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Review

'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.

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,

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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 (Brugger, Lariviere, Mumme, & Bushnell, 2007; Chudek, Baron, & Birch, 2016; DiYanni, Corriveau, Kurkul, Nasrini, & Nini, 2015; Elsner and Pfeifer, 2012; Flynn, 2008; Frick, Clement, & Gruber, 2017; Gruber, Deschenaux, Frick, & Clement, 2017; Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013; Lucas et al., 2016; Marno and Csibra, 2015; McGuigan and Burgess, 2017; McGuigan, 2012; McGuigan, Gladstone, & Cook, 2012; McGuigan and Graham, 2010; Nielsen, 2013; Nielsen, Mushin, Tomaselli, & Whiten, 2016; Ronfard, Was, & Harris, 2016; Schachner and Carey, 2013; Simpson and Riggs, 2011; Yu and Kushnir, 2011; Yu and Kushnir, 2015), 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 et al. (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 Fig. 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 (Bannard, Klinger, & Tomasello, 2013; Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007; Dunham, Baron, & Carey, 2011; Kupan et al., 2017; Price, Wood, & Whiten, 2017) 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 S1 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 S2 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.

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, 2016a, 2016b; 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.

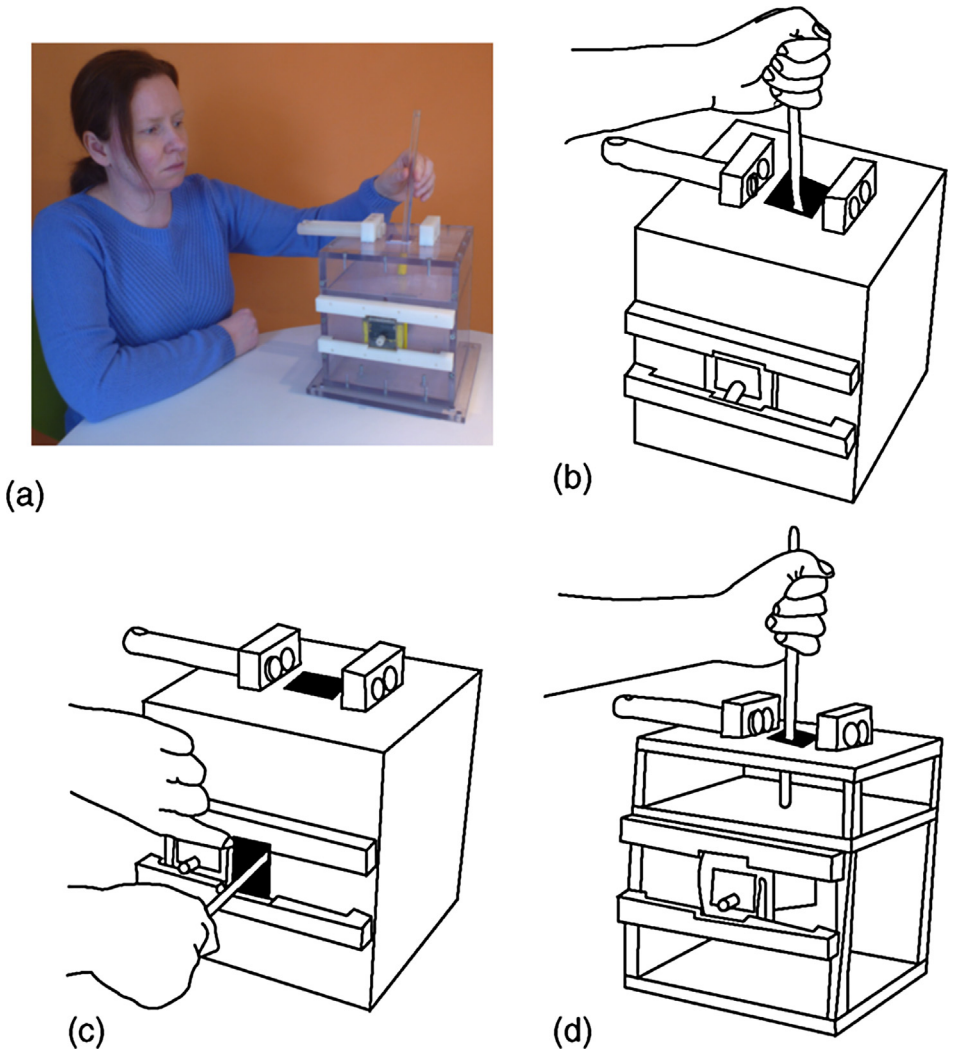

Fig. 1. Opaque and transparent puzzle boxes as used by Horner and Whiten (2005) and subsequent replications and extensions: (a) adult model demonstrating a causally unnecessary action on the transparent box; (b) model probing in top of opaque box; (c) extraction of reward from the opaque box; and (d) 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).

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

Table 1
Overview of "hidden factors" with regard to main experimental approaches (for a detailed discussion see electronic supplementary information).

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 model', see below)	– Human or puppet – Gender – Number of models
Baseline condition	– Yes/no
Coding OI	– Proportional scores – Total frequency – Number of repetitions – Binary – Dealing with partially performed irrelevant actions

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 et al. (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, Moore, & Mohamedally, 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., 2007, 2011). 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 et al. (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 et al. (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., 2015, 2016; 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; Keupp et al., 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 inappropriate 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 et al., 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 et al. (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. Fig. 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.

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., 2019; 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.

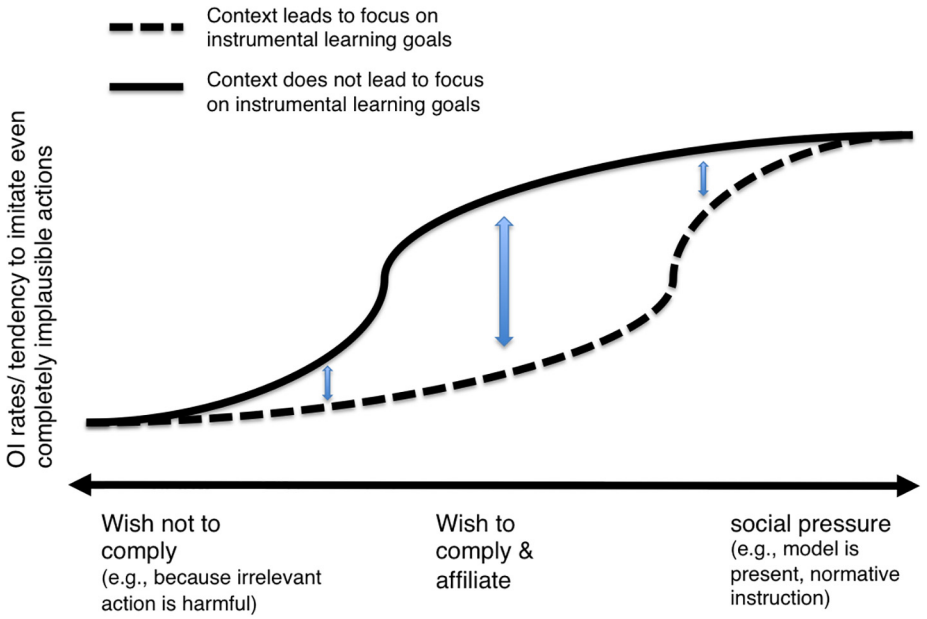

Fig. 2. Illustration of the hypothesized interaction between the degree of social motivation/ social pressure and the focus on instrumental learning goals in the given context on OI rates. Actual scores illustrated are notional.

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, 2019). 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 Etten, Hannah, 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 Etten et al. (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; Etten et al., 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 & Tomaselli, 2010; Nielsen, Mushin, Tomaselli, & Whiten, 2014), 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, 2017, 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' (GCB; see Fig. 1, e.g., Whiten et al., 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 3–6 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, Cooper, and Mareschal (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., 2007, 2011). 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., 2007, 2011). 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, 2019) 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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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dr.2018.12.002.

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