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Original Article

Do as I say *and* as I do: Imitation, pedagogy and cumulative culture

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Abstract

Several theories, which attempt to give an account of cumulative culture emphasize the importance of high-fidelity transmission mechanisms as central to human learning (Boyd and Richerson 1985; Galef 1992; Tomasello, 1994). These high-fidelity transmission mechanisms are thought to account for the ratchet effect, that is, the capacity to inherit modified or improved knowledge and skills rather than having to develop one's skills from the ground up via individual learning. In this capacity, imitation and teaching have been thought to occupy a special place in the explanation of cumulative culture because they are thought to both function as high-fidelity transmission mechanisms (e.g, Boyd and Richerson; 1985Galef 1992; Tomasello 1994; Richerson and Boyd 2005; Thornton and Raihani, 2008; Fogarty et al. 2011; Moore 2016).

In contrast to this standard view, I will argue that imitation and teaching are not both best construed as primarily high-fidelity transmission mechanisms. Rather, I'll argue that though both can contribute to the high-fidelity transmission of information, imitation and teaching make two distinct contributions to cumulative culture. I will claim that imitation functions primarily as a high-fidelity transmission mechanism while teaching is primarily responsible for the innovation and creativity characteristic of cumulative culture.

Imitation, innovation, pedagogy, cumulative culture

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The richness, sophistication, and variety of human culture—our norms, practices, and technologies—are beyond compare in the animal world. One reason why we are able to inhabit a complex and diverse cultural environment is because we are able to build on the skills, knowledge, and innovations of previous generations. That is, our culture is sophisticated, rich, and diverse because it is cumulative. Cumulative culture refers to the transmission via social learning of behavioral changes that accumulate over many generations in a population (Galef 1992; Boyd and Richerson 1985, 1995, 2005; Tomasello 1993, 1999).[1] Specifically, cumulative culture exhibits what Michael Tomasello (1993, 1999) has called the "ratchet effect". This effect refers to traditions that become more complex as new generations build on the innovations of previous ones. Importantly, the ratchet effect produces complex technologies and practices that could not be developed or learned by any one individual or group in a single lifetime.

In order to account for cumulative culture, philosophers and psychologists often focus on the cognitive mechanisms that make the transmission of traditions possible. In this way, imitation and teaching are seen as central to the question of cumulative culture. Specifically, imitation and teaching are often identified as the high-fidelity transmission mechanisms that make the transfer of skills, customs, and knowledge possible (Boyd and Richerson 1985, Galef 1992, Tomasello 1994/2009, Straus 2004, Richerson and Boyd 2005, Thornton and Raihani, 2008, Fogarty et al. 2011; Dean et al. 2014, Morgan 2015, Moore 2017).

However, we should notice that accounting for cumulative culture requires more than explaining the high-fidelity transmission of traditions and technologies. Indeed, a theory of cumulative culture requires explanation of at least two principles: (1) the transmission of traditions among members of a population and (2) the modification and improvement of inherited traditions.[2] In the current literature, the identification and investigation of imitation and teaching as mechanisms of transmission address only the first principle. The second principle, concerning innovation is largely taken for granted. [3]

In this paper, I will argue that taking for granted the innovation of inherited traditions is shortsighted. This is because high-fidelity mechanisms for the transmission of normative practices, customs, languages, and opaque, complex skills must stand in tension with the innovation characteristic of cumulative culture. In particular, as a learning mechanism that can deliver the long-term, high fidelity transmission of skills and practices, imitation, by its very nature, must be opposed to the variation, modification, improvement and innovation of the tradition. That is, imitation must stand in opposition to modification lest the modifications undermine the transmission of the tradition. This means both that imitation has to be conservative and, accordingly, that we cannot take the creativity of cumulative culture for free.[4] As such, an adequate theory of cumulative culture will need not

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[1] We should distinguish cultural inheritance, which is acquired via social learning, with genetic inheritance, which may be cumulative but which uses a distinct set of transmission mechanisms, i.e., genetic mechanisms.

[2] See Tomasello 1999, Tennie et al. 2009, Mesoudi et al. 2013, Dean et al. 2014 and Legare and Nielsen 2015 for similar points.

[3] See, for instance, Tomasello 1999, Tennie et al. 2009, and Dean 2014, who assume that innovation and creativity are the easy aspects of cumulative culture. For a detailed defense of this claim, see Charbonneau 2015.

[4] Moreover, we cannot investigate innovation without getting clear on the demands of cumulative culture because, in doing so we risk misidentifying our explanandum. This is why an account of innovation that focus exclusively on taxonomizing innovation kinds or identifying conditions which make innovation more or less likely, though useful for various purposes, are insufficient for

only to account for the high-fidelity transmission of traditions but also for the kind of innovation that does not undermine these transmitted traditions. I will suggest that teaching makes such innovation possible.

In contrast to the standard view, I will argue that imitation and teaching are not both best construed primarily as high-fidelity transmission mechanisms. Rather, I'll argue that though both *can* contribute to the high-fidelity transmission of information, imitation and teaching make two distinct contributions to cumulative culture. I will claim that imitation functions primarily as a high-fidelity transmission mechanism, accounting for principle (1). In contrast, teaching is primarily responsible for the modifications, innovation, and creativity characteristic of cumulative culture, thus, explaining principle (2).

Moreover, I'll argue that there is a clear connection between imitation and the kind of teaching required for cumulative culture insofar as both exploit what Richard Moore and I (Fridland and Moore, 2014) have termed the technique-centric orientation. The technique-centered orientation in imitation is a concern for replicating the precise observed strategy of a demonstration. Importantly, this concern is not reducible to the instrumental value of the precise, detailed strategy or procedure that is replicated. Rather, the technique-centered orientation betrays an interest in or motivation to reproduce the means themselves, seemingly for their own sake.

This orientation becomes evident both in the overimitation behaviors of human children and in comparisons between human imitation and the copying behaviors of non-human primates. I will argue that once teachers leverage the technique-centric orientation, the possibility to transmit information and skills in both a conservative and creative manner becomes viable. Specifically, in technique-centered pedagogy, focusing on the precise means by which a task is instantiated allows teachers to communicate to students which aspects of a technique or procedure are relevant and which irrelevant. This kind of teaching can also promote understanding of the underlying nature and significance of the elements composing a technique or task. As such, technique-centered teaching frees the student from the bonds of strict replication by fostering understanding. This understanding allows for the variation in technique that is required for cultural innovation; variation that does not undermine the high fidelity transmission of traditions that imitation has made possible. As such, by focusing on the technique-centered orientation, we gain both a clear connection between imitation and pedagogy, as well as a way of overcoming the conservatism of imitation, which on its own should inhibit the innovation and creativity required for cumulative culture.

This paper will proceed in four parts. In section 1, I will introduce the technique-centered orientation defended by Fridland and Moore (2014). In section 2, I will explain why imitation as it relates to cumulative culture is an inherently conservative learning mechanism and, as such, why the diversity of human culture

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addressing my concerns here: specifically, identifying a process that is both conservative and creative in the ways that I outline in sections 2 & 3 (For examples of the above kinds of approaches to innovation, see Ramsey et al. 2007, Mesoudi et al. 2013, Flynn et al. 2015, Sheridan et al. 2015, Tebich et al. 2016, Reader et al. 2016).

cannot be generalized from the creativity seen in the rest of the animal world. In section 3, I will specify three kinds of innovation: refinement-B, recombination, and exaptation, which can account for the creativity of cumulative culture while respecting the conservative transmission of traditions via imitation. Lastly, in section 4, I will suggest that technique-centered teaching makes refinement-B, recombination, and exaptation possible by promoting understanding.

1. IMITATION, OVERIMITATION, AND THE TECHNIQUE-CENTERED ORIENTATION

One aspect of human imitation that becomes salient when we review the literature in comparative and developmental psychology is that human children are precise but impractical imitators. This is not to say that children are irrational in their choice of what or whom to imitate,[5] but it is to say that once they have decided to imitate, often for rational reasons, children imitate in an impractical way. That is, children imitate in a highly detailed manner that does not simply aim to replicate the instrumentally relevant aspects of an observed action strategy. This impractical copying behavior is most evident in children's tendency to overimitate. That is, to imitate not only those aspects of a modeled behavior that they have determined to be relevant for task success, but even the obviously irrelevant portions of a demonstration, which can include the style or exact gestures with which a demonstration is performed.

There is substantial evidence demonstrating that children are staunch overimitators (Lyons et al. 2007; McGuigan et al. 2007; Whiten et al. 2009). These studies show that children frequently include details or action elements into their imitation, which they understand to be causally irrelevant for the successful completion of the task (Lyons et al. 2007; Horner and Whiten 2005). From the evidence, it seems safe to conclude that the imitation strategies of children are not exclusively goal-bound but include detailed techniques or procedures that are copied for reasons that are not merely instrumental.

This impractical orientation is demonstrated vividly by Lyons et al. (2007). In a very nice study, Lyons et al (2007) presented three to five-year old children with a demonstration of a model manipulating a novel object containing a toy. The model used a technique that included an irrelevant feather-tap. After training the children to recognize the feather-tap as causally irrelevant, Lyons et al. set out to determine how this knowledge would impact the imitative behaviors of the children. Surprisingly, even after children determined that the feather-tap was irrelevant for retrieving the toy inside the novel object, they continued to incorporate it in the production of their own behavior. Moreover, children that were better at identifying an action as causally irrelevant were not in any way less likely to replicate it in their own behavior.

[5] See Fridland and Moore (2014), p. 860-865 for an in-depth discussion of selective imitation. For empirical evidence of selective or rational imitation, see, for instance: Meltzoff 1995, Bellegamba & Tomasello 1999, Carpenter et al. 1998, Bekkering et al. 2000, Gleissner, Meltzoff, & Bekkering, 2000 Carpenter, Call, & Tomasello, 2002, Gergely et al. 2002, Huang et al. 2002, Schweir et al. 2006, Williamson & Markman, 2006.

The peculiarity of human imitation becomes even more striking when we compare the behavior of human children to non-human primates. This is because in non-human primates, the kind of impractical orientation towards the technique or details of an action plan is almost entirely absent (Kohler 1959, Galef 1992 Tomasello et al.1987, Tomasello 1994, Visalbhergi and Fragaszy 1990, Horner and Whiten 2005). That is, we see that chimpanzees are much more practical about which behaviors they reproduce, avoiding replicating irrelevant actions or superfluous details. [6] As Byrne and Russon (1998) put it, non-human primates imitate at the program level but not at the action level. This is similar to Kohler's (1959) observation that apes imitate only "the substance of an action (the purpose of the sequence movements) not its form (the movement themselves" (Galef, 1992, 168).[7]

The distinction between the practical mindset of chimpanzees and the impractical orientation of human children is elegantly demonstrated in Horner and Whiten (2005). Horner and Whiten presented chimpanzees and three-and four-year-old children with a demonstration of a complex series of actions aimed at opening a locked box that contained a reward. The demonstration proceeded in two conditions, a transparent condition where the causal connections between the model's actions and the box were visible to the children and chimpanzees and an opaque condition where the causal connections between the demonstration and the box opening were not visible. In both conditions, the demonstration included a causally irrelevant behavior and, accordingly, the behavior could only be recognized as irrelevant in the transparent condition.

Interestingly, Horner and Whiten found that chimpanzees reproduced the entire action sequence, including the causally irrelevant movement, in the opaque but not in the transparent condition. Children, on the other hand, reproduced the causally irrelevant movement in both conditions. So, once chimpanzees determined that a behavior was causally irrelevant for the task at hand they dropped it from their behavioral repertoire whereas children continued to reproduce both the relevant and irrelevant actions. Two points to notice here: (1) the capacity of three and four year olds to determine the causally relevant and irrelevant aspects of the demonstration were tested separately and found satisfactory. (2) The fact that chimpanzees reproduced all the action elements of the demonstration in the opaque condition shows that chimpanzees are capable of somewhat detailed behavioral replication, even if they don't default to this strategy.

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[6] It has been suggested that children overimitate for reasons of social affliation, desired identification, intersubjective connection and shared intentionality (Byrne & Russon 1998, Lakin and Chartrand 2003, Horner and Whiten 2005, Nielsen & Blank 2011, Nielsen et al. 2008, Over & Carpenter 2009, 2012, Tomasello et al. 2005). The empirical challenges notwithstanding (Lyons et al. 2007), it is important to see that considerations of social benefit are not sufficient to explain overimitation. This is because there are many paths towards winning the affection of others or building a stronger connection with them and it isn't obvious that imitation is a very good method, never mind the most effective method, for this purpose. For an in-depth discussion of this point, see Fridland and Moore 2014, 870-871.

[7] Several studies support this claim, e.g., Whiten et al. 1996, Whiten, Horner, Litchfield, & Marshall-Pescini, 2004, Horner & Whiten 2005, Tennie, Call, & Tomasello, 2006.

Together, overimitation in children and the differences between human and non-human primate copying combine to illustrate the peculiarity of human children when it comes to replicating the detailed strategies or techniques of a demonstrated task. It is this peculiarity that Fridland and Moore (2014) attempt to capture in our definition of imitation by isolating what we call "the technique-centered orientation". We claim that true imitation incorporates a particular concern for replicating the detailed strategies or exact procedures of an observed action—a concern which is not reducible to the instrumental value of the procedure and which is not simply a matter of fortuitously reproducing the observed actions.[8] That is, human children are not only motivated to achieve ends or goals but they are also motivated to reproduce means.[9] It's important to see that this intentional orientation needs to be identified if we hope to differentiate true imitation from cases where the exact action sequence is reproduced for merely instrumental reasons but without any interest in reproducing the action sequence itself. That is, cases like the opaque chimpanzee condition tested in Horner and Whiten (2005).[10]

For the purposes of this paper, I should emphasize that the impractical, high-fidelity reproduction of behavior is very useful for transmitting both causally opaque information about complex tools and also for passing along language, norms, rituals, and other causally arbitrary or conventional behaviors. That is, imitation is an effective strategy for learning how to manipulate tools where the relevant causal structure and sub-goals are not easily reconstructed from observation because imitation does not require the imitator to understand how the goals, sub-goals, and particular actions are connected.[11] And imitation is useful for learning norms, customs, gestures, and languages since there is often nothing in these phenomena that is directly constrained by the causal features of the environment (Millikan 2005, Moore 2013a, b, c). As such, learning by imitation rather than through the individual reconstruction of relevance appears essential for passing along complex, opaque skills and technologies, norms and practices.[12]

In this way, imitation, in its refusal to ignore causally irrelevant aspects of a demonstration, can function as the requisite high-fidelity transmission mechanism accounting for principle (1) of cumulative culture. That is, through imitation, by fully reproducing an observed behavior, a novice can take on board the modifications, improvements, or innovations directly from the model demonstrating

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[8] In Fridland and Moore (2014) we take ourselves to be refining the definition that Tomasello offers (Tomasello 1993, 1999, 1994/2009).

[9] See Tomasello et al. 2005, Shea 2009, and Moore 2013c who raise the possibility that the distinction between human and non-human primate imitation may be a matter of motivation and not a matter of a capacity to imitate.

[10] For an in-depth defense of this way of interpreting Horner and Whiten (2005) see Fridland and Moore 2014.

[11] See Meltzoff 1995, Gergeley and Csibra 2005, and Fridland and Moore 2014, for claims that imitation does not require an overly sophisticated understanding of intentions.

[12] In fact, it may be that imitation of the human variety is particularly well-suited for transmitting in a high-fidelity manner causally arbitrary, conventional practices. Accordingly, the benefit for complex, opaque technologies piggybacks on mechanisms selected for this more fundamental object of transmission. See Kenward et al. 2011, Kenward 2012, Neilsen 2014, and Legare and Nielsen (2015) for defense of this hypothesis.

it, even when the novice doesn't herself appreciate why those actions or procedures are important. And, in this way, one need not reinvent efficiencies on one's own but, rather, one can incorporate the modifications and improvements of previous generations directly into one's behavioral repertoire. So, whereas social learning is possible for many animal species (Galef 1992, Heyes and Galef 1996, Laland and Galef 2009, Galef and Laland 2005. See Hoppitt and Laland 2008, Rappaport and Brown 2008 for reviews) the capacity to retain the progress of previous generations requires mechanisms for the high-fidelity transmission of information, skills and knowledge, which allow relevance to be determined by the model and not by the observer. The upshot is that humans apparently impractical orientation has very practical pay-offs.

2. IMITATION IS A CONSERVATIVE TRANSMISSION MECHANISM

In this section, I'd like to argue that if imitation is going to function as a high fidelity transmission mechanism of the sort that cumulative culture requires then imitation, by its very nature, has to be conservative. That is, imitation should be in opposition to the innovation and creativity that also appears necessary for cumulative culture. This is because the modifications that would result from innovation could change the details of a demonstrated behavior, thus jeopardizing the faithful transmission of the tradition. In short, if imitation is a method for transmitting causally opaque technologies or conventional practices, customs, and languages and if its function relies on the precise, detailed, high fidelity transmission of those practices, then changing the details of the practice, as innovation would require, could undermine its function.[13]

Another way of thinking about this is from the perspective of perceived as opposed to actual relevance. The way in which imitation works is by allowing relevance to be determined by the model or demonstrator rather than grounding relevance in what appears relevant to the observer. The demonstration becomes authoritative. This seems critical for establishing faithful replication of causally opaque and conventional behaviors since apparent relevance or irrelevance will turn out to be an unreliable guide to actual relevance and irrelevance. So much should be clear since what's required for successfully using a tool with an opaque causal structure or repeating a conventional and thus causally arbitrary custom or practice will have little to do with features whose relevance can be observed independently of the procedure or custom modeled. That is, relevance, in these cases, cannot be discerned by individual perceptual, causal or logical reasoning. As such, in order to acquire a complex tradition, the observer has to default to precisely

[13] As Shea writes: "Another way that the fidelity of the copying process may be lowered is by individuals thinking for themselves. Individuals may be able to infer a more efficient way of bringing about the goal of some observed action. Or they may be able to discover a more efficient solution by trial and error learning. It can seem as if such modifications can only increase the potential of an imitation mechanisms to give rise to cumulative adaption, by allowing individuals to improve the adaptiveness of the behaviours they pass on. However, suppose the model has used a novel means for a good reason, but one that is transient: the model might act with their foot because their hands are occupied. Those kinds of individual innovations, although individually rational, from the point of view of an inheritance system would constitute noise in the process of transmission" (2009, p. 2433). For similar points, see Godfrey-Smith (2012) and Charbonneau (2014).

repeating the observed behavior. After all, relying on one's own sense of relevance can lead one astray: it may lead to an omission of various necessary elements or to the addition of superfluous and possibly mistaken others. These can then undermine successful transmission of the skill or knowledge.

2.1 Some examples of the need for imitation to be conservative

In the following, I'll present three examples in order to clarify why the successful long-term, high fidelity transmission of traditions must be conservative.

2.1.1 Example 1: Custom

Let's take a simple example to elucidate the problem: Imagine that a novice is learning a custom through imitation. The custom is to take off one's shoes before entering a home. The novice watches a demonstrator bend over and take off her right shoe first and then her left and then place both shoes together to the right of the door.[14] Now, it might be that the exact details of the shoe-removal procedure are irrelevant to the custom but it could be that they are not. Either way, the possibility that the details of the procedure are not irrelevant to the custom should make it the case that, in order to learn the custom, the novice should remove her own shoes in the precise manner that she has observed the model removing hers: bend over and remove the right shoe first, then left, then place both shoes to the right of the door. If each of the action elements of the demonstration are part of the custom (as they very well may be) and if the novice starts playing around with the sequence of the procedure then she risks not learning or undermining the custom. That is, if it is required to place both shoes to the right of the door but the novice decides to get creative and place one shoe to the right of the door and the second to the left then the practice has not been transmitted. Likewise, if one always has to remove the right shoe before the left but the novice performs the sequence backwards, or kicks off her shoes instead of bending over to remove them, then she will have undermined the successful transmission of the custom. The point is that because it is not the causal or environmental affordances that constrain the custom but, rather, conventional and arbitrary (from the perspective of the goal of, e.g., getting one's shoes off) practices, one cannot simply alter elements of the action procedure willy-nilly. One must imitate faithfully and, thus, conservatively. That is, in order to transmit conventional traditions successfully, creativity must be resisted.

2.1.2 Example 2: Opaque Skills

Another example where faithful and conservative imitation is the best solution for transmission is complex skills with an opaque causal structure. Whereas the necessary components of customs, rituals, or conventional behaviors often cannot, in principle, be discerned through observation alone, the relevant and irrelevant

[14] It may be that the novice does not regard the model as a reliable guide to the custom. It may be that for various rational reasons this person is not taken as authoritative and then no imitation of the demonstration will ensue at all (See footnote 5 above and Fridland and Moore (2014) for a detailed discussion of rational imitation). To be clear, my point here is about what happens after the model is determined to be worthy of copying. In this case, the imitation must be conservative.

features of opaque skills are often just very difficult to decipher in practice. Sometimes the practical challenge borders on the impossible whereas in other instances the challenge is simply very difficult or only available in retrospect or through reverse engineering. However, these practical challenges for acquiring complex skills through individual discernment of relevant causal structure make imitating in a faithful and conservative manner a straightforward strategy for guaranteeing successful transmission. That is, in cases of complex skills and practices, imitation offers not the only but the most effective solution to the transmission problem.

Take, for instance, the following example that Nick Shea offers:

> Scientists generally copy all the details of a protocol. There may be no good reason for using 10ml rather than 20ml or 5ml of some solvent, say. That may just be the way it was first done, and since it worked no one has bothered to find out if the quantity could be varied. Indeed, some experiments are so tricky to get right that practitioners show an almost religious adherence to the letter of a known protocol. When an experiment takes hours or days to perform, there is very little motivation to put the result at risk in order to identify which steps or quantities are essential and which can be varied. So all sorts of techniques and steps are copied without any appreciation of whether or why they are necessary to achieve the goal – following an experimental protocol can feel rather like following a magic spell (2009, p.2434).

It seems clear that when it comes to the learning of complex procedures or skills, the particular contribution that each element of a task makes will be difficult, if not, in some cases, almost impossible to discern through observation and individual reasoning alone. This is especially true of elements or sub-tasks that do not have their effects immediately but, rather, many steps down the line. When this is the case, it seems likely that those effects will not be the kind of things that could be recognized in any straightforward manner by an observer. Accordingly, when complex tasks or skills have an opaque causal structure their successful transmission requires a high degree of conservatism. That is, the learner must perform each of the elements of a procedure faithfully, resisting modification, despite not understanding the purpose of each of the individual steps. This is because omitting or modifying a step in the procedure has the risk of undermining the successful transmission of the practice. This is not to say that no modification to the skill can ever be applied but it is to say that changes, additions, or subtractions have both a risk and a cost. Accordingly, innovation cannot be produced blindly or randomly but will require a certain degree of understanding. This means that the replication of a technique or procedure conservatively is an efficient strategy for transmission of a technology or skill. This also means that innovation cannot remain ubiquitous and unconstrained.

Now, clearly, not all skills have an opaque causal structure. For example, the relevant causal structures of simple tools such as hammers and rakes can easily be observed and appreciated through observation. As such, the transmission of e.g., hammering skills or raking skills need not be conservative in the same way that more complex procedures must be. Remarkably, this may explain why imitation isn't always the default strategy for human children (Kenward et al. 2011, Carr et al, 2015, Legare and Neilsen 2015, Neilsen et al, 2015)**.** That is, when a task is clearly performed for instrumental reasons and the relevant causal structure of the skill is easily discernible through observation, then exact, detailed imitation need not be the default strategy.[15] However, we should notice that when it comes to cumulative culture, that is, for those traditions that are so complex that they cannot be learned in a single lifetime—the technologies and traditions that are transmitted are often both complex and opaque. As such, we see that for these kinds of skills, transmission mechanisms must remain conservative.

2.1.3 Example 3: Language

Perhaps the most straightforward example of the necessary conservatism of imitation can be gleaned if we consider the learning of words in a natural language. It seems plain that if one is going to learn the words of a language by replicating the speech behavior of others, as we often do, then one must copy the sounds that one hears faithfully. So, for example, if one is learning to say, e.g., the word "astronaut" one cannot simply decide to get creative and change the pronunciation of the last syllable to "astro*noun*".[16] In this case, one has not learned to say the word. That is, the relevant practice has not been transmitted because, in innovating, the novice has undermined the tradition, which depends on the exact replication of each phenome. This point, I think, may seem trivial but it is key to understanding the nature of high-fidelity cultural transmissions, especially when it comes to conventional practices. That is, without committing to a strictly conservative imitation strategy, word learning would become largely impossible. In this way, imitation as a high fidelity learning mechanism must be inherently opposed to creativity and innovation.

All of this should help us to see that if one is learning a custom, complex skill, or language through imitation rather than, say, through individual, trial-and-error learning, then the amount of similarity we'd expect to see between the observed behavior and the transmitted behavior must be quite high. That is, imitation must function to constrain the diversity of solutions. As such, it must function conservatively. If this is right, then accounting for the possibility of innovation and creativity in cumulative culture will require substantive explanation.

In contrast, if a behavior is learned through a combination of observation and individual, trial-and-error learning then one should expect to see a high degree of variability in arrived at solutions. This is because, in most cases, there are multiple solutions to any given problem. As such, there is no reason to think that the results of trial and error learning will home in on one unique solution. Accordingly, solutions should proliferate. And this is exactly what we see in the non-human animal world (Tomasello et al. 1993, Boesch 1995, Whiten et al. 2001, Weir et al

[15] If this proposal is correct, then in interpreting the Lyons et al (2007) study we should consider whether children overimitate because they assume that they are not in a straightforward instrumental context. That is, the assumption of the children may be that the irrelevant movement is relevant for some other reason—a reason that is not simply related to opening the jar with the toy.

[16] This is not to say that languages and pronunciations do not change—but it is to say that there are clear constraints on those changes.

2002, Biro et al. 2003, Reader & Laland 2003, Mendes et al. 2007, Tennie et al. 2009, Charbonneau 2015). Importantly, however, simply because creativity is the norm in the non-human animal world does not mean that the creativity characteristic of human cultural traditions can be taken for granted. This is precisely because imitation, as a high fidelity mechanism underpinning cultural, normative, and linguistic transmissions, must stand in opposition to the creativity of individual, trial and error learning.[17] As such, we see that the kind of processes that we must seek to account for the innovation of cumulative culture need to be both conservative and creative.[18] And, it should be clear that not any kind of innovation will be able to deliver on these criteria. Accordingly, we cannot simply generalize from the creativity of non-human animals to the innovations and improvements of cumulative culture.

3. INNOVATION: CONSERVATIVE CREATIVITY

In this section, I will present a taxonomy of innovation kinds in order to differentiate between various types of innovation and their respective contribution to cumulative culture. In the following section, I will argue that technique-centered teaching can ground the kinds of innovation that support cumulative culture by providing a pupil with the understanding necessary to produce cultural transmissions that are both conservative and creative.

Before discussing different kinds of innovation, it is worth noting that the question that I am asking here is importantly distinct from the questions that researchers typically ask in the literature on innovation. What I want to pursue is a question about the kind of innovation that supports cumulative culture. That is, I want to identify the kind of innovation that can respect the conservatism required for successful cultural transmission of cumulatively enhanced complex skills, conventional behaviors, and languages while also providing the opportunity to improve and modify those traditions further. I am also interested in identifying the cognitive underpinnings that can ground this kind of innovation. It should be clear that these questions are significantly different from questions like: do animals with bigger brains innovate more (Wyles et al. 1983, Wilson 1985, Lefebre et al. 1997, Reader & Laland 2002, Navarrete 2015)? Is innovation a domain-general cognitive achievement (Reader & Laland 2003, Chiappe & MacDonald 2005, Reader et al 2011)? And what contexts and circumstances promote human innovation (Flynn et al. 2015, Sheridan et al. 2015, Tebich et al. 2016, Reader et al. 2016)?

I will begin by following Mesoudi et al. in presenting a taxonomy of innovation kinds. It will become clear that at least 3 of the 6 kinds of innovation listed below cannot support cumulative culture. Meanwhile the others can but only if grounded in understanding. Mesoudi et al. break down innovation into the following categories:

(1) <u>Chance:</u> accident, copy error

[17] Perhaps this helps to explain why human children do not appear to be particularly adept innovators (Beck et al. 2011, Neilsen 2013, Cutting et al 2014).
[18] For a similar point see Lewis & Laland (2012).

(2) Trial and Error: exploration, random testing
(3) *Refinement-A: improvement of existing process/technique
*Refinement-B: modification of existing process/technique
(4) Recombination: combining existing elements into a new variants
(5) Exaptation: applying existing technology to new function
(6) Break-through: Insight

3.1 The possibilities for innovation and cumulative culture

(1, 2) Chance, Trial and Error

It should be clear that chance, accident, or copying error will not preserve traditions in the way required to respect the accumulation of improvements over many generations. That is, chance can increase the diversity of a culture but it cannot do so in the precise way that is required for the ratchet effect. After all, there is no guarantee that the gains from previous generations' modifications and improvements will be retained if an innovation is produced by chance. Clearly, this is because accident and copying error do not differentiate between the necessary and irrelevant aspects of a skill or norm in such a way that will ensure that only the features that would not undermine the tradition are changed or modified while the others remain fixed or are enhanced in a targeted fashion.

Similarly, trial and error innovations, which result from random testing or exploration, will be unable to support the conservatism required for cumulative culture. This is because, as with chance, there is no guarantee that the modifications that result from trial and error learning will respect the integrity of a tradition in such a way that will ensure that the improvements and modifications of previous generations are retained in the current iteration of the practice. Of course, an individual can stumble upon a solution using trial and error learning and, in many cases, that solution may even be particularly well-suited for handling the given context. However, there remains a danger that this new solution will undermine the success of the tradition in other circumstances (Shea 2009). As such, trial and error innovation is problematic not because it is ineffective but because it is risky. That is, in its randomness it is too risky to serve as the basis for the creativity characteristic of human cumulative culture.

(3-A) Refinement-A: Improvement of existing technique

Refining Mesoudi et al.'s taxonomy, I've split the innovation category of refinement into two. This is because in their formulation, under refinement, there seem to be at least two distinct kinds of refinement that have distinct implications for cumulative culture: modification of technique and improvement of technique. First, I'd like to consider improvement of technique, which I'll label "refinement-A". What I have in mind here is the kind of refinement that progresses by way of improving the execution of an existing skill or technique. In this kind of refinement, one's technique becomes more efficient, effective or controlled over time, often as a result of practice. When it comes to refinement-A, we encounter a different problem from the one with chance and trial and error innovation. Whereas chance and trial and error threaten cumulative culture by potentially undermining accumulated knowledge and skill, refinement comes up short in that it does not advance culture enough. That is, refinement does not change or modify in a way that will sufficiently support the creativity and progress of cumulative culture.

This is not to suggest that refinement-A plays no role in cumulative culture but only to say that the creativity and innovation that are part and parcel of human technologies and traditions are not well explained by appeal to refinement-A. We can see the problem if we take a simple example. Let's think of a person learning to fold a paper airplane. Now, at first, the student may learn the basic procedure required for folding the plane. Over time and with practice, the student is likely to improve her technique: folding more accurately, more cleanly and producing a better paper airplane as a result. However, if the student engages exclusively in refining-A her technique, she'll only produce a better version of the same plane; she will not produce a better kind of plane. And the difference between producing a better version of the same plane and producing a better version of the plane is important to appreciate if we are seeking an account of cumulative culture. This is because cumulative culture is cumulative largely as a result of modifications that lead to the latter kind of improvements. As such, it seems clear that if innovation is only of the refinement-A variety, then the progress of cumulative culture would stall.[19]

(3-B, 4, 5) Refinement-B, Recombination, Exaptation

What is striking about the remaining kinds of innovation—refinement-B , recombination, and exaptation—is that if they are to be effective and resist collapsing into trial and error learning, then they will have to be grounded in understanding. That is, if we are interested in accounting for innovation of the kind that is compatible with and supportive of cumulative culture, then that innovation must be intelligent, systematic, targeted, and precise. That is, the right kind of innovation for cumulative culture cannot be blind or random. As we'll see, at the very least, we must add understanding of which features or elements of a tradition are relevant to its success and which are secondary, incidental or irrelevant. Moreover, in other cases, a deeper understanding of relevance is needed to drive innovation. That is, in some cases, simply identifying which elements are relevant and which irrelevant will not be enough for innovation. We will need, additionally, to understand *why* those elements are relevant.

If we start with refinement-B, it should be clear that modifying a technique in a way that builds on previous improvements and innovations requires some understanding of which aspects of a technique can be modified and which elements need to stand fixed. If we return to our example of custom above, it becomes clear that to modify the shoe removal custom in a way that will support cumulative culture will require not only reproducing the practice faithfully but also being able to understand which parts of the practice can be modified and which are essential and, thus, unalterable. This sort of understanding can allow improvements and modifications that retain the efficacy or function of the current technique or

[19] See Fridland (2013, 2014) for more on how refinement-A is connected to the technique-centered orientation and skill-refinement in general.

procedure. And it is these kinds of innovations that are required for building upon and transmitting the accumulated improvements of a tradition.

The same is true of recombination. That is, if one is going to recombine existing elements and one isn't going to go about the recombination in a random, trial and error fashion, then one needs to be aware of which elements can be recombined and in which ways. This will require, at the very least, differentiating between those aspects of a tradition that are required and those that are not. That is, in order to recombine in a targeted and controlled manner, an agent must understand what can and what cannot be recombined. Otherwise, we are confronted with the same problems as above: recombination would undermine high fidelity transmissions and, thus, stand in opposition to cumulative culture rather than be a force propelling accumulation forward.

Moreover, in order for exaptation to prove successful, an agent should be able to recognize both which features of a technology or technique are relevant to its effectiveness and why. That is, if one is going to use an existing technology for a new purpose, one must understand which features of the current technology make it successful and how those features contribute to the current function.[20] To take a simple example, think of using a hammer as a doorstop: if you are going to do this in a way that isn't simply reducible to trial and error innovation then you must have some understanding of how a hammer works and what the properties of the hammer are that allow it to work this way. That is, one will have to identify the distribution of weight in the hammer and its shape as relevant to its function. Further, however, one should understand the way in which these properties are relevant to its present function. Only then can one intelligently apply a new function to the existing artifact. I should note that the requirement of understanding in exaptation is less about protecting the accumulated knowledge or skill of a previously transmitted tradition and more about the potential to expand the possibilities of the tradition. That is, in order to innovate effectively, understanding is required.

What's important to notice here is that all of the innovations that support cumulative culture support it by way of understanding of one kind or another. That is, in order for innovations to be controlled and effective they must be produced with understanding. In the absence of understanding, the innovations that are characteristic of cumulative culture remain impossible.

(6) Breakthrough

I think that many of us naturally think of innovation as a sort of breakthrough or eureka! moment. We think of people like Benjamin Franklin, Albert Einstein, and Francis Crick.[21] There's a sense in which this sort of innovation seems almost mystical: it appears to be the very essence of human creativity and intelligence—an expression of what is sacred in us. The truth is that it is hard to know what to say

[20] See Campbell (2011) for a detailed defense of this position.

[21] We think this despite knowing that Rosalind Franklin discovered the double helix and Watson and Crick "snuck a peak" at her work before having their own very productive "eureka!" moment.

about innovation of the breakthrough variety. Some of what's hard about saying something sensible about breakthrough is that it isn't clear that the place or character of such innovation is correctly identified in the public consciousness. For reasons of brevity, I'll limit myself to the following three points:

i) Despite their centrality in our cultural consciousness, it is likely the case that most of the innovations constituting cumulative culture are not instances of novel invention, eureka moments, or breakthroughs. Rather, cumulative culture is likely based almost entirely on incremental innovations made possible by refinement-A and B, recombination, and exaptation (Henrich & Boyd 2002, Lewis & Laland 2012, Lane 2016). As such, the central place that eureka moments have in our social consciousness is not justified by their peripheral contribution to cumulative culture.

ii) The idea of a eureka moment seems to imply an almost complete disconnect from current knowledge and culture. There's the idea that there's a moment of pure insight that catapults the genius forward into understanding. But it isn't clear that eureka moments should be understood as independent of the countless small and unsexy innovations that form the intellectual foundation of a time. Rather, it may be that a better way of thinking of breakthrough innovation is as advancing or synthesizing ideas that are already in the air. In which case, breakthroughs would really be a version of recombination or exaptation. If we think of breakthrough in this way then we have some explanation of why many breakthroughs occur simultaneously in different minds and places (think of calculus or the telephone). The idea here would be that cumulative knowledge prepares the ground for breakthrough. The genius, then, need only put the pieces together.

iii) On the other hand, one might think that the correct characterization of breakthrough innovations is as sufficiently disconnected from previous knowledge or technology such that they should be understood as moments of sheer insight. But, in this case, breakthrough wouldn't really be cumulative in the way cumulative culture requires. That is, if breakthrough is not built on the cumulative knowledge and technologies of previous generations then this kind of innovation is not progressive or incremental like the innovations that create the ratchet effect. If breakthroughs are altogether new and ungrounded in the knowledge and skills of the inherited culture then they are simply momentous instances of individual learning. In this way, they are not the results of the ratchet effect though they can advance the ratchet. We should also notice that if all innovation was of the novel invention variety then cumulative culture would not exist, since people would not build on previous technologies but simply, seemingly out of the blue, in a state of pure, individual inspiration, invent new traditions. Those traditions could be adopted but

> the improvements and modifications would not be incremental—they would not be cumulative.[22]

Together, these considerations seem to suggest that the heart of cumulative culture lies in innovations of the following kind: refinement-B, recombination, and exaptation. I suggest that we focus on the cognitive underpinnings that make these kinds of innovations possible in order to make headway in our understanding of cumulative culture. In the following section, I will introduce technique-centered teaching as the kind of transmission mechanism that can give us an account of the understanding required for innovations of these types.

4. TECHNIQUE-CENTERED TEACHING

Before moving ahead, in may be useful to clarify our problem space. Our current dilemma rests on the fact that cumulative culture is characterized by two features: the faithful inheritance of enhanced traditions from generation to generation and the innovation and improvement of those traditions by individuals or groups, after they've been inherited. I've argued that imitation can account for the faithful inheritance portion of cumulative culture but that in being an effective high-fidelity transmission mechanism, imitation stands in opposition to the unbridled creativity that results from chance or trial and error learning. As such, we were left in the position of identifying the kinds of innovation that can retain the faithful transmission of tradition across generations but also to free up individuals to innovate in a way that will not undermine the accumulated improvements of the transmitted tradition. In the previous section, I suggested that refinement-B, recombination, and exaptation are the primary kinds of innovation that underlie cumulative culture. Together, I'll refer to this group of innovations as "cultural innovations". Further, I've claimed that all cultural innovations require a certain kind of understanding to function properly. In this section, I'll introduce technique-centered teaching and propose that this type of teaching can produce the understanding required for cultural innovations.

To be clear, it is not my goal in this section to provide a comprehensive overview of the literature on teaching. Nor is it my goal to determine the existence and extent of teaching among human or non-human animals. Rather, I'd like to suggest that an important and largely overlooked kind of teaching, what I'll call "technique-centered teaching", can play an important role in grounding the kind of understanding required for cultural innovations, that is, those innovations that are compatible with and support cumulative culture.

4.1 What is technique-centered teaching?

While some theorists have emphasized continuities between the kinds of teaching available to both human and non-human animals, such as teaching by tolerance (Sterelny 2012, Kline 2015), local or stimulus enhancement (Hoppitt et al. 2008,

[22] This may go some way in explaining the results of Lewis and Laland who found that "in terms of creative processes… relative combination rate had the greatest effect, and novel invention the least effect, on cumulative culture" (2012, 2177).

Kline 2015), opportunity provisioning and scaffolding (Caro and Hauser 1992, Kline 2015) and teaching by coaching (Caro and Hauser 1992, Kline 2015). Others have been interested in identifying the unique character of human teaching such as natural pedagogy and its use of ostensive cues (Csibra and Gergely 2006, 2009, Csibra 2010, Gergely and Cibra 2013), teaching as intentional communication (Csibra 2010, Moore 2013c, 2017), or teaching as requiring an understanding of other minds (Tomasello et al. 2005). In this section, I'd like to identify an important kind of teaching that exploits the technique-centered orientation in order to create the opportunity for a pupil to both learn a technique and to understand it. Specifically, this kind of teaching leverages the technique-centered orientation that we saw was central to imitation. It does this in order to allow naïve individuals to differentiate relevant from irrelevant aspects of a procedure or technique and, at times, to develop an understanding of *why* certain features or elements of a procedure are relevant. In this way, technique-centered teaching makes room for cultural innovations by promoting the understanding required to support them. I'd also like to suggest that technique-centered teaching is not reducible to any of the other more familiar forms of teaching, nor are those forms of teaching sufficient for grounding the understanding required for cultural innovations.

When I talk about "technique-centered teaching" I'll have in mind any kind of teaching that aims to facilitate learning in a pupil by focusing on the means, strategy or technique by which a task, practice, or tradition is performed. So, if we start with a commonly adopted definition of teaching offered by Caro and Hauser (1992):

> An individual actor A can be said to teach if it modifies its behavior only in the presence of a naïve observer, B, at some cost or at least without obtaining an immediate benefit for itself. A's behavior thereby encourages B's behavior or provides B with experience, or sets an example for B. As a result, B acquires knowledge or learns a skill earlier in life or more rapidly or efficiently than it might otherwise do, or it would not learn at all (p. 153).

And follow Richard Moore (2017) in simplifying and clarifying the criteria that Caro and Hauser offer in the following way:

> (1) the teacher (T) modifies its behavior (2) the modification occurs only in the presence of a naiive (or appropriately inexpert) observers (P), (3) the modification does not benefit the teacher and (4) it facilitates learning in the pupil (P). (Moore 2017, p. x)

And, then, also following Moore, drop criterion (3) since it seems open to obvious counterexample.[23] What we are left with is:

[23] For instance, it seems clear that I can teach my daughter to give me a back massage by letting her practice on my back and this teaching is of immediate benefit to me, since I love massages, but it does not seem that this alone should disqualify the back massage lesson from being an instance of teaching.

> (a) the teacher (T) modifies its behavior (b) the modification occurs only in the presence of a naiive (or appropriately inexpert) observer(P) (c) it facilitates learning in the pupil (P). (Moore 2017, p. x)

Now, to identify a subset of teaching, what I call "technique-centered teaching", we can amend the above definition in the following way:

> (a) the teacher (T) modifies its behavior (b) the modification occurs only in the presence of a naiive (or appropriately inexpert) observer (P) (c) it facilitates learning in the pupil (P) (d) by focusing on the means, strategy or technique of a practice.

My claim is that technique-centered teaching is in a unique position to facilitate two kinds of understanding: (1) the distinction between relevant and irrelevant aspects of a tradition and (2) an understanding of why the elements of a technique or procedure are relevant for the success of the tradition. The idea is that technique-centered teaching, by transferring information about the technique itself, has the capacity to highlight important features about the means by which a goal is achieved. And this leads to the understanding that can produce cultural innovations.

4.2 Technique-centered teaching grounds understanding

One obvious benefit of using the technique-centered orientation is that we can directly teach a technique itself. That is, as has often been claimed teaching can encourage high fidelity transmission of skill and knowledge by focusing on the precise detailed strategy of a practice (Boyd and Richerson 1985, Galef 1992, Tomasello 1994/2009, Straus 2004, Richerson and Boyd 2005, Thornton and Raihani, 2008, Fogarty et al. 2011; Dean et al. 2014, Morgan 2015, Moore 2017). In this way, using technique-centered teaching, one can teach a pupil how to reproduce a particular technique more accurately or effectively and, thus, to adopt a practice or tradition more easily.

But, we should notice that there is a lot of technique-related information that we may want to teach above and beyond that which will contribute directly to the effective transmission of a tradition. For instance, one may want to teach a shortcut for how to implement the technique under time constraints or about the connection between the different elements of the technique and the overall goal, or one may want to teach how some particular technique is related to other techniques such that they could both be used to achieve the same goal. That is, we may want to teach about how a practice, skill, or technology can be applied or exploited in multiple contexts and for multiple purposes. All of this, of course, can contribute to effective transmission of a tradition but it can also do much more: technique-centered teaching, in emphasizing technique or strategy, is poised to deliver different degrees of understanding.

Importantly, if we are to teach a technique or procedure effectively, at the very least, we will have to differentiate those aspects of the technique that are relevant from those that are incidental. That is, to effectively transmit skills and knowledge in a way that focuses not only on goals but on the way those goals are achieved, we should seek to demonstrate those aspects of the technique that are most important for achieving the goal. Not incidentally, it seems that this is indeed the way in which we teach small children various skills and practices. Using demonstration, we emphasize those aspects of a procedure that are important by exaggerating them in gesture. Further, we use eye contact and other ostensive cues to draw the pupil's attention to the exaggerated elements of a demonstrated technique. Thus, we communicate which elements or features of the technique matter most. This kind of teaching is called motionese and it seems fairly common amongst human parents and teachers (Brand et al. 2002, Brand & Shallcross, 2008, Koterba & Iverson 2009, Fukuyama & Myowa-Yamakoshi 2011, Dunst et al. 2012).[24] Notably, this kind of communication does not require language and, as such, can serve as an evolutionary precursor to a more full-blooded understanding that likely requires linguistic competence.

What's of immediate concern for my purposes, however, is that emphasizing or exaggerating the important, central, or most relevant aspects of a technique or strategy transmits more than the ability to reproduce a procedure or technique. It transmits understanding. That is, teaching of this sort fosters an understanding of relevance and contingency. And, importantly, this understanding can ground the sort of refinement-B and recombination that is required for cultural innovations since, in understanding which elements of a procedure are relevant, a student is in a position to modify or recombine in ways that will not undermine the transmitted tradition. That is, the student can innovate in an intelligent targeted way, altering those elements that are inessential or enhancing those that are.

The point is that by using technique-centered teaching we are in a unique position to account for cultural innovation since we are essentially promoting not only the high-fidelity transmission of a tradition but the understanding of technique. As such, technique-centered teaching can free up an individual to modify, combine and recombine elements or features of a tradition intelligently. This is because the pupil will have an understanding of what can and what cannot be modified, combined and recombined. As such, technique-centered learning can bolster high-fidelity transmissions of tradition by highlighting relevant aspects of a technique—those that are necessary to pay attention to in order to perform the technique successfully. However, in doing this, technique-centered teaching also frees up the pupil to innovate since she will be equipped with an understanding of relevance and irrelevance. And this understanding produces the ability to innovate in a controlled and directed manner—a manner that can promote rather than undermine cumulative culture.

Moreover, once we combine language with technique-centered teaching, the possibilities for understanding expand significantly. This is because with the addition of language, we can introduce explanation and not simply demonstration. That is, we can teach not only *that* some feature or element is relevant but *why* it is relevant. And this in turn promotes countless possibilities for both understanding and innovation. We can begin to teach how various elements of a procedure are

[24] Motionese has even been observed once in the wild (Masataka et al 2009).

related to each other and what contribution the individual elements make to the overall skill or technology. We can teach how various elements behave in different circumstances, how they are related to other techniques, practices or elements, we can identify their causal role, explain their social significance, isolate where they belong in a theoretical framework, and so on. This obviously entails more subtle and powerful opportunities for innovation since one will have more predictive power over one's innovations. But one will also have the power to determine more precisely how a modification or improvement will effect a transmitted tradition.

It may be that this sort of deep understanding is required for exaptation and breakthrough. Once we have an understanding of *why* certain features or elements do what they do, that is, not just a recognition *that* they contribute but an understanding of *how* they contribute, we can apply those features to new contexts and tasks. This seems to open up a whole new world of intelligent, controlled, and directed innovation. As such, we see that technique-centered teaching is powerful as a cognitive ground for innovation.

4.3 Technique-centered teaching versus other kinds of teaching

To conclude, we should notice that no other kind of teaching facilitates understanding of the kind that technique-centered teaching does. This is because no other form of teaching puts technique or means on center stage. And since determining relevance requires consideration of the technique itself, no other form of learning will be in a position to deliver the kind of understanding that promotes cultural innovations. So, if determining relevance is required for innovations of the kind that support cumulative culture, as I've argued above, and relevance and irrelevance are features of the precise means by which a task or tradition is instantiated, then teaching that does not focus on means cannot foster understanding of relevance. Hence, teaching that is not technique-centered will not be able to promote intelligent, precise, targeted, and controlled innovation.

First off, it should be clear that teaching by tolerance cannot provide us with the understanding of relevance necessary for innovation. After all, tolerating observation by another does not require any explicit communication or transfer of information at all either about goals or means. So, if we are looking for relevance to be determined by teacher and communicated to student, teaching by tolerance will come up short.

Further, teaching by location or stimulus enhancement makes a location or stimulus more salient to an inexpert observer but is silent about technique and relevance. For example, a mother hen may peck vigorously at a particular location that is a rich food source in order to attract her chicks to that location (Nicol & Pope 1996). This kind of teaching can engender new goals, behaviors, and understanding insofar as some location or object is involved. Importantly, however, we do not get understanding of the right type for cultural innovation out of this kind of teaching. This is because, in being silent about technique, teaching by location and stimulus enhancement is silent about which aspects or elements of a technique are relevant and which are irrelevant to a task or tradition. So, even though, of course, some understanding does result from making a location or stimulus salient, this isn't the kind of understanding we need for intelligent, precise, targeted innovation.

Similarly, opportunity teaching, which provides pupils with the chance to practice a skill, and sometimes even scaffolds their practice according to skill-level, is silent about how exactly the skill should be developed or performed. So, while an adult meerkat may give its young a scorpion that has been disabled to different degrees depending on the age or ability level of the pup, this sort of teaching does not focus on technique (Thornton & McAuliffe 2006). That is, the teacher provides the opportunity to practice but no direction as to *how* to practice. Thus, opportunity teaching is silent about which actions or procedures need to be performed to successfully execute the skill being developed and, as such, is silent on relevance. Moreover, we should notice that the type of understanding that results from opportunity teaching is the product of individual learning and not the product of teaching, *per se*. As such, opportunity teaching cannot promote the requisite kind of understanding for cultural innovation since this kind of innovation requires that the relevance of a procedure is established by the teacher not the student.

Likewise, coaching encourages learning using praise and punishment but, on its own, it has no particular interest in strategy or technique either. We should note that we can combine coaching with technique-centered teaching to promote or discourage various sorts of innovation, but the point remains that, on its own, coaching is not in a position to account for the understanding we need for cultural innovation.

The same goes for natural pedagogy. Natural pedagogy is construed as a selective adaptation for teaching generalizable knowledge. The idea is that ostensive cues alert children to the fact that certain situations are rich with valuable and generalizable information.[25] But natural pedagogy is not by itself concerned with differentiating relevance from irrelevance inside of a teaching situation, even if it is concerned with differentiating teaching situations from other kinds of contexts. For our purposes, it is important to note that though ostensive cues signal a teaching situation, they do not by themselves highlight anything about the particular aspects of the teaching situation that the student must learn. And, as such, they are not sufficient for fostering the kind of understanding that we need for cultural innovations. This is not to say that natural pedagogy and ostensive cues are not useful for enhancing the learning of technique. As we saw above, motionese makes use of ostensive cues to demonstrate technique. The point is only that, by itself, natural pedagogy cannot deliver the kind of understanding required for cultural innovation.

Lastly, it should be clear that metarepresention cannot promote the right kind of understanding either. That is, to represent the knowledge or ignorance of a pupil is surely helpful for teaching all sorts of things but it is not by itself going to engender understanding about relevance or irrelevance. Metarepresenting can be

[25] I should note that it does not seem necessary to follow Gergeley & Csibra (2013) and Csibra & Gergeley (2009, 2011) in claiming that natural pedagogy is an evolutionary adaptation in order to take seriously their findings concerning the importance ostensive cues in teaching and learning. See Vorms (2012), Nakao & Andrews (2014), and Moore (2017) for critiques of natural pedagogy as evolutionary adaptation.

helpful for honing a teacher's approach, but it doesn't seem to give us an account of the origins of understanding that can support cultural innovation.

All of this seems to suggest that if we want an account of a social learning mechanism that is not going to undermine the benefits of conservative imitation but will also free up the agent for creativity and innovation, it is technique-centered teaching that we ought to be concerned with. This is the case since it seems that technique-centered teaching is uniquely placed to teach pupils to be sensitive to relevant aspects of a skill or body of knowledge and, thus, to provide them with the requisite degrees of freedom for innovation without undermining their accumulated inheritance.

5. CONCLUSION

I hope that this essay has clarified some important connections between cumulative culture, imitation, pedagogy and the technique-centered orientation. I hope that it has become clear that the high-fidelity mechanisms for the transmission of normative practices, customs, languages, and opaque, complex skills stand in tension with the innovation characteristic of human traditions. And that this means that we cannot take the creativity of cumulative culture for granted.

Further, I hope to have convinced the reader that once we identify the technique-centered orientation as central to human cognition, then we are in a position to explain both how the high-fidelity transmission of traditions becomes possible through imitation and how cultural innovation becomes possible through teaching. Lastly, I hope that it has become clear why I propose that imitation and teaching ought to be understood as making distinct contributions to cumulative culture such that imitation is primarily responsible for the high-fidelity transmission of tradition and teaching is primarily responsible for innovation.

Before closing, I'd like point out that if my account of cumulative culture is correct then we have a fairly straightforward explanation of why there is an extended period in human history (about 300,000 years or so) where innovation was relatively rare but high-fidelity transmission was common. After all, until relatively recently, that is, the last 100,000 years or so, human technological advances were especially conservative. As Sterelny explains, "the capacity to add regularly to cognitive capital by reliably preserving and amplifying innovation may be relatively recent. Even so, the reliable preservation of expertise is ancient" (2012, pg. 14). That is, hominin technology dating back 400,000 years was already more advanced then could have been invented by a single individual without building on the improvements and knowledge of previous generations. So, there was a significant period in human history where high-fidelity transfer of skill and knowledge was common but innovation was not.

Now, if we think of imitation and teaching as two distinct social learning mechanisms that are both rooted in the same psychological orientation towards technique, and if we think of these mechanisms as developing independently of one another then we seem to have a fairly straightforward explanation of the extended lull in human innovation. That is, if imitation evolved before teaching, and I'm right that teaching lays the groundwork for innovation, which imitation constrains, then we should expect to see a fairly conservative transmission history of steady, incremental refinements but no clear, big, game-changing innovations before teaching comes onto the scene.

In short, a population that imitates but does not teach and, thus, does not innovate should be characterized by wide-spread and faithful reproduction of practices that display some degree of sophistication but which lack the diversity and progress of true cumulative culture.[26] We should note that the technique-centered orientation present in imitation also makes room for refinement of the refinement-A variety. That is, even before teaching enters the scene, a conservative kind of refinement or improvement of technique is possible since individuals that harbor a technique-centered orientation could focus on the way or manner in which they perform their skills and practices. As such, even before technique-centered teaching spreads through a population, the technique-centered orientation present in individuals could be cultivated both to transmit and refine the execution of skills and practices.

Of course, we are still left with an important question about why the technique-centered orientation should be limited to imitation and skill-refinement but remain unharnessed for teaching for such a long period of human history. After all, the step from imitation and skill-refinement to teaching does not appear, on its face, to be especially cognitively demanding. One productive way to think about this problem may be not to focus exclusively on cognitive requirements but rather on the cost and benefit of teaching for an individual in its environment. In this way, we may recognize that factors such as population density, which Sterelny (2012) emphasizes as central to human culture and which impact how influential a teaching episode would be on a population, may be the relevant factor for encouraging or inhibiting teaching.[27] That is, we might think that with a sufficiently high population density, teaching becomes worthwhile but at lower densities the cost outweighs the benefit. If this is correct, then it would seem that once the technique-centered orientation is cognitively available, then, insofar as individuals are concerned, they have the capacity for cumulative culture. However, if individual receptivity is not sufficient for cumulative culture (as it likely is not), then we should also require a host of external factors to make the flourishing of cumulative culture possible.

[26] Morgan et al (2015) has recently conducted a study claiming to show that imitation is a poor mechanism for transmitting skills due to the degradation of information across generations. However, the study shows only that information passed from novice to novice via imitation is hugely degraded. It does not show that expert to novice information transmission via imitation is ineffective, even if it is passed through many generations.

[27] Sterelny (2012) notes that “high fidelity flow depends on three factors: individual cognitive adaptation, adapted learning environments, and demographic support” (Sterelny, p. 59). See also Sterelny (2016).

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