in the retrieval of the reward. After three demonstrations of the sequence, it was the child's turn.	**Design:** between-groups design Dependent variable: Over-imitation (number of irrelevant actions, irrelevant imitation score, irrelevance quotient, fidelity quotient) Independent variable: demonstration **Conditions**: Demonstration vs. no demonstration condition	Compared to children in control groups, children in demonstration conditions more often performed irrelevant actions and strings of actions in the same order as the demonstration (higher fidelity quotient). In the demonstration condition, Aka children copied fewer irrelevant actions and had less copying fidelity than Aka adults. Also, Aka children showed lower

	little exposure to Western influence.			proportions of irrelevant actions and higher emulation than Ngandu children and Aka adults.
Yu & Kushnir (2015). Understanding young children's imitative behavior from an individual difference perspective.	2 years (n = 48)	**The task:** retrieve reward from three puzzle boxes/ matching goal in puppet show task **Irrelevant action:** physically unnecessary actions to retrieve reward (puzzle box task) / irrelevant actions for matching goal (established by the experimenter's intentions, Puppet show task) **Relevant action:** actions necessary to retrieve reward/ goal-directed behavior (location in house condition or style in No house condition) **Demonstration specifics:** Tasks were always presented in a fixed order. After a warm-up phase, children started with the **puzzle box task**: each child played with three puzzle boxes, one from each of the three sets. For each task, E showed an action sequence (one/two irrelevant and one/two relevant actions). Then it was the children's turn. This was followed by 4 trials of **Puppet show task**: children were presented with either an empty mat or a mat with two cardboard houses on it. E moved a puppet towards a final location (center of mat with either house on it or not) by using one of two actions styles (hopping or sliding, accompanied by matching sound). Then it was the children's turn to play with the puppet. After the puppet show task, children completed a third set of puzzle boxes.	**Design:** within-subjects design Dependent variables: - goal-directed imitation (imitation of goal-relevant actions in puzzle box task/number of matched goals in Puppet show task) - faithful imitation (imitation of goal-irrelevant actions/matching of style and sound regardless of condition) Independent variables: Contextual influences and type of goal were manipulated (instrumental goals in puzzle box and social goals in puppet show task) **Conditions** for Puppet show task: - House condition (E moves puppet to cardboard house; goal-directed behavior = final location) - No House condition (E moves puppet in a certain style to same location without a house; goal-directed behavior = style) Trials were further manipulated regarding: - final location (puppet was moved into cardboard house/towards same spot on the mat but not into house on either left vs. right side of the mat) action style and sound (E moved puppet by either hopping vs. sliding it towards final location; accompanied by matching sound)	On a group level, children showed tendencies for both goal-directed and faithful imitation. Results showed stable individual differences in children's imitation (imitative behavior correlated both within and between different types of imitation tasks). The Puppet show task revealed different imitative behavior between conditions, but matching style and sound correlated across conditions (implies stability in children's faithful imitation). Also, matching of final location in the House condition was correlated with matching of style and sound in No House condition (implies stability in children's goal-directed imitation). Both goal-directed and faithful imitation were positively correlated respectively across tasks for individual children. Factor analysis revealed that faithful imitation explained 32% of total variance and goal-directed imitation an additional 19%.
Nielsen, Mushin, Tomaselli, & Whiten (2016). Imitation, Collaboration, and their interaction among Western and Indigenous Australian Preschool Children.	**Exp. 1:** 3 – 5 years (n = 48 Westernized children) **Exp. 2:** 3 – 5 years (n = 26 Indigenous Australian and n = 26 Brisbane children)	**The task:** retrieve reward (toy) from opaque or clear puzzle box **Irrelevant actions:** removing top door, pushing top door using the stick, inserting stick into top compartment **Relevant actions:** using tool to open front door, sliding front door open, using stick to retrieve toy **Demonstration specifics:** E performed opening the first box and retrieving the toy by using the stick. The reward was then placed back into the box and the action sequence was demonstrated a second time. Then it was the children's turn. The whole procedure was repeated for the second box.	**Design:** mixed design Dependent variables: Imitation score in causally irrelevant action category and in causally related action category; collaboration score Independent variables: Opacity of box and context of testing were varied **Conditions:** - peer condition: two children were tested together - solitary condition: children were tested on their own **Exp. 2**: all children were tested according to the peer condition.	**Exp. 1:** Regardless of box type and of having been tested alone or in pairs, children overimitated at similar rates. There was little collaboration across testing. **Exp. 2:** Both groups overimitated at similar rates on both types of boxes. Indigenous children showed more collaborative behavior than Western children but only with opaque boxes. The rates of collaboration were correlated with OI, but only for Indigenous children.
Hewlett, Berl and Roulette (2016). Teaching and Overimitation among Aka hunter-gatherers.	**Exp. 1:** 1 year (n = 10 Children from Aka community in Congo Basin)	**Exp. 1:** Aka children were filmed in a naturalistic setting to see if they display behavior of natural pedagogy (NP) or other types of teaching. **Exp. 2:** **The task:** retrieve reward transparent puzzle box	**Exp. 1:** A coding system was established to identify NP (transfer of generalizable knowledge by e.g. explicit gestures eye contact) **Exp. 2:** **Design:** between-subjects design Dependent variable: Over-imitation score	**Exp. 1:** 8 of 10 videotapes showed at least one instance of NP. **Exp. 2:** Participants in all groups who observed the demonstration were much more likely to exhibit irrelevant

	Exp. 2: 4 – 7 years (n = 28 Aka and n= 29 Ngandu children) and 20 – 38 years (n = 14 Aka adults)	**Irrelevant actions:** actions performed on top of box or aside from front door: tapping right/left side of box, sliding top door, tapping barrier **Relevant actions:** sliding front door and retrieving the reward **Demonstration specifics:** Participants observed an adult male model from their ethnic group performing a sequence of actions (four irrelevant and two relevant actions) that resulted in reward retrieval. The sequence was demonstrated three times, then it was the participant's turn.	Independent variable: Demonstration **Conditions:** Participants in each group (Aka children, Ngandu children and Aka adults) were randomly assigned to: - Demonstration condition - Control condition (box and tool were placed in front of participant without any demonstration)	actions than those in control conditions. Aka children tended to used emulation, were the least likely to overimitate and had the lowest fidelity in copying the model. Aka adults were most likely to overimitate and scored especially high on the fidelity score. Most measures of Ngandu children did not differ significantly from both Aka groups.
Chudek, Baron, & Birch (2016). Unselective Overimitators: The Evolutionary Implications of Children's Indiscriminate Copying of Successful and Prestigious Models.	2 – 7 years (n = 161; 96 in **Exp. 1**; 65 in **Exp. 2**)	**The task:** retrieve toy from two different transparent boxes (Rod and Pull Box) **Irrelevant actions:** using redundant tool, rotating it, removing rod/hinge, tapping top of the device with tool, opening top door, rotating disconnected propeller/hinge **Relevant actions:** using hand to open bottom door and pull out toy/ pulling tray and opening lid to retrieve toy **Demonstration specifics** of **Exp. 1 (Parallel Actions Experiment):** After a warm up phase for familiarization, children viewed one of two videos in which two adult models were differently cued regarding their status. Next, they saw a demonstration video of two models performing an inefficient strategy to retrieve the reward; then it was the child's turn. The procedure was repeated a second time with the other box. Same procedure in **Exp. 2 (Conflicting Actions Experiment)** except for: one model demonstrated an inefficient strategy on the box; a second model used only the efficient actions for the same box. There were additional manipulation checks to make sure children understood the status cuing videos.	**Design:** between-subjects design Dependent variable: (selective) over-imitation rate Independent variable: status of model **Conditions**: The model's status was varied along two dimensions: - Prestige (high vs. low): two clips showed two models working with tools. Two bystanders carefully watched the high status model and ignored the low status model. The second clip was similar expect that there was a different pair of bystanders. - Success (high vs. low): a single clip showed the high status model retrieving five, and the low status model retrieving only two reward stickers after flipping switches on a metal box.	Children imitated unnecessary actions in both high and low status conditions (unselective imitation). Older children overimitated slightly more but there was no significant age difference in selectivity. Children's tendency to overimitate was insensitive to whether inefficient actions/redundant steps were demonstrated by a high or low status (in prestige or success) model. The tendency to overimitate was only slightly reduced when a second model skipped the redundant steps.

Whiten, Allan, Devlin, Kseib, Raw, & McGuigan (2016). Social learning in the real-world: 'Over-imitation' occurs in both children and adults unaware of participation in an experiment and independently of social interaction	n = 221 (100 in the demonstration condition; 121 in the control condition) 16 – 62 years (n = 93) 10 – 15 years (n = 64) 4 – 9 years (n = 64)	**The task:** retrieving a reward from a transparent puzzle box using a magnet tipped probe in a naturalistic area **Irrelevant actions:** remove bolt defense; insert tool into top hole **Relevant actions:** remove door defense; insert tool into lower hole **Demonstration specifics:** *Demonstration Condition:* Two experimenters, pretending to be zoo visitors, interacted with items in the vicinity of the puzzle box. When the participant (a real zoo visitor) entered the room and interacted with the activity adjacent to the puzzle box, experimenter 1 began interacting with the puzzle box by demonstrating irrelevant and relevant actions to goal retrieval using different styles (pulling vs. pushing). After E1 retrieved the reward, she laughed and moved on to another interactive item out of the visitor's sight. Then it was the visitor's turn, which ended when the visitor extracted the reward. Both experimenters observed the visitor inconspicuously and coded their actions while he/she was interacting with the puzzle box. After reward retrieval the visitor was informed about the experiment and asked control questions. *No demonstration Control Condition:* The procedure was the same as the Demonstration Condition except that there was no model the visitor could observe first.	**Design:** between-subjects design Dependent Variables: irrelevant actions, stylistic fidelity Independent Variables: demonstration vs. no demonstration, style **Conditions:** It was varied if there was a demonstration or not and which technique/style was demonstrated (pulling vs. pushing). Demonstration condition: experimental condition No demonstration condition: control condition	All participants indicated that they did not believe themselves to be under observation of the experimenter(s), or to be taking part in an experiment. Demonstration condition: 84 of 100 participants performed all or part of the irrelevant action sequence. No demonstration condition: 18 of 121 participants performed all or part of the irrelevant sequence. There was no significant age difference in the occurrence of over-imitation in either the demonstration or the control condition. There was a significantly greater number of irrelevant actions performed in the demonstration condition than the control condition at each age. Across all age groups most participants used the same technique/style as demonstrated.
Moraru, Gomez, & McGuigan (2016). Developmental changes in the influence of conventional and instrumental cues on over-imitation in 3- to 6-year-old children	3 – 6 years (n = 185) 3 years (n = 41) 4 years (n = 43) 5 years (n = 57) 6 years (n = 44)	**The task:** retrieve reward from transparent Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts, tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box and insert stick tool inside **Demonstration specifics:** The experimenter provided the child with a pre-demonstration prompt that indicated that there was either single or multiple solutions to the task, before providing a task demonstration (containing both irrelevant and relevant actions). On completion of the task demonstration the box was reset and the child provided with one of four post-demonstration instructions (varying in instrumentality), before being presented with the task. **The task:** retrieving reward from transparent Glass Ceiling Box	**Design:** between-subjects design with prompt instrumentality (pre and post demonstration) and observer age as factors Dependent Variables: Number of irrelevant and relevant actions performed Independent Variables: Instrumentality of pre-demonstration prompt (single solution or multiple solutions prompt), instrumentality of post-demonstration prompt ("your turn", "however you like", "silly"), observer age (3, 4, 5, or 6 years) **Conditions:** The instructions varied in their instrumentality both pre and post demonstration Pre-demonstration instructions: Single Solution: "I will show you how to get the toy out" Multiple solutions: "I will show you one way to get the toy out" Post-demonstrations instructions: Cond. 1 – Single solution-Your Turn: "Now it's your turn" Cond. 2 - Multiple solutions-Your Turn: "Now it's your turn" Cond. 3 - Multiple solutions-However: "You can get the toy out however you want" Cond. 4 - Multiple solutions-Silly: "Some of the things I did when I	Children performed significantly more causally irrelevant actions in the Single Solution condition than in the Multiple Solutions conditions. OI increased with age in the Multiple Solutions conditions and varied little with age in the Single Solution condition. OI was highest and increased with age in the "Multiple Solutions–Your Turn" condition, whereas in the "Multiple Solutions–Silly" condition the rate of OI was slower and unaffected by age. In the "Multiple Solutions–However" condition increasing age led to an increase in OI.

			got the toy out were silly. I want you to try your best and not do those things"	
Wood, Harrison, Lucas, McGuigan, Burdett, & Whiten (2016). "Model age-based" and "copy when uncertain" biases in children's social learning of a novel task	4 – 6 years (n = 140)	**The task:** retrieve token (a gibbon) from a largely transparent plastic puzzle box ("Slotbox") using a tool (rake or arrow) **Irrelevant actions:** tap the rake end at the front opening of the box four times, slide down the flat surface of the arrow down the back of the box four times **Relevant actions:** insert the rake through the front opening and use it to pull the toy out, insert the arrow into the side slit of the box and use it to push the toy out **Demonstration specifics:** In the warm-up phase the experimenter familiarized the child with games that involved getting the gibbon out of objects and being rewarded with a sticker after successful retrieval. Then E placed the gibbon into the Slotbox and introduced the two models (one adult and one child) whose waving hands appeared on two different monitors (one monitor per model). The participants in the control group where told, that the models had played with the Slotbox and were subsequently invited to play with it. All the other children were shown a video clip of the adult's hands retrieving the token twice and a video clip of the child's hands retrieving the toy twice. Each model used a different tool to retrieve the token. Half of the children saw clips in which both models performed irrelevant actions four times before the relevant action. The demonstration efficacy and efficiency varied depending on condition. Then it was the child's turn, which was allowed up to five successes.	**Design:** mixed-design Independent Variables: within-group variables: model age (adult or child), method of reward retrieval between-participant variables: demonstration efficacy, demonstration efficiency Dependent Variables: successful retrieval, method of success and latency to first success **Condition:** Six experimental and one control condition (no demonstration of any kind) Demonstration efficacy (completeness) / Demonstration efficiency (irr. actions) No / Yes Partial: Group 1 (n = 20) / Group 2 (n = 20) Near-complete: Group 3 (n = 20) / Group 4 (n = 20) Complete: Group 5 (n = 20) / Group 6 (n = 20) Partial: Each model held and inserted a tool into the relevant opening of the Slotbox so that it made contact with the token. Near-complete: Same as partial, plus the tool moved the token to the front opening of the box. Complete: Same as near-complete, plus the token was removed from the front opening of the box.	116 children from experimental condition and 6 from the no-demonstration condition were successful at retrieving the token. Children who saw the demonstration were more likely to obtain the token than children who did not. Older children, and those who saw a more complete demonstration, were more likely to be faster to success. Children who were successful with a tool were more likely to use the tool, which was demonstrated by the child model. 114 successful children completed five trials. The child method was used more often across the five trials. Five children used both methods simultaneously at some point, after they had used each of the methods separately. Irrelevant action reproduction: 37 0f 60 children who watch irrelevant actions from both produced an irrelevant action of some sort on their first trial. No child from the no-irrelevant-action conditions produced an irrelevant action.
Gruber, Deschenaux, Frick, & Clément (2017). Group Membership Influences More Social Identification Than Social Learning or Overimitation in children.	4 – 6 years (n = 94)	**The task:** recover ball from wooden box in Possible (PLS) and Mandatory Social Learning (MSL) Task **Irrelevant action:** lifting shutter above box before opening it (= shutter touch in MSL task) **Relevant actions:** two possible strategies in both PLS/MLS task: lifting piece on top or pushing on piece on side of box/ pulling lever and using elevator or pulling string **Demonstration specifics:** Before testing, children were given a choice of a yellow or blue cloak. In the following 7 trials of the **PLS task**, children engaged with the box on their own to develop potential preferences for one of the two possible strategies (= Previous experience). Then	**Design:** multifactorial design (Generalized Linear Models were tested) Dependent variable: y/n: strategy change (PLS), same as team (ST, MSL, TT), Over-imitation (shutter touch, MSL) Independent variables: group membership, team identification **Conditions:** children who chose a cloak in the beginning were allocated to one of the experimental conditions: - Congruent condition (model of same team displayed the same strategy as participant had previously used) - Incongruent condition (model of same team displayed the opposite strategy) - Children who did not want to choose a cloak at the	In Congruent condition, older children were less likely to overimitate if the opposite team displayed the useless action, while in Incongruent condition, they overimitated less when the same team displayed it. In both conditions, especially girls were more likely to overimitate if their team displayed the useless action. Prior experience and identification with team were the most important factors in learning tasks: When equipped with previous experience (PLS) children mostly relied

		they saw a video of two models of similar age from both teams (i.e. yellow and blue) subsequently modeling either of the strategies; followed by another 7 trials. After, children were given a **Similarity Task (ST)** to assess preference toward the models/teams in the videos. The following **MLS task** was similar to PSL task except that children watched mandatory video *before* engaging with box. Plus, there was a useless third action that only one of the models demonstrated. Finally, a **Trust Task (TT)** tested social identification with group.	beginning were allocated to the Control condition (the two strategies were displayed by one member of each team)	on their own knowledge in following trials. Younger children often stuck with their own strategy while older ones were more likely to explore the alternative after demonstration. The more children identified with their team, the more they copied useless actions of the same-team model. Group membership had most influence on social identification tasks (ST, TT).
Vivanti, Hocking, Fanning, & Dissanayake (2017). The social nature of overimitation: Insights from Autism and Williams syndrome.	4 years (n = 68; 31 children with Autism spectrum disorder; 18 age- and IQ-matched children with Williams syndrome; 19 age-matched TD children)	**The task:** retrieve toy from three different boxes **Irrelevant actions:** tapping box twice on the sides and lifting lid/ pushing box forward with elbow and turning lid clockwise/ lifting box and pulling lid up **Relevant actions:** pushing slides down/ pulling handle up/ pulling latches up **Demonstration specifics:** Children were shown three videos in which a female actor demonstrated how to open the box by using an unfamiliar sequence of three actions (two causally relevant, one irrelevant action). Inside was a toy that the child had shown to be motivated by in a previous free play episode. After each demonstration, it was the children's turn to interact with the toy.	**Design**: 3 (group) x 2 (condition) between-groups design Dependent variables**:** over-imitation score, visual attention (**eye-tracking**) Independent variables: conditions varied along the dimensions of social motivation and causality understanding **Conditions**: causally irrelevant vs. relevant trials	Compared to children with ASD, children with WS and TD children were significantly more likely to overimitate. ASD group over-imitated fewer actions compared to both the WS and TD groups, while there was no difference between WS and TD group. Although there were no group differences in visual attention to the model's actions, WS and TD children increased their attention to the demonstrator's face during causally irrelevant actions.
McGuigan & Burgess (2017). Is the tendency to conform influenced by the age of the majority?	4 – 6 years (n = 120 in **Exp. 1**; n = 82 in **Exp. 2**)	**The task:** retrieve reward from transparent Glass Ceiling Box **Irrelevant actions:** five actions directed to the top of the box: remove two bolts, tap on false ceiling with stick tool three times **Relevant actions:** open door on front of the box and insert stick tool inside **Demonstration specifics:** in Phase 1 children viewed five task demonstrations (presented via video display) performed by a group of five identically aged models. Four models (the majority) performed both irrelevant and relevant actions, and one model (the minority) performed only the relevant actions. On completion of the demonstrations the child attempted the task. Phase 2. As a test for the influence of the experimental context, the children completed a 'post experiment' trial in which they were asked to check if the reward was in the box for the next participant. **Exp. 2** followed a similar procedure, with the exception that all models were unfamiliar to the participants.	**Exp. 1:** Mixed design with condition as the between subjects factor and phase as the within subjects factor Dependent variable: Number of irrelevant actions performed Independent variables: Age of the models comprising the majority (3, 5, 8, 11, or 13 years), task context (experimental or non-experimental) **Conditions**: **Exp. 1**: children were allocated to one of six conditions: - Five "inefficient majority" conditions: models were either all younger than the participants (3 years) vs. same age (5 years) vs. older (8, 11, or 13 years) - One "no-majority" control condition: participants viewed two task demonstrations; one by an efficient model and one by an inefficient model **Exp. 2:** - Three "inefficient majority" conditions: 3- vs. 5- vs. 13-year-old models	In both Exp. 1 and 2 children in the inefficient majority conditions overimitated more often than children in the control conditions. Children copied selectively: less OI occurred following task demonstration by the youngest than by same-aged or oldest models (both were copied with equally high levels of fidelity). In **Exp. 2,** model familiarity had no significant influence on imitative fidelity within each individual model group. However, familiarity influenced the copying fidelity witnessed (lower OI rate across unfamiliar model conditions than across familiar model conditions). In both Exp. 1 and 2 less irrelevant actions were performed in post-experimental trials than in inefficient majority conditions.

			- One "no-majority" control condition: participants viewed four task demonstrations; two by efficient models and two by inefficient models Post experiment trial: after the experimental trials were complete (both Exp.1 and Exp.2) each participant was asked to check if the reward was inside the box for the next participant.	
Frick, Clément, & Gruber (2017). Evidence for a sex effect during overimitation: boys copy irrelevant modelled actions more than girls across cultures.	5 – 12 years (n = 208; 102 urban French and 106 rural Serbian children)	**The task:** retrieve reward from glass bottle (Hook task) **Irrelevant actions:** circling bottle with the string before making hook with the pipe cleaner **Relevant actions:** seizing pipe directly on the middle and making a hook to retrieve reward **Demonstration specifics:** after a Warm-up task, children were presented with a transparent glass bottle containing a reward. E displayed a pipe cleaner and a piece of string and told children that they may use these object to retrieve the reward. Children first were given the chance to succeed without any demonstration (pre-demonstration phase); then E displayed how to make a hook with the pipe and use it for reward retrieval.	**Design:** between-subjects Dependent variable: success, innovation (manufacturing a hook in pre-demonstration phase) and over-imitation (first using string to make a circle before manipulating pipe cleaner) Independent variable: demonstration **Conditions:** For children who successfully retrieved the reward within a minute in the pre-demonstration phase, the experiment finished. The other children were then allocated to either - Control Condition (Demonstration included only relevant action) or - Over-imitation Condition (Demonstration included irrelevant action)	Only 32% of children successfully retrieved the reward in the pre-demonstration phase. In both countries, older children (>10 years) manufactured a functional hook significantly more than younger children. For the post-demonstration phase, in both conditions and cultures older children were significantly more likely to successfully retrieve the reward than younger children. Boys were significantly more likely to overimitate than girls.
Schleihauf, Graetz, Pauen, & Hoehl (2017). Contrasting social and cognitive accounts on overimitation: The role of causal transparency and prior experiences.	5 years (n = 100) Exp.1: n = 44; (n = 28 in exp. cond.; n = 16 in baseline cond.) Exp. 2a: n = 28 Exp. 2b: n = 28	**The Task:** retrieval of marbles from a transparent container inserting a magnetic rod in order to exchange them for stickers **Irrelevant actions:** clapping hands, pushing the lever attached to the top of the container, tapping the rod on the palm three times while counting to three, pushing the button attached to the side of the container with the rod **Relevant actions:** lifting the flap covering the opening to the tube and remove a marble with the magnetic rod **Demonstration specifics: Exp. 1:** In the warm- up phase E1 explained to the child the concept that the marbles could be exchanged for stickers. After the warm-up phase the child was introduced to the transparent container and E1 explained that there were marbles hidden in it, which the child could exchange for stickers after successful retrieval. In the transparent tube cond. of phase 1 children observed E1 retrieving a marble from the container in an inefficient way demonstrating 4 irrelevant and 1 relevant action sequence. Then E1 instructed the child to retrieve a marble any way her or she liked and then left the room. After successful retrieval E1 returned, exchanged the marble for a sticker and busied herself/himself. In Phase 2 children observed E2 entering the room and retrieving a marble using only	**Design:** mixed design Independent Variables: demonstration of inefficient/efficient strategy or no demonstration Dependent Variables: nonfunctional action score (NFA score) **Conditions:** sex of children and experimenters was balanced across conditions. Exp. 1: Participants were randomly assigned to either the transparent tube cond. or the baseline cond. Transparent tube cond.: demonstration of inefficient strategy by E1 and efficient strategy by E2 Baseline cond.: children interacted only with one communicative E, who offered no demonstration Comparison cond. from Hoehl et al. (2014): opaque tube cond.: n =28, baseline cond.: n = 15 |	Phase 1: inefficient demonstration		Phase 2:efficient demonstration	
Opaque tube (comparison cond.)	Communicative	Test Trial 1	Noncommunicative	Test Trial 2
Transparent tube	Communicative	Test Trial	Noncommunicative	Test Trial		Exp. 1: NFA scores of the transparent tube condition were significantly higher than in the baseline condition even after having observed the efficient solution. Compared with the data from Hoehl et al. (2014) there was a significant effect for the factor test trial, but neither the interaction between test trial and transparency, nor the main effect of transparency was significant. Exp. 2a: In Test Trial 1, the mean NFA scores was significantly lower than in the baseline cond. The NFA score in Test Trial 2 did not differ significantly from baseline level. Exp. 2b: Children did not switch to the communicatively demonstrated inefficient strategy. Exp. 2a and Exp. 2b: There were more nonfunctional actions in Test Trial 2 compared to Test Trial 1. The

				1	2

Exp. 2:

	Phase 1: Efficient demonstration		Phase 2: Inefficient demonstration	
Exp. 2a	Communicative	Test Trial 1	Communicative	Test Trial 2
Exp. 2b	Noncommunicative	Test Trial 1	Communicative	Test Trial 2

Reference group: baseline cond. from Exp. 1

		the efficient strategy to exchange them for stickers. Then E2 left the room and E1 returned and told the child, that it was his/her turn again to retrieve a marble. Following that E1 left the room and returned to exchange the marble after successful retrieval. In the baseline cond. children didn't observe any prior demonstrations. **Exp. 2a:** Materials were the same as in Exp. 1 and the procedure similar. The warm-up phase was the same is Exp. 1 except that the child played with both experimenters. Afterwards they introduced the container, E1 retrieved a marble by using only the functional action, while E2 busied him-/herself. Then it was the child's turn, while E1 and E2 had left the room. After successful retrieval E1 and E2 returned and E2 retrieved the marble using nonfunctional actions, while E1 busied him-/herself. Then it was the child's turn again. **Exp. 2b:** Warm-up phase was identical to Exp. 1. The imitation task was similar to Exp. 2a except that only E1 interacted with the child and the efficient strategy was now demonstrated in a noncommunicative way during the first phase, followed by the demonstration of the inefficient strategy in a communicative way.		interaction between test trial and the factor communicativeness was marginally significant. In Exp. 2a there was a marginal, but nonsignificant difference in children's NFA score between Test Trial 1 and 2. In Exp. 2b there was a significant difference of children's NFA scores between Test Trial 1 and 2.
Clay & Tennie (2017). Is overimitation a uniquely human phenomenon? Insights from human children as compared to bonobos	Children: 3 – 5 years (n = 77) Bonobos: 3 – 29 years (n = 46)	**The Task:** Opening of a wooden box to retrieve a reward. **Irrelevant actions:** placing the hand on top of the box and slowly rubbing it in a circular motion four times, next raising the hand into the air next to the box and rotating the wrist four times (uncommon action cond.); holding the box with the left hand and tracing a cross across the top of the box with the index finger, next tracing around the groove of the box around its full diameter (typical action cond.) **Relevant actions:** opening of the wooden box pulling the two wooden halves apart **Demonstration specifics:** In the demonstration phase a human demonstrator performed two consecutive irrelevant actions either typical or uncommon for both children and bonobos depending on condition. Afterwards the demonstrator opened the box and revealed the reward inside. Then it was the participant's turn. This procedure was repeated three times.	**Design:** between-subjects design Dependent variables: occurrence of any of the four demonstrated actions Independent variables: demonstration of typical or uncommon actions or no demonstration **Conditions:** Uncommon action condition: uncommon actions for both children and bonobos were demonstrated (rub-rotate) Typical action condition: rare, but race-typical actions were demonstrated (cross-trace) Control condition (children only): no demonstration was performed.	The majority of children readily copied at least one of the two observed actions in both conditions—rub–rotate: 77.8% of children (21/27); cross–trace: 81% of children (21/26). Of these children, approximately one-third spontaneously copied both actions demonstrated to them—rub–rotate: 39% children (8/27); cross–trace: 27% children (7/26). In both conditions it was most often the second demonstrated action that was copied. In contrast no bonobo copied any of the target actions in either condition.
Taniguchi, Y., & Sanefuji, W. (2017). The boundaries of overimitation in preschool children. Effects of target and	Exp. 1: 2 – 5 years (n = 59) 2 years (n = 16) 3 years (n = 20) 5 years (n =23)	**The Task:** retrieval of a reward from a transparent box (main apparatus A) and a semitransparent folding container (main apparatus B) using a tool **Irrelevant actions:** taping on the main apparatus/palm using a tool, drawing a circle on the apparatus/palm with a tool, rubbing the apparatus/palm with a tool, pushing	**Design:** within-subjects design Dependent variables: performance of irrelevant actions Independent variables: actions were performed toward an apparatus or person; connectedness of the apparatus; tool use **Conditions:** **Exp. 1:**	Exp. 1: Children overimitated as age increased. Numbers of over-imitation trials in the Same Apparatus–Tool and Different Apparatus–Tool conditions were observed to be more than the number

tool use on imitation of irrelevant actions	Exp. 2: 4 – 6 years (n = 24)	the apparatus/palm with/by a tool **Relevant actions:** opening the partition with the hand and inserting a tool into the apparatus to retrieve the reward **Demonstration specifics:** Exp. 1: Following a warm-up phase E put one main apparatus and the subapparatus on the desk and showed one irrelevant action and then one relevant action to retrieve the reward. Subsequently E asked the child to retrieve the reward and observed the child's performance. After conducting all three conditions, E switched to the second main apparatus and three further trials followed. Exp. 2: The general procedure was the same as in Exp. 1 except for the number of conditions.	The contact principle and the target of irrelevant actions were investigated. Cond. 1: Same apparatus–tool: an irrelevant action using a tool was directed toward the apparatus, which was the same apparatus involved in the relevant action for retrieving the reward Cond. 2: Different apparatus–tool: an irrelevant action using a tool was directed toward the subapparatus, which was not involved in the final goal Cond. 3: Actor–tool: an irrelevant action using a tool was directed toward the actor's body **Exp. 2:** Cond. 1: Different apparatus–tool: same as in Exp. 1 Cond. 2: Actor–tool: same as in Exp. 1 Cond. 3: Actor–no tool: irrelevant manual movement toward a human actor Cond. 4: Different apparatus–no tool: irrelevant manual movement toward the subapparatus	in the Actor–Tool condition. Exp. 2: The number of over-imitation trials in the Different Apparatus–Tool condition was observed to be more than in the Actor–Tool, Actor–No Tool, and Different–No Tool conditions.
Clay, Over, & Tennie (2018). What drives young children to over-imitate? Investigating the effects of age, context, action type and transitivity	4 – 6 years (n = 167) 4 years (n = 61) 5 years (n = 54) 6 years (n = 52)	**The Task:** Opening of two different boxes (treasure chest and wooden box) **Irrelevant actions:** Action combination 1: presenting the elbow on/over the box and a manual sawing action on/over the box; action combination 2: circle trace action on/over the box and presenting the forehead on/over the box; **Relevant actions:** operating the flip clasp mechanism (treasure chest) and operating the lock-and-key mechanism (wooden box) **Demonstration Specifics:** According to the three contexts (normative, communicative or instrumental) E1 introduced the activity. Next E performed two actions sequentially. Each action was either performed in contact with the box (transitive) or above the box (intransitive) with transitivity kept constant for given participant. For each trial there was a manual action and one body part action. Afterwards E2 opened the box. E1 replaced the box with a closed identical box. Then it was the child's turn. After successful opening, the box was replaced with the next box type and the procedure was repeated.	**Design:** mixed design (2 x 3 x 2) Dependent Variables: imitation behavior (irrespective of whether the child attempted to open the box) Independent Variables: factors of context (verbal cues), transitivity, action type **Conditions:** **Between-participants variables:** Normative context: Transitive or intransitive Communicative context: transitive or intransitive Instrumental context: transitive or intransitive **Within-participants variable:** Action type: Manual action + Body part action (order counterbalanced across participants)	There was a significant interaction between age and context; specifically, whereas over-imitation increased with age within the normative context, younger children were more likely to over-imitate in the instrumental context as compared with older children. There was no significant interaction between age and context for the communicative condition. There was a main effect of transitivity, suggesting that children were more likely to copy transitive actions as compared with intransitive actions. Younger children preferentially copied transitive actions over intransitive actions compared with older children, who preferentially copied intransitive actions over transitive actions. Children were significantly more likely to copy manual actions as compared with body part actions, although rates of body part imitation were higher in the normative context as compared with the communicative and instrumental contexts.

Table SI 2

A number of studies were considered for inclusion in the table, but were finally judged not to meet our definition of over-imitation; however, these studies are often intrinsically relevant to the principal issues of interest, so for completeness we list them here, as they may be helpful to researchers in this field

Authors (year)	Age (sample size)	Task description	Design & Conditions	Results
Nagell, Olguin, & Tomasello (1993). Processes of Social Learning in the Tool Use of Chimpanzees (Pan troglodytes) and Human Children (Homo sapiens).	**Study 1:** 4 – 8 year-old chimpanzees (n= 15) **Study 2:** 2 year-old children (n= 24)	**The task:** retrieve food item/toy with tool **Inefficient actions:** "rake strategy": pulling food/toy with rake with widely spaced teeth (obvious solution) **Efficient actions:** "edge strategy": flipping the rake so that a flat edge could be used to pull food/toy (less obvious, required preparatory step; two action task) **Demonstration specifics:** After habituation, subjects participated in a total of 50 1-min trials (given over a 2- to 5-day period). Before each trial, the two tools were positioned in front of the subject and E. Two food items were placed on the platform. As soon as the subject was attending, E performed the model demonstration (condition). Study 2 was similar but conducted with children and used a new apparatus, smaller (wooden) tools and toys instead of food as target item. After demonstration, children were encouraged to retrieve the toy.	**Design:** between-subjects Dependent variable: emulation vs. imitative learning (e.g. tool use, strategy, success) Independent variable: demonstration **Conditions:** - full-model condition: entire task solution including the preparatory flipping step was modeled - partial-model condition: only consummatory part of efficient task solution was modeled (i.e., object pulled in with the edge but no preparatory flipping) no-model control condition	**Study 1:** Compared to observation-groups, no-model subjects used the tool at lower levels throughout trials (with a strong bias toward rake strategy) and were almost never successful. Partial- and full-model subjects used both strategies approximately equally but were successful nearly twice as often with the edge strategy. **Study 2**: Full-model subjects performed significantly more edge use than other groups (who did not differ from each other). Both no-model and partial-model subjects almost exclusively used the rake strategy but partial-model subjects were more successful. Children in observation groups were equally successful overall. However, partial-model subjects were only successful with rake strategy while full-model subjects were successful with both rake and edge strategy.
Nielsen & Hudry (2010). Over-imitation in children with autism and Down syndrome.	2 – 8 years (n = 34; 22 children with Autism spectrum disorders; 12 children with Down syndrome)	**The task:** retrieve reward (toy) from three opaque wooden puzzle boxes **Effortful/inefficient actions:** using arbitrary toy object to open lid on box **Less effortful/efficient actions:** using hands to open lid on box (disengaging switch mechanism by pushing/twisting/sliding) **Demonstration specifics:** With each box, E presented a different randomly chosen object that he used to open the box mechanism. This opening procedure was demonstrated three times, then it was the child's turn. The procedure was repeated for the other two boxes.	**Design:** between-group design Dependent variable: OI score (for opening the boxes with object; 0-3) Independent variables: boxes and object used to open box Order of boxes was counterbalanced across participants; objects were chosen randomly. Additionally, Vineland Adaptive Behavior Scale- Communication subscale was used to measure children's current levels of adaptive behavior.	On average, children opened either one or two boxes using the object. Children with ASD were equally successful as children with DS. VASBS-C score was positively associated with the number of boxes children opened by object and the number they opened by hand after having failed to open them by object.
Buchsbaum, Gopnik, Griffiths, & Shafto (2011). Children's imitation of causal action sequences is influenced by statistical and pedagogical evidence.	4 – 6 years (**Exp. 1:** n = 81, **Exp. 2:** n = 27)	**The task:** make one of two novel toys (blue ball and stuffed toy with rings and tabs) play music **Unnecessary actions:** depending on condition, different sequences of actions were followed by the desired outcome (music). Therefore, children were to identify unnecessary actions within causally effective sequences by using statistical inference (→ unnecessary actions = all actions that were inferred to be causally irrelevant)	**Design:** between-groups/ Bayesian Model of causal inference was defined to guide the manipulation of the probabilistic evidence (i.e. different patterns) and was compared to the results Dependent variables: Imitation of (correct causal) subsequence within complete action sequence: triplet (reproducing complete three-action sequence), double, single (reproducing just the final action in isolation) or other (new combinations of actions) Independent variable: pattern of statistical evidence (statistical	If children encode the model's successful actions as causally necessary then they should exclusively imitate triplets in both ABC and BC condition; if they also use more complex statistical information, they should conclude that the BC sequence by itself is more likely to be causal in the BC than in the ABC

		Necessary actions: all actions believed to be necessary to activate causal mechanism **Demonstration specifics:** In **Exp. 1**, children watched a naïve informant (who claimed to have no knowledge of how the toy worked) demonstrate one of three action patterns that each involved a 3-action sequence and its outcome repeated twice. Only some of these sequences were followed by a musical effect as an outcome. After having demonstrated all five of the 3-action sequences, it was the child's turn. **Exp. 2** followed the same procedure as the BC condition of Exp. 1. But action sequences were now demonstrated by a teacher who emphasized pedagogical intention, knowledge of the toy and indicated that she expected each resulting outcome (e.g. "See? No music").	relation between action and outcome differed across conditions in ways that supported different causal hypotheses) and demonstrator's pedagogical stance/knowledge were manipulated **Conditions:** three experimental conditions ("+"= positive outcome: action sequence is followed by music effect) *ABC condition*: **ABC+** (e.g. A=Knock, B=Pull, C=Roll); DEC; **ABC+**; EDC; **ABC+** *BC condition*: A**BC+** (e.g. squish-pull-shake); ADC; D**BC+** (e.g. flip-pull-shake); AEC; E**BC+** *C condition*: AB**C+**; AD**C+**; DB**C+**; AE**C+**; EB**C+** **Exp. 2: "**Pedagogical BC" mode	condition (and triplet sequence more likely to be causal in the ABC condition). Children seemed to selectively imitate based on statistical evidence: triplets were more often imitated in ABC than in BC condition; while double (BC subsequence) was more often reproduced in BC than in ABC or C condition. Children in C condition produced C-actions more frequently than children in BC condition. In **Exp. 2**, children imitated more irrelevant actions with the pedagogical and knowledgeable model compared to the naïve demonstrator, indicating that they also attend to pedagogical evidence.
Elsner & Pfeifer (2012). Movement or goal: Goal salience and verbal cues affect preschoolers' imitation of action components.	3 – 5 years (n= 50)	**The task:** reproduce movement or goal (Imitation choice task) **Actions:** move puppet (toy sheep) up/down **Demonstration specifics:** After an exploration phase and verbal comprehension task, children started with the direct imitation phase to ensure they had the needed motor and representational capacities to reproduce the actions. Children watched E moving a puppet up or down a ramp, terminating at a certain end state (i.e. placing puppet onto one of the objects, varying across conditions). Then the puppet was put back and children were asked to imitate the actions ("Show me what Nicky did"). In the imitation choice phase (8 trials total), children were handed a second ramp with the target objects at reversed positions so that children had to choose between copying the observed motion path [movement component] or end state [goal component]. Demonstrations in this phase were accompanied by verbal cues (varying across trials).	**Design:** mixed design Dependent variable: reproduction of action components, i.e. patterns of behavior (number of trials in which demonstrated actions components were performed) and preference score (+1 if child performed observed movement at expense of goal component; -1 vice versa) Independent variable: goal salience and verbal cues **Conditions:** - Low-salient group (objects: green and red plastic bowls) - High-salient group (socio-functionally relevant objects: green bench and red boat) Demonstrations were accompanied by verbal cues: - Verbalizing only the movement component (Cue M, e.g. "Nicky is going up") - Only goal component (Cue G, "Nicky is sitting on the bench") - Both movement and goal (Cue M+G, "Nicky is going down and sitting in the red bowl) - None of the components (Cue N, "Look was Nicky is doing"; in trial 1+2; remaining trials were accompanied by each of the remaining cues)	The high-salient group imitated the observed goal component more often than the movement component (low preference score), irrespective of which verbal cue was used. Children in the low-salient group did not show preferences for any component. In general, children preferred to copy the goal component at the expense of the movement in those trials where the end state had been verbally marked (cues G and M+G). They showed no preference when the movement or none of the components was emphasized (Cues M and N). Verbal cues seemed to have stronger effects in the low-salient condition.

Herrmann, Legare, Harris, & Whitehouse (2013). Stick to the script: The effect of witnessing multiple actors on children's imitation.	3 – 4 years (n = 128) 5 – 6 years (n = 131)	**The task:** interact with pegboard **Modeled actions:** pushing yellow peg up, pushing red peg up, tapping hammer, pushing green peg up, pushing green peg down, pushing peg down with hand. No specific outcome/effect was to be attained, therefore relevance of actions cannot be specified. **Demonstration specifics:** Children were first familiarized with the video screen and the E. In the following imitation task, children watched videos of one or more actors interacting with the wooden mallet and pegboard in the exact manner in each video. Depending on condition, E prefaced the video with a specific frame. Then the pegboard (similar to the one in video) was placed in front of the child and it was their turn. Last, children were asked if they did the same/something different as the models and were asked to explain why (explanation task).	**Design:** between-subjects design Dependent variables: fidelity of imitation; explanation of actions Independent variables: stance of action sequence (through verbal framing) and models **Conditions:** Each child was presented with one of 8 possible combinations of type of modeling and verbal frame. Frame: - Outcome-orientated (Emphasizing instrumental outcome of actions) - Convention-orientated (emphasizing conventionality) Type of modeling: I) Single model with two demonstrations II) Two successive models with each a single demonstration III) Two synchronous models with each two demonstrations III) Two synchronous models with each a single demonstration	Children engaged in greater imitative fidelity after the convention-orientated than the outcome-orientated frame. Imitative fidelity was highest for synchronous models (III and IV) and lowest for the single model (I). Older children engaged in greater imitative fidelity than younger ones. Convention-orientated frame was associated with higher levels of conventional explanations (e.g. "I had to do what she does"), while with outcome-orientated frames, children were more likely to provide an agentive explanation ("I can do whatever I want"). Children also provided more conventional explanations for their actions after viewing the synchronous models.
Schachner, Carey (2013). Reasoning about 'irrational' actions: When intentional movements cannot be explained, the movements themselves are seen as the goal.	Adults, 18+ (**Exp. 1:** n= 128; **Exp. 2**: n = 62, **Exp. 3:** n = 154)	**The task:** infer agent's goal in violation-of-expectations task **(Ir)relevant actions:** study did not involve OI tasks **Demonstration specifics:** Online experiment. Participants watched a video of an animated character (Tim) performing a sequence of movements (alternating left-right pattern). In a second video Tim first performed the same movements and then one of two possible continuations (either left- or rightwards). Participants were then asked whether this was what they expected Tim to do (or not) in order to test whether they inferred movements themselves to be Tim's goal (i.e. expectation: Tim continues same movement-pattern) or an external goal (expectation: Tim continues fulfilling goal, even by violating the established movement pattern). **Exp. 2** tested whether participants truly inferred movement-based goals or simply described the agent's movements because they did not know the answer. Thus they were asked a question to which they did not know the answer to ("What was Tim keeping secret?"). If movement-based answers were simply caused by participants' uncertainty, they should answer by describing the movements. **Exp. 3**: Participants saw one of 5 animated stimuli (character holding a star and jumping towards/away from box) and had to describe the character's intention.	**Design**: between-subjects Dependent variable: inference about agents goal (answer to "What was Tim's intention?/Was this what you expected?/What was Tim keeping secret" in Exp. 2) Independent variable: Inefficiency and intentionality of agent's actions were manipulated **Exp. 1 conditions:** - Objects-present (Tim moves to sort balls into boxes → external goal; violation of movement pattern necessary to reach goal) - Objects-absent (moves in empty space → movement-based goal) Half of participants in each condition saw video in which Tim moved to left (violating movement pattern); others half saw him moving to the right (continuing movement pattern). **Exp. 2 conditions:** - Intentional movement (same as Objects-absent in Exp. 1) - Unintentional movement (Tim moves unintentionally while sleeping → If the goal inference measures are valid, participants here should not identify movements as Tim's intention) **Exp. 3 conditions:** Video showed character doing different jumping patterns: 1 set of jumps (toward-only: character jumps twice towards box)	**Exp. 1**: In objects-present condition, all participants inferred an external goal to be Tim's intention and reliably expected him to violate the movement pattern, consistent with the goal. In object-absent condition, only about half of participants inferred an external goal. Participants who inferred movement-based goals reliably expected Tim to continue his movement pattern, while participants who inferred external goals or no goal did not. **Exp. 2:** None of the participants who saw Tim moving un-intentionally inferred movement-based goals, while about half of participants in intentional-movement condition did so. Movement-based inferences were not simply caused by uncertainty (as none of the participants stated Tim's movements as answer when faced with a question to which they did not know the answer to). **Exp. 3:** Participants did not infer movement-based goals when jumps were an efficient path towards the box (only in toward-only condition) but they did so in the other four conditions. Taken together, participants

			vs. 2 sets (toward-away: twice toward then twice away from box) vs. 3 sets (toward-away-toward) vs. 4 sets vs. 5 sets	inferred movement-based goals when actions were intentional and not an efficient means to external goals.
Wood, Kendal, & Flynn (2013). Copy me or copy you? The effect of prior experience on social learning	5 years (n = 167)	**The task:** retrieval of a capsule containing a sticker from a transparent "Sweep-Drawer Box" **Causally irrelevant actions:** not specified **Functional actions:** push the silver sweeper or pull a blue drawer to retrieve the capsule **Demonstration specifics:** Children were tested individually at a table. First the experimenter introduced the child to the puppet "Pip". Then the experimenter requested the child and Pip to take turns on the box to open it and retrieve stickers. Then the experiment consisted of two phases which involved information acquisition and the child's subsequent task interaction. In Phase 1 children were given either (a) no information, ''You play with it first'' or social information (B) 'It's Pip's turn first'' and given a demonstration prior to interacting with the task themselves. The puppet's sequence of actions consisted of relevant (solutions sweep or drawer) and five irrelevant actions. After extraction, a sticker was put on Pip's pile. Demonstration of the two solutions (sweep or drawer) was counterbalanced across conditions. Children then had two response trials, T1 and T2, and could interact with the task to successfully extract the reward (success) or fail to extract the reward (failure). If successful in T1 a sticker was added to the child's pile and the child was allowed a second trial (T2). In Phase 2 all children were told that it was Pip's turn and	**Design: ??** Independent Variables: personal experience or social information (phase 1) and agreeing, alternate, no further information or first information (phase 2) Dependent Variables: sticker capsule removal (success), which solution was used and number of irrelevant actions copied (out of five) **Conditions:** In phase 1 the source of the child's original task information was manipulated (no information or demonstration). In Phase 2 the subsequent task information was manipulated (agreeing, alternate, first demonstration or no information), resulting in 8 different conditions. **1** Personal-then-social-alternate: Phase 1 information: No information; Response Trials: Success; Phase 2 information: Alternate **2** Personal-then-social agreeing: Phase 1 information: No information; Response Trials: Success; Phase 2 information: Agreeing **3** Personal-then-none: Phase 1 information: No information; Response Trials: Success; Phase 2 information: No information **4** Social-then-social-alternate: Phase 1 information: Demonstration; Response Trials: Success; Phase 2 information: Alternate **5** Social-then-	Children in social-then-social-alternate condition are more likely to switch strategy children in social-then-none or social-then-social-agreeing condition. Children with personally acquired information were more likely than children with prior social information to discover multiple solutions in Phase 1. Children in personal-then-social-alternate condition copied alternate solution significantly more than in other personal conditions. Children receiving alternate info in the two phases were much more likely to demonstrate multiple strategies in phase 2. Children performed OI actions in Phase 1 of social info condition significantly more often than baseline. Children who had personal information in Phase 1 consistently performed fewer irrelevant actions in Phase 2 than those who had social information in Phase 1. Children with prior social information continued to perform irrelevant actions regardless of the

		watched the puppet do one of four things: (a) no information (the puppet looked at the box but made no contact with it), (b) an agreeing demonstration (the puppet extracted the reward twice, both times using the same solution as the child had used in phase 1), (c) an alternate demonstration (puppet extracted the reward twice, both times using the solution the child had not previously used), or (d) a first demonstration (for those who had failed: watched the puppet extract the reward twice using the same solution, with solution choice counterbalanced). Children were told that it was their turn again and then they had two (first 82 children) or five (remaining children) response trials.	social-agreeing **6** Social-then-none Initial-fail Groups **7a** No information **7b** None-then-social	tion Demonstration Phase 1 information No information No information	 Success Response Trials Failure Failure	 No information Phase 2 information No Information Demonstration	absence or presence of subsequent social information.
Legare, Wen, Herrmann & Whitehouse (2015). Imitative flexibility and the development of cultural learning.	Study 1: 4 – 5 years (n = 57) Study 2: 4 – 5 years (n = 105) 5 – 6 years (n= 106)	**The task:** manipulating objects and pegboard (Study 1)/ detect differences in actions sequence and interact with previously seen objects (Study 2) **Modeled actions:** Causal and goal opacity were high, so relevance of actions cannot be specified (all actions were arbitrary but intentional). Tapping cube on yellow peg twice, pressing fists together, tapping sphere on red peg twice, sliding box lid open (with different object depending on condition → different end-states), closing box lid. **Demonstration specifics:** Children watched a single presentation of a videotaped demonstrator performing an action sequence with different objects on a pegboard. The same objects (in same configuration) were then placed in front of the child and it was their turn. **Study 2**: Children were shown two variants of an action sequence and asked to identify similarities and differences (Difference detection task). Then children were presented with objects previously seen in videos and were allowed to interact with them (imitation task).	**Design:** between-subjects Dependent variable: imitative fidelity, innovation (Study 1)/ response in detection task and imitative fidelity (Study 2) Independent variable: relationship between end-and start-states was manipulated to prime goal (Study 1)/ verbal cuing of social information (Study 2) **Study 1 conditions:** - Conventional: modeled action sequence ended as it began (no distinct end-state → conventional goal) - Instrumental: new, previously occluded object introduced (green pipe) and used in an instrumental way at end of action sequence (different end-state→ instrumental goal, i.e. opening box to place an object inside of it) **Study 2 conditions:** 4 verbal cues (2 conventional, 2 instrumental) - Conventional-consistent (“this is how she always does it”) - Conventional-collective (“this is how we do it) - Instrumental-process (“she moves blocks”) - Instrumental-goal cue (“she puts it in the box”)	**Study 1**: In the conventional condition, children imitated with greater fidelity and engaged in less innovative behavior than in the instrumental condition. **Study 2**: Children’s imitative fidelity and rates of accurate difference detection were higher in the conventional cue conditions than in the instrumental cue conditions. Younger children were less accurate and showed less imitative fidelity than older children. Taken together, imitative fidelity was highest, innovation was lowest and difference detection was more accurate when cued with information about conventional rather than instrumental behavior.
Subiaul, Winters, Krumpak, & Core (2015). Vocal overimitation in preschool-age children	3 – 5 years (n = 120) Exp. 1: 3 years (n = 40) 4 years (n = 40) Exp. 2: 3 – 5 years old (n = 40; 20 in each condition)	**The task:** pronouncing familiar and unfamiliar nouns after hearing them and seeing a picture on a screen **Inefficient action:** pronouncing the noun the way it was heard when it was the incorrect pronunciation **Functional action:** pronouncing the noun correctly (emulation) **Demonstration specifics:** Exp. 1: After a warm-up period, in which the experimenter played and talked with the child, the training started. The training consisted of four trials. The child was placed in front of a computer and shown PowerPoint slides containing images of nouns. When the child saw the first image, a voice from an audio	**Design:** within-subjects design (Exp. 1); mixed-design (Exp. 2) Dependent Variables: familiar imitation (overimitation), familiar emulation (correctly pronouncing the mispronounced noun), novel imitation (correctly reproducing the pronunciation of the novel word), novel emulation (stressing the first syllable when the model stressed the second syllable of a novel word) Independent Variables: correct or incorrect pronunciation; class (common or proper noun) and frequency (familiar or novel) **Conditions:** Exp. 1: 4 randomized lists, each consisting of 80 nouns (= 80 trials); each noun was paired with a visual stimulus, an audio clip	Exp. 1: A comparison of imitation rates during the first half and second half of testing was statistically significant for novel words. Children imitated significantly more than they emulated. Exp. 2: In both the Social and Ghost demonstrations the imitated rates were greater than 22%. However, this effect was more robust for social

<table>
<tr><td></td><td></td><td>clip pronounced the familiar common noun in Standard American English, the experimenter repeated the pronunciations in the same way, then it was the child's turn. In the testing phase the child was presented with one of four randomized word lists consisting of 80 two-syllable nouns (one noun per trial). The procedure was the same as in the testing phase except that half of the trials included nouns with the incorrect, the other half with the correct pronunciation. After the participant named the noun, the experimenter nodded, smiled and moved on to the next noun regardless of the pronunciation used.
Exp. 2: The training procedure was the same as in Experiment 1. In the testing phase all the children participated in the baseline condition. They had to name all the images on the screen without listening to any demonstrations first. Then the participant was either receiving Social or Ghost demonstration. In the Social demonstration the experimenter pronounced the noun twice, in the Ghost demonstration the computer did. Half of the 18 nouns were pronounced correctly, the other half was mispronounced. After the demonstration of each noun it was the child's turn.</td><td>pronunciation and the experimenter's pronunciation; one of the lists was presented to the participant;
One half of the list: correctly pronounced nouns (10 familiar common, 10 familiar proper, 10 novel common, 10 novel proper nouns)
Other half of the list: incorrectly pronounced nouns

Exp. 2:
Only high-frequency familiar nouns were used (one half correctly pronounced, the other half mispronounced). Every child participated in the baseline condition and afterwards in the ghost or social condition.
Baseline condition: no voice
Ghost condition: voice from the computer
Social condition: voice of the experimenter</td><td>demonstration.
Neither imitation nor emulation rates significantly differed between demonstrations (Ghost vs. Social).</td></tr>
<tr><td>Marno & Csibra (2015). Toddlers favor communicatively presented information over statistical reliability in learning about artifacts</td><td>18 months (n = 40 in both baseline & experimental conditions)</td><td>The Task: Pressing a button (reliable or less reliable) on wooden box
Inefficient action: Pressing the less reliable button
Functional action: Pressing the reliable button
Demonstration specifics:
Baseline: Children observed E1 pressing one button (reliable or less reliable). Then they observed E2 pressing the other button. Neither of the experimenters was communicative. Then it was the children's turn.
Experimental: Children observed an uncommunicative E1 pressing the reliable button. Then Children observed a communicative E2 pressing the less reliable button. Then it was the children's turn.</td><td>Design: 2x2 Condition (Baseline vs. Exp.) and Button (reliable vs. less reliable)
Dependent variable: the first button children touched
Independent variable: Information about button efficacy
Conditions: It was varied how communicative the demonstration was performed.
<table><tr><td></td><td>Demonstration of the reliable button</td><td>Demonstration of the less reliable button</td></tr><tr><td>Baseline
Experimental</td><td>uncommunicative
uncommunicative</td><td>uncommunicative
communicative</td></tr></table></td><td>More children chose the unreliable button in the experimental condition than in the baseline condition. There was no effect of demonstration order. Children seem to favor communicatively presented information over statistical reliability in learning about artifacts.</td></tr>
<tr><td>DiYanni, Corriveau, Kurkul, Nasrini, & Nini (2015). The role of consensus and culture in children's imitation of inefficient actions.</td><td>Exp. 1: 3 – 5 years (n = 87; 43 Caucasian American, 44 first-generation Chinese American children)
Exp. 2: 3 – 5 years (n = 16 first-generation</td><td>The task: crush cookies with tool
Inefficient action: using non-affordant tool to crush cookies
Efficient action: use functionally affordant tool
Demonstration specifics: Children were first shown the tools and the cookie in a Baseline exposure period. Then they watched a video of either a single model or three models who rejected an efficient tool for crushing the cookies in favor of an inefficient tool. Next, children were invited to use one of the two tools to perform the same</td><td>Design: between-groups design
Dependent variable: tool choice (faithful imitation)
Independent variable: conformity/consensus was manipulated
Conditions:
- Single model condition (one model chose the same inefficient tool three times)

Consensus condition (three models each chose same inefficient tool once)</td><td>Exp. 1: There were no cultural differences in imitation in the Single Model condition but Chinese American children were significantly more likely than Caucasian Americans to copy the inefficient choice of the consensus. Exp. 2 showed that Caucasian American children imitated significantly less than first-generation Chinese Americans, but imitation rate between first- and</td></tr>
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	Caucasian American children)	task themselves. Finally, there was a memory check to see if children remembered the model's tool choice. **Exp. 2** was identical to the consensus condition from Exp. 1.		second-generation Caucasian Americans did not differ significantly.
Ronfard, Was, & Harris (2015). Children teach methods they could not discover for themselves	n = 100 (preschool-aged children) Exp. 1: 4 – 6 years (n = 36; 12 in each condition) Exp. 2: 4 – 6 years (n = 32; 16 in each condition) Exp. 3: 4 – 6 years (n = 32; 16 in each condition)	**The task:** extract stickers from a puzzle box (only the top of the box was transparent) and demonstrate the method to a puppet. **Inefficient actions:** apply the inefficient taught method (4 actions) to extract the stickers from the box in Experiment 1. In Experiment 2 and 3 the taught and self-discovered methods were equally efficient. **Functional action:** apply the self-discovered method (e.g. lifting the transparent lid) in Experiment 1. **Demonstration specifics:** Exp. 1: The child was presented with a puzzle box that contained two stickers and was taught a method for retrieving these rewards by an Experimenter (Cond. 1). Children in the Exploration + Instruction Conditions were also invited to try to retrieve the stickers by themselves before the demonstration (Cond. 2 + 3). After the demonstration, the child was asked to reproduce the method. If the child failed, the method was demonstrated again. Then E1 left the room and E2 entered with a puppet. E2 invited the child to show the puppet how the toy works. Exp. 2 and Exp. 3: The Procedure was the same as in Experiment 1 except that the opacity of the taught information was varied and only Conditions 1 and 2 were included. Furthermore, after the demonstration phase, the child was not asked to reproduce the experimenter's method, but immediately invited to teach the puppet.	**Design:** between-subjects design Independent Variables: opacity, exploration (supervised or unsupervised in Exp. 1) Dependent Variables: children teaching their own method, the experimenter's method or both methods. **Conditions:** The opacity (efficiency and ease of discovery) of the taught information was varied. In Exp. 1 the taught method was harder to discover and less efficient than the self-discovered methods. In Exp. 2 the taught method was no harder to discover and just as efficient as the self-discovered method. In Exp. 3 the taught method was harder to discover but as efficient as the self-discovered method. Condition 1 – Instruction Only (in Experiment 1, 2 + 3) Condition 2 – Supervised Exploration + Instruction (in Experiment 1, 2 + 3) Condition 3 – Unsupervised Exploration + Instruction (only in Experiment 1)	Exp. 1: Children always taught the elaborate and opaque method they had previously been taught. They did this even if they had discovered a more efficient and more obvious method on their own. Exp. 2: Children were much less likely to teach a method they had been taught that was just as simple and obvious as the method they discovered for themselves. Exp. 3: Most children taught a method that had been demonstrated to them that was just as easy to execute as the method they discovered for themselves, but less easy to discover. Indeed, the opaquer the taught method relative to children's self-discovered knowledge, the more children faithfully transmitted the information they were taught instead of the information they discovered for themselves.
Lucas, Burdett, Burgess, Wood, McGuigan, Harris, & Whiten (2016). The Development of Selective Copying: Children's Learning From an Expert Versus Their Mother.	**Exp. 1:** 5 – 6 years (n = 50, 25 in each condition) **Exp. 2:** 7 – 8 years (n = 25) and 9 – 10 years (n = 25) **Follow-Up:** 6 – 7 (n = 15) and 9 – 10 years (n = 15)	**The task:** retrieve reward (plastic egg containing a sticker) from opaque practice and test puzzle box **Inefficient/nonfunctional actions:** pulling handle on practice box ("Handle" method) **Efficient/functional actions:** moving flap on practice box ("Flap" method)/ sliding handle back and forth ("Slide" method) or pulling lever in and out ("Trapdoor" method) on test box **Demonstration specifics:** Children played a video game with E1 (distraction task) while the mother was trained to perform one of the two actions (Slide or Trapdoor) on the test puzzle box. E2 then demonstrated two methods (Handle or Flap) on a practice box in order to show the child that it was possible to perform an incorrect action. Next, a stranger (/expert) and the mother were brought into the room and performed their particular action twice in succession on the test box. Then it was the	**Design:** between-subjects design Dependent variable: selective copying (which method did child use first; number of completions) Independent variables: model's familiarity and expertise **Conditions:** - Mother vs. stranger - Mother vs. expert: children were familiarized with the stranger in an extra stage after distraction task (stranger presented as "very good at getting prizes out of puzzle boxes"; then three videos showing the successful retrieval of prizes by the expert and unsuccessful try of an unknown person) **Follow-up study**: children were not given demonstrations from two models. Instead, E demonstrated each of the two possible methods and then asked children about their causal efficacy.	**Exp. 1** showed that 5 – 6-year-olds preferred copying their mother over both a stranger and an expert. However, they did not tend to say that their mother was "better" at the task. **Exp. 2** revealed that 7 – to 8-year old children copied their mothers significantly less than 5- to 6-year olds and instead switched to copying the expert. However, older children (9-10-year-olds) performed at chance in copying their mother vs. the expert and showed a strong bias toward the slide over the trapdoor method. In the **follow-up** study, children in both age groups found the slide method to be more causally plausible than the

	child's turn. Children then were asked why they chose the used method and which of the models was better at getting the reward. **Exp. 2** followed the same procedure of the mother vs. expert condition in Exp. 1.	trapdoor.