6 Flexible Social Learning of Technical Skills: The Case of Action Coordination

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Introduction

Technical expertise can encompass a wide variety of skills and knowledge, such as the functional, mechanical, or material properties of objects or tools with which one must work or causal relationships between objects and their environment. The type of technical knowledge that we focus on is the motor form: that is, how one moves one's own body in order to successfully perform some technique. In cases of action-oriented techniques such as sport or dance, the way one moves is clearly integral to the intended outcome, but learning how to move one's body is also fundamental to object-oriented techniques such as playing a musical instrument, throwing clay on a potter's wheel, sailing a boat, or even tying one's shoelaces. Expert performance of many techniques requires precise motor plans, sophisticated control of the timing and trajectory of one's movements, and careful monitoring and integration of sensory and proprioceptive feedback.

However, the specific cognitive mechanisms responsible for cultural transmission of technical motor skills remain an open question (Heyes 2016; Stout 2002). Part of the challenge in addressing this lies in the flexibility with which technical skill transmission occurs: someone looking to learn how to prepare a specific meal may learn it by reverse-engineering the preparation process from its taste or looks, or they may follow a recipe book or cooking program, or they may observe an experienced chef prepare the dish, or they may ask an experienced chef to teach them. These are all cases of social learning, and each will offer unique opportunities and challenges to learning.

Despite the wide variety of scenarios, experimental studies of cultural transmission of techniques do not tend to focus on the cognitive factors allowing for such flexible adaptation to different learning environments. Indeed, transmission chains are the most common design in the study of cultural transmission, where a simple skill (such as constructing a paper airplane or a spaghetti tower) is transmitted through iterated generations of learners who observe either the actions or the end-product of a previous generation (Mesoudi and Whiten 2008; Miton and Charbonneau 2018). In turn, the transmission of a technique is evaluated by comparison of the artifacts produced at each generation on some prespecified coding metric (e.g., the distance the paper plane flies or the height of the tower). The information passed to learners at each generation is therefore tightly constrained, and the grain of analysis of this kind of data coding is too coarse to allow for much flexibility in transmission (Charbonneau and Bourrat 2021). As a result, such studies offer little insight into the cognitive mechanisms at play in these transmission episodes, as they "black box" the cognition of social learning (Heyes 2016) in favor of measuring input-output relationships between artifacts produced by different generations (Charbonneau and Bourrat 2021).

So far, the specific cognitive mechanisms supporting cultural transmission of technical motor skills remain an open question. In our chapter we propose that, to address the flexibility of technical traditions, it is important to situate social learning within an interaction context. To this end, we show how current discourse on observational learning through imitative copying typically presupposes a unidirectional type of interaction that imposes rather than demonstrates rigidity on the learned behavior. We go on to differentiate between *know-how* and *information flow* and show that while the former is necessarily unidirectional in social learning episodes, the latter rarely is. We then show that by expanding the range of social learning interaction contexts to allow for bidirectional information flow, it is possible to draw clear parallels with the literature on action coordination. Finally, we show that considering social learning as a type of action coordination can help to explain both the flexibility and rigidity of technical traditions in a way that is coherent with the anthropological record on complex skill learning.

The Unidirectionality Problem

Social learning has been defined as "learning that is influenced by observation of, or interaction with, another animal . . . or its products" (Heyes 1994), or more precisely, "learning that is *facilitated* by observation of, or interaction with, another individual or its products" (Hoppitt and Laland 2013, emphasis added). It is interesting to note that under either definition, observation is only one way by which individuals can socially learn from conspecifics. Yet many discussions of social learning treat observation as the basic phenomenon of interest, and discussions of mechanisms involved in social learning tend to focus on those that characterize the relationship between a learner's observational input and their behavioral output—for example, as the result of imitation, emulation, local enhancement, and so on (Caldwell and Millen 2009; Henrich 2016; Henrich and McElreath 2003; Heyes 2001; Mesoudi 2011; Whiten et al. 2009).

This emphasis on learners and how they unpack or decode the learning input helps us to simplify complex and variable social learning interactions and find a common denominator; then we can explore what specific adaptations or mechanisms allow a learner to acquire input by reading out information encoded in the actions or behaviors of others. The assumption inherent in this approach is that the mechanisms the learner uses to decode input in one scenario can be generalized to other scenarios where they are learning different content with a different model in a different environment. Observational learning therefore serves as a minimal working example where the social input to the learner from the model can be treated as if it were any other stimulus in the environment. Minimal working examples are important for guiding theoretical and empirical work, particularly on such varied phenomena as social learning, where interactions are diverse and complex and individuals can learn using a range of methods such as observation, local enhancement, or even direct teaching (Kline 2015).

To say that the example is minimal is not to say that the question of how an individual learns through observation is trivial—far from it. But explaining this episode of social learning does not require knowing what is going on in the mind of the model, nor anything of the prior knowledge or experience of either agent, nor the local ecology or social environment in which the interaction is situated. One need only identify the learning processes going on in a single individual's mind under the assumption that these processes can then be generalized to more conceptually complex scenarios.

Another point in favor of using observational learning as a minimal working example is that this kind of learning is very important early in human development: infants cannot act independently, so learning through watching and imitating adults is very important to the acquisition of early motor skills, together with the ability to discern who and what to imitate (Gergely, Bekkering, and Király 2002; Gergely and Csibra 2006; Meltzoff 1988; Wood, Kendal, and Flynn 2013). Developmental research increasingly recognizes that interactivity plays a crucial role in early observational learning, as it relies on the receptivity of the learner to communicative signals from the model and on the model's anticipation and recognition of the learner's needs (Csibra and Gergely 2009; Gergely and Csibra 2005, 2006; Király, Csibra, and Gergely 2013; Gergely and Király, this volume). However, such interactivity is frequently missing from laboratory studies of intergenerational transmission chains with adult participants, where learners' inputs are usually observations of single instances of the to-be-learned behavior with no chance for repeated practices (Caldwell, Renner, and Atkinson 2018; Caldwell et al. 2020; Caldwell and Millen 2008b; Mesoudi and Whiten 2008; Miton and Charbonneau 2018).[1]

To our minds, this treatment is problematic because it carries with it an assumption of unidirectionality: that is, there is no opportunity for mutual exchange of information between the model and the learner. As a result, learners in an observational scenario offer no input to shape the learning outcome. In such accounts, the only control a learner can exert is over where and how they allocate their attention (Heyes 2012). A learner may preselect models to learn from—for example, on the basis of social reputation or prestige (Henrich and Gil-White 2001; Jiménez and Mesoudi 2019). Learners may also discard or down-weight inputs from models who appear incompetent or unreliable (Dautriche et al. 2021; Koenig and Woodward 2010; Poulin-Dubois, Brooker, and Polonia 2011), but they do not have any direct impact on the model's behavior itself. Laboratory studies in turn construct learning scenarios where there can be no interactivity, either because the model demonstrates the action and then leaves before the learner first practices the behavior (Caldwell and Millen 2009) or the learner watches prerecorded videos rather than a live model (Strachan et al. 2021). When laboratory studies of technical transmission do involve interactivity, the dynamics of these interactions—particularly how feedback channels from the learner to the model are exploited during teaching—tend to be overlooked in favor of comparing the production outputs of learners who acquired the skill through teaching against those of learners who learned by imitation or emulation (Morgan et al. 2015). On the other hand, laboratory studies of joint actions (Sebanz, Bekkering, and Knoblich 2006; Sebanz and Knoblich 2009, 2021) indicate that during interactions, dynamic coupling between interaction partners is a complex phenomenon involving sophisticated prediction, planning, and signaling to ensure successful coordination (we discuss this in further detail below in the section on coordination, flexibility, and rigidity).

In cognitive science, this problem of unidirectionality is also known as the "fourth wall" problem, and it has been well documented with regards to eye gaze processing (Gobel, Kim, and Richardson 2015; Risko, Richardson, and Kingstone 2016). The crux of the problem is that within laboratory experiments where participants look at scenes or faces on computer screens, their patterns of gaze fixations are very different from live recordings of participants physically interacting with those scenes or people in real life. When observing another person in real life, the observed individual can detect that they are being watched, which can result in audience effects (Bateson, Nettle, and Roberts 2006; Cañigueral, Ward, and Hamilton 2021; Cañigueral and Hamilton 2019; Hamilton 2016) and even interfere with the performance of skilled behavior (Belletier et al. 2015; DeCaro et al. 2011). Given that audience effects can elicit changes to behaviors that may be context-specific and tailored to other people within the interaction (Krishnan-Barman and Hamilton 2019), their effects on the interaction and learning should be considered in all but truly unidirectional observations (cases where the informational channels are such that a learner can watch a model without any chance of affecting their behavior). Such cases are rare outside of laboratory settings where unidirectionality can be guaranteed through the use of apparatus such as videos or one-way mirrors. In the real world, nearly all social learning interactions are to some degree bidirectional in nature, as a learner *can* affect the behavior of the model and may do so in ways that can be unobservable to those outside the interaction (Stout 2002). An explanation of the mechanisms of social learning should therefore aim at identifying how and when a learner *does* affect the behavior of the model.

We propose to embrace the bidirectionality of social learning interactions by examining the distinction between *know-how* and *information*. In the next section, we clarify this distinction and discuss the implications for broadening the scope of research on social learning.

Know-How versus Information

A social learning episode involves at least two people. One, the model, possesses some technical knowledge (henceforth know-how) that the other, the learner, will acquire as a result of the episode. In this sense, it is a necessary precondition that a social learning interaction has an asymmetry in know-how and a consequent unidirectional flow from the model to the learner. However, know-how is not the only thing communicated in a learning interaction; there is other information that need not flow unidirectionally from the model to the learner. Students can ask questions of their teachers, or learners can make statements about what they are learning or try out ways of using the technique that the model can then react and adapt to. Considering this, it is important to distinguish know-how flow from information flow as dimensions along which interaction contexts can vary. In brief, we use know-how to refer to the context-independent representation of an action or sequence of actions that are necessary to produce a certain outcome, while information is the context-specific feedback from the social interaction partner that allows an actor to make online adjustments that can satisfy either instrumental or communicative goals.

Imagine a situation in which two people—a model (Maria) and a learner (Luisa)—are involved in preparing a meal according to a family recipe of Maria's. Maria knows the recipe but Luisa does not. This is an example of a know-how asymmetry and is a necessary precondition for social learning—the know-how (the family recipe) is held by the model (Maria) and not by the learner (Luisa) who will acquire this know-how over the course of the learning interaction. This know-how (the family recipe) is context-independent because it is not restricted to the immediate context of the interaction in which Maria and Luisa find themselves but instead extends beyond this particular interaction—once learned, Luisa could go on to cook this meal without Maria, and she could do so in a different kitchen with different tools and ingredients of different sizes or quality.

However, while a social learning interaction must have a unidirectional know-how flow through the interaction because of some know-how asymmetry, it can have many different types of *information* flow. This information flow can be unidirectional—Luisa could be learning to cook the recipe by reading a cookbook of family recipes that Maria has published—but it need not be. If Luisa and Maria are in the kitchen together, then Maria can see what Luisa is doing as well and adjust her actions accordingly, perhaps by changing her position at the stove so that Luisa can look over her shoulder. The information flow is also affected by the dynamics of the interaction itself: Luisa could sit in the kitchen and watch Maria prepare the meal, but she could also help Maria in preparing the meal. Any of these situations is an example of social learning, and all can result in the successful transfer of know-how from Maria to Luisa. But, for the two members of the interaction, they are very different scenarios that require very different cognitive mechanisms to act.

These different interaction structures, characterized by different patterns of information flow, highlight a key aspect of social learning interactions, which is the many varied opportunities for coordination between models and learners that are overlooked in many treatments of social learning. Drawing on research in cognitive science in joint action and coordination, we propose that research on social learning can lean into this complexity by considering cognitive mechanisms in social learning episodes that may not be specialized for learning per se but rather for action coordination. This approach centers the social learner not as a spectator or information scrounger but as an actively engaged participant in the behavior.

Learning by Active Engagement

Considering the social learner as an active participant in an interaction that is defined by particular situational constraints opens up opportunities for nonvertical patterns of transmission that researchers describe as collaborative learning (Tomasello, Kruger, and Ratner 1993)—children can play with their peers at grown-up jobs before they are allowed to participate with adults. For example, in Papua New Guinea, Asabano male children who are prohibited from joining adult hunters on the search for dangerous game like feral pigs or cassowaries will often band together and structure their playtime around hunting smaller targets like lizards (Little and Lancy 2016). This gives young children important basic experience running around and throwing sticks at lizards, and it gives older children the valuable opportunity to plan and manage a team of individuals of various ages and skill levels, which can give them much better functional understanding of the mechanics at play in the behavior that will serve them well when they eventually join the adult hunting parties.

Learning through interaction with peers can also be seen in cases where the canonical transmission model of learning through observation of an expert appears otherwise unidirectional. In cases where interaction with elders is discouraged as inappropriate and children must instead congregate to watch experts perform a skill without disturbing them (as in the case of the Akha; Ongaro, this volume), the vertical transmission of skills from adults to children appears unidirectional. However, even in this scenario, transmission is not wholly unidirectional, as the model is undoubtedly aware of the audience and tolerates the observation (see above). Nonetheless, even here there are opportunities for interaction, as learners can take social cues from their peers who are also watching. Collaborative learning can lead to better retention and transfer of information (Craig, Chi, and VanLehn 2009), and this finding echoes laboratory research showing that collaborating partners can efficiently distribute their attention during visual search tasks (Brennan et al. 2008; Wahn et al. 2020). In a case where a pooled group of observational learners consists of different age groups, younger learners may gain a particular benefit by dynamically following the gaze of their more experienced older peers to relevant features of the actions being performed (Richardson and Dale 2005; Williams et al. 2002).

Even in cases where coordination is not strictly necessary to achieve an outcome—as in the case of stone knapping to make tools, for example—established experts will intentionally perform individual actions in social configurations, discussing their tasks with each other in a line or a circle, where each can have perceptual access to what others are doing and where novices can watch multiple experts at work in parallel (Stout 2002, 2005). Beyond ethnographic evidence, there is evidence from the archaeological record of southern African stone tools throughout the Pleistocene that technological innovations can and do occur through bottom-up or learner-driven contributions to the behavior, as opposed to through purely top-down mechanisms of transmission (Wilkins 2020).

We argue that it is this kind of learning through coordination that allows for the flexible transmission of technical traditions. That is, techniques can be learned in a wide variety of ways, and although each may have some idiosyncratic properties favoring certain types of learning interaction over others, an episode of social learning is subject to the specific coordination demands that are dictated by the task constraints, individual motivations, and interaction structure. In turn, learners—and models—recruit specialized coordination mechanisms to address these specific coordination demands, and these mechanisms play a role in determining both what is learned and how it is learned. In the following section, we explore how different coordination mechanisms can lead to systematic behavioral modulations in response to different contextual demands that allow learners and models to adapt to various social learning scenarios. We also offer some speculation as to how rigidity in the way that cultural traditions are practiced (rather than in the way they are transmitted) can be explained as a potential coordination strategy. In doing this, we show how centering interactivity in technical transmission can help to address flexibility and rigidity at the level of cultural variants within a population as well as their transmission.

Coordination, Flexibility, and Rigidity

We now give a brief overview of some literature in joint action and action coordination that describes some of the cognitive mechanisms supporting coordination and demonstrates how they can inform social learning and research into technical evolution and transmission.

Specifically, we describe how a drive to make oneself predictable during coordination can result in rigid and stable patterns of behavior, while having to represent another person's task during a joint action when that actor has different constraints on their actions can lead to dynamic and flexible action modulations to compensate. Finally, we describe the few existing studies that examine social learning and teaching from a joint action perspective.

Coordinating actions between two or more individuals in order to realize some shared or joint outcome is a demanding task subserved by a host of mechanisms (Vesper et al. 2010). A key driving principle behind how these mechanisms are expressed is whether and how they help to facilitate a partner's anticipation of the relevant features of one's actions. Several studies have shown that, when coordinating, actors become less variable from trial to trial than when they act alone as a way of making themselves predictable (Sacheli et al. 2013; Vesper et al. 2011, 2016). While this kind of variability modulation is a very basic way of facilitating coordination, which has even been observed in macaque monkeys (Visco-Comandini et al. 2015), humans are also able to adapt their behavior in more systematic ways.

For example, a study of joint improvisation (Hart et al. 2014) found that expert improvisers who were instructed to synchronize their actions modulated the velocity profiles of their actions such that both partners deviated significantly from how either of them would move individually. Furthermore, rather than simply converging on a pattern of behavior somewhere between the two actors' styles of movements (i.e., averaging out each other's idiosyncrasies), the resulting coordinated actions reflected some universal characteristics across dyads. This suggests that both agents adjusted their behavior in systematic, general ways that they considered easy to predict for any potential interaction partner.

The role of predictability in coordinating joint action is a fundamental one, and one that interacting partners are very sensitive to. This is particularly evident in cases of competition: while coordinating participants modulate their behavior to be predictable, competing participants do the opposite as they try to mislead their opponents' predictions (Glover and Dixon 2017). However, anticipating another's actions is difficult even when both interactants are cooperating; researchers have found that even when participants choose to coordinate with somebody in a cooperative context, this coordination results in systematic performance costs relative to when acting alone (Curioni et al. 2022).

Considering social learning episodes as instances of coordination allows for a great degree of flexibility in the trial-to-trial expression of behaviors and techniques. The mechanisms supporting coordination in joint action are versatile and sensitive to the situational context and local interaction demands. Actors are sensitive to their partners' ecological constraints and embody these in their own movements (Schmitz et al. 2017), and individuals with an easy task will make more adjustments to their behavior to coordinate with a partner who has a more difficult task (Vesper et al. 2013). In cases of unidirectional information flow, coordinating partners will use leader–follower role assignments to dictate the distribution of online adjustments (Curioni et al. 2019). Even specific coordination mechanisms such as adjusting the speed of one's movement are dependent on the local task demands. In cases where partners are trying to synchronize the timing of oscillatory movements such as tapping or swaying, people speed up in an attempt to minimize variability (Vesper et al. 2011; Wolf et al. 2019), while in cases where partners are trying to synchronize the spatial endpoints of actions, they tend to slow down and adjust the ascent-to-descent velocity ratio of their movements to highlight the upcoming target (McEllin, Knoblich, and Sebanz 2018). Actors will even tailor their actions on the basis of their partner's ability in order to ensure that they do not communicate redundantly (Candidi et al. 2015).

Until now, there has been comparatively little work examining how coordination mechanisms are expressed and exploited in instances of social learning and what role these mechanisms might play downstream in the transmission, propagation, and stabilization of cultural traditions. However, early work does show that pedagogical demonstrations share some kinematic characteristics with coordinated joint actions. In one study (McEllin, Knoblich, and Sebanz 2018), where participants learned to play a series of notes on a modified xylophone, the kinematics of the participants who knew the sequence were examined under three conditions: a turn-taking demonstration, where the participant played the piece through for someone who had to learn to play it themselves; an unequal coordination condition, where the knowledgeable participant and a naive participant had to play together at the same time; and an equal coordination condition, where both participants knew the piece and had to play it together at the same time. In all three conditions, participants (demonstrators, leaders, and co-actors) exaggerated the peak height of their movements relative to an individual baseline. When participants had to play together at the same time (unequal and equal coordination conditions), they slowed down the descent phase of their movements in order to facilitate temporal coordination. However, when participants were coordinating with a naive participant, they also slowed down the ascent phase of their movements in order to facilitate their partner's spatial predictions about the upcoming end of the movement. These kinematic signatures, which map clearly to different coordination demands and constraints, are clear evidence of individuals flexibly adapting their behavior to facilitate coordination and communicate information.

In another study (Okazaki, Muraoka, and Osu 2019) the kinematics of participants were monitored during a turn-taking imitation learning task where a teacher demonstrated to a student how to complete the Tower of Hanoi task in order to quantify the interactional dynamics of teaching, which they describe as a type of reciprocal interpersonal coordination. Importantly, they found not just feed-forward information flow from the teacher to the learner but also feedback information flow from the learner to the teacher. Furthermore, this changed over time as teachers interactively scaffolded the learners' behavior by providing more pedagogical information when learners struggled; as learners improved, the transfer of know-how from teacher to learner became a bidirectional exchange of common ground information.

In a later study (Strachan and colleagues 2021), it was examined how learners interpret these pedagogical cues in observed demonstrations (playing a piece of music, this time on a modified set of drums) and specifically whether they incorporate these action modifications into their own reproductions. If participants were observational learning through copying the model's demonstration, then they would reproduce this behavior because these exaggerations are embedded features of the actions. However, as we have shown, under a coordinative framework, it is not always necessary for both actors to adjust their behavior if this is not relevant to the end-goal, so there would be no need to copy the pedagogical modifications that learners observe. This study did indeed find evidence in support for a pragmatic reconstructive learning process whereby learners did not incorporate the modifications they observed into their own productions.

Rigidity as a Coordination Strategy

We have so far discussed the role that coordination mechanisms play in supporting flexibility at the level of social learning interactions. That is, through the use of various cognitive mechanisms specialized for interpersonal action coordination, learners can adapt to a range of situational constraints that allow them to learn a wide array of technical skills. As such, technical skill learning can be made flexible through the use of coordination mechanisms. Coordination mechanisms are also highly important for flexibility at the level of the tradition itself, when those traditions involve joint actions with multiple individuals performing skills together in highly dynamic environments such as team sports; improvised dance, music, or theater; and surgery. However, when dealing with the flexibility and rigidity of technical traditions themselves (rather than the flexibility of the learning interactions), the inverse can also be true: that is, the rigidity of technical traditions as they are practiced can be used as a focal point for successful coordinated action.

Given the cognitive demands of coordination and its objective and measurable costs to performance, participants may use any tools at their disposal to offset these costs and maximize the predictability of their own and their partners' actions. One such tool may be through rigid cultural traditions that transmit a prescribed pattern of behavior from the constituent individuals in an interaction. Strict adherence to an inherited tradition serves a pragmatic coordinative function in that it facilitates the prediction of others' behavior and establishes what people are expected to do. Such mutually manifest information allows any group member with the background knowledge of that tradition to successfully coordinate without having to engage in costly prediction and planning.

If rigid traditions can serve to stabilize coordination, then this may encourage the high-fidelity transmission of cultural practices across generations that involve a component of coordination. Take driving a car as an extreme example. In the United Kingdom, the cultural practice is to drive on the left side of the road. There may have been potential pragmatic reasons for this practice when it first originated, but whatever these were at the time, they are now clearly obsolete as most of the rest of the world drives comfortably on the right side. This obsolete cultural practice is suboptimal: British drivers who drive overseas experience real costs of having to adapt to the other side of the road and having to adapt to different blind spots in their car, as do right-side drivers who visit the United Kingdom. And yet the practice resists innovation or change. Learner drivers in the UK are still taught to drive on the left and adhere to this rigid practice, despite its suboptimality in relation to the rest of the world, because they must still share the road with the previous generation from whom they learned.

When acquiring a technique that involves coordination or joint action, functionally opaque or even transparently obsolete features of the tradition may be preserved purely because they serve to facilitate prediction among coordination partners, particularly if after learning the technique the learner must coordinate with members of the previous generation. The common ground afforded by a rigid tradition allows individuals to partially offset the cognitive costs of coordination, and so any innovation or change that may optimize a technique must first overcome the coordination costs involved with deviating from the shared action plan. Given that breakdowns of coordination are invariably costly in terms of time, materials, or even risk of harm, the usefulness of rigid traditions for coordination may result in strong inertia or resilience to change.

Conclusion

In this chapter, we have outlined an approach for investigating the cognitive mechanisms involved in social learning responsible for the flexibility of technical transmission that emphasizes the interactivity of such interactions. We have described the problem of unidirectionality, which we argue does not place enough emphasis on the interactive context in which the learner is embedded. Specifically, the bidirectional flow of information along mutual channels between models and learners allows for the strategic use of coordination mechanisms to make one's actions more predictable and in turn more learnable.

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Note

1. A notable exception is the use of closed groups or replacement paradigms (Mesoudi and Whiten 2008). In closed-group paradigms, small groups of participants learn a task with the option to learn (copy) from peer members of their own group. Such paradigms are typically used to explore selection strategies in social learning—*what* and *who* learners copy—or the prevalence of social learning versus individual learning within a population. Replacement group paradigms are similar in that they consist of small groups learning the task, but they also involve an iterated replacement of group members to approximate generational turnover. Both types of paradigms involve multiple opportunities for sustained interaction between participants, setting them apart from transmission chain studies by permitting bidirectional information flow. However, both paradigms (especially replacement groups) are more costly and logistically challenging to run than transmission chains, and they are typically run using decision-making games or mental problem-solving rather than action-based technical skills (e.g., Gürerk, Irlenbusch, and Rockenbach 2006; Insko et al. 1983; Toyokawa, Whalen, and Laland 2019). In the rare cases of exceptions (Caldwell and Millen 2008a, 2009), these paradigms are subject to some of the same criticisms as one-off transmission studies in that they measure transmission and cultural change on the basis of input-output relationships and do not study the dynamic information transaction during learning.

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