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THE TASMANIAN CASE
(REPLY TO HENRICH'S RESPONSE)

Dwight Read

Good application of a mathematical model depends on conformity with empirical observations. Mathematical models based on Dual Inheritance Theory and purporting to demonstrate that population size is a primary determinant of the complexity of tool assemblages in hunter-gatherer societies have been proposed despite their obvious contradiction with data from hunter-gatherer groups. One such model has relied on archaeological data from Tasmania for its validation, but has been extensively critiqued. A response to that critique attempts to justify the application of the model to the Tasmania data but does not succeed in so doing and still fails to address the more fundamental problem of disconnect between model prediction and empirical observation. The problem does not lie in the mathematical formulation of the model but the use of an invalid assumption when the model is used to account for variation in the complexity of tool assemblages in hunter-gatherer societies.

Introduction

In a recent paper, "Demography and Cultural Evolution: Why adaptive cultural processes produced maladaptive losses in Tasmania.," Henrich (2004) presented the novel notion that maladaptive behavior could be the outcome of evolutionary change driven by direct phenotypic transmittal of behavior through imitation when there has been reduction in population size. The latter, he argues, leads to reduction of average skill levels needed for maintaining a behavior in the population through imitation of a highly skilled individual whose level of skill would only be found in a large population. Henrich claimed that Tasmania, with archaeologically documented disappearance around 8,000- 10,000 *ya* of the bone points that the inhabitants of Tasmania had previously been making and using for the manufacture of clothing, provides an example of the model in action. In the reverse direction, the theme of tool complexity driven by population size has been used to account for the florescence in the variety and complexity of stone tools in the Upper Paleolithic in Europe through change in population density (Powell et al. 2009).

I critiqued both the application of Henrich's model in general and his specific use of the Tasmanian data in my paper, "Tasmanian Knowledge And Skill: Maladaptive Imitation Or Adequate Technology?" (2006), by pointing out that application of his model was in-consistent with data on the complexity of tools used by hunter-gatherers, required unrealistic parameter values for the alleged maladaptive evolutionary change to occur, and was not consistent with the Tasmania data. In place of his behavior transmission model, I suggested a decision-making model based on amortizing, over the time period resources would be procured, the start up costs for making complex tools and learning the skills needed for their effective use. I argued that this model would better account for variation in tool complexity among hunter-gatherer groups.

In response to my paper, Henrich (2006) claimed that I mischaracterized his argument, had empirical errors in the data I presented, and I misunderstand the relationship between cost-benefit and cultural-evolution models. In a more recent publication, "An Interaction Model for Resource Implement Complexity Based on Risk and Number of Annual Moves" (2008a), I show that the second claim is baseless by providing a detailed statistical analysis of the relevant data. This analysis shows unequivocally that tool complexity in hunter-gatherer societies is causally related to an interaction effect between risk exposure and frequency of relocation by a hunter-gatherer group during the year, with risk the more important factor. Once these factors are taken into account, the Tasmanian tool kit, though simple, is found to be completely in accord with the pattern for all other hunter-gatherer groups

with regard to the complexity (or simplicity) of the tools used in the procurement of resources.

Contrary to Henrich's argument, the statistical analysis demonstrates that variation in population size is independent of variation in the complexity of tools used for resource procurement. For example, the Angmaksalik Inuit of the eastern part of Greenland had one of the most complex tool kits of any hunter-gatherer group, including the most complex tool made by any group ("the *ultimate* weapon in terms of its technological complexity … the toggle-headed harpoon … [which] consisted of thirty-three parts" (Oswalt 1976: 99, emphasis in the original)), yet they only numbered around 600 individuals and were sufficiently isolated on the coast of Greenland that they remained genetically differentiated from the Inuit groups nearest to them on the southern coast of Greenland (Helgason et al. 2006). Despite their isolation, they maintained the high skill levels needed for both the production and use of complex tools within an isolated group of 600 yet allegedly, according to Henrich's model, 4,000 Tasmanians were too few to be able to maintain the skills needed for making bone points (see Figure 1), one of the simplest forms of tools used by hunter-gatherers.

Much of what Henrich discusses in his response to my critique are non-issues as I neither made the claims he attributes to me nor do I disagree with the mathematical correctness of the model that he developed for showing the relationship between the highest level of skill for any individual in a population and the average skill level achieved through imitation of that highly skilled individual.[1] The problem lies in the invalid assumptions and unrealistic parameter values that must be assumed for Henrich's predictions from the model regarding maladaptive loss (or even loss) of a behavior through reduction in skill levels due to a decrease in population size. To put the matter simply, using more realistic parameter values such as defining a skilled target person to be 3σ above the mean skill level (thereby making the target person highly skilled in comparison to the average skill level), Henrich's model (even with its invalid assumptions, see below) implies that only a population size of $N = 26$ imitators is needed to maintain the average skill level of imitators at a constant level (discussed in more detail below).

Henrich's original paper, my critique, and his response all appeared in the journal, *American Antiquity*. Because *American Antiquity* has an editorial policy of only allowing one round of comments on an article, that venue cannot be used for showing that Henrich's model uses invalid assumptions and his response does not validate application of his model to the Tasmanian data, fails to address the issues I raised, badly mischaracterizes what I wrote, and fails to substantiate his claims about my use of the data on tool complexity in hunter-gatherer groups. In the first part of this paper I discuss the invalid assumptions and add a few more arguments regarding the inappropriateness of his model not already covered in Read (2006) and Read
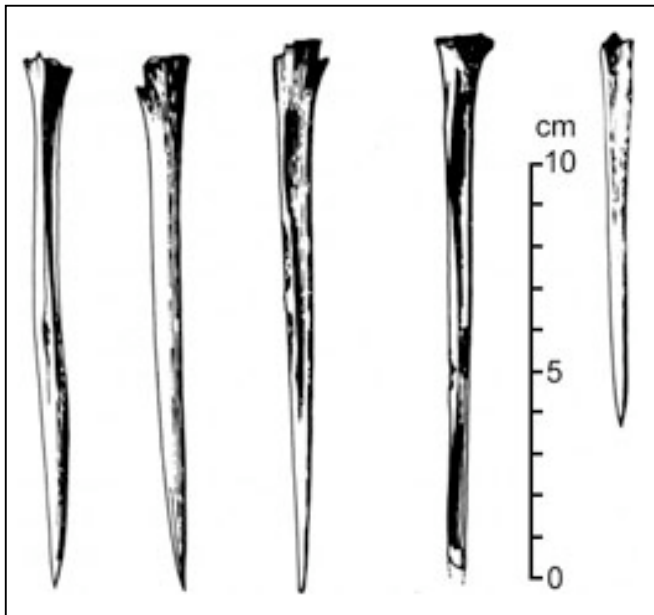

Figure 1: Bone points from Cave Bay Cave, Tasmania, as depicted in Weber (1997). Drawing adapted from (Bowdler 1974).

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[1] Imitation is being used here in the broad sense of one person learning skills from another and without paying attention to the details of the kind of interaction taking place between learner and expert. Distinctions have been made between "*imitation*, in which an observer copies the specific set of actions enacted by a role model to accomplish some task, and *emulation*, in which an observer focuses only on the outcomes of those actions" (Tehrani and Riede 2008: 318 and references therein), on the one hand, and "teaching … in which an experienced individual modifies [the] behaviour [of a novice] with the specific aim of facilitating learning in a novice" (p. 319), on the other hand. In the case of artifacts, these distinctions have been related to sources of variation in the artifacts produced by the novice in comparison to the expert, but Henrich's claim has to do with whether the novice learns how to make a bone point at all, not on the degree of variation between the bone points made by a novice and the expert from whom the novice is learning to make bone points.

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(2008a).[2] Then I document that his response to my critique is without substance.

Invalid Assumptions

First Invalid Assumption: Imitation bias α is independent of N

Henrich concludes that complexity of tasks will monotonically increase with population size by (implicitly) assuming that imitation bias, measured as the difference between target skill and average imitator skill after imitation has taken place, remains constant even as the skill level of the target, most skilled person increases with growth in the population size. But the assumption of constant imitation bias is not valid. To see the problem, some of the details from the model presented by Henrich (2004) are needed.

Henrich's model assumes that when some one imitates a target person doing a task that requires skill level, z_h, the imitator will end up with skill level $z = (z_h - \alpha) + e$, where α measures the imitation bias common to all imitators due to imperfect imitation and e is an error term measuring the deviation from $z_h - \alpha$ due to the characteristics of a particular imitator. Henrich assumes the most skilled person in the population with skill z_h – who engages in a task requiring skill level z_h – is the target for all imitators. With this assumption, the change in average skill level in the population before and after imitation will be $\Delta \bar{z} = (z_h - \alpha + \bar{e}) - \bar{z}$. (Note that $\bar{e}$ will not be 0 as is the case with a normal distribution of error terms and will be invariant with population size since Henrich assumes the e values come from a fixed, Gumbel distribution and a Gumbel distribution has a positive skew.)

The value of $\Delta \bar{z}$ is linked to population size, N, through the expected value of z_h: $E[z_h] = a + \beta(\varepsilon + \log N)$ and so $E[z_h]$ scales with $\log N$, where $\varepsilon \sim .5772$ is

Euler's constant and a and β, analogous to μ and σ in a normal (Gaussian) distribution, are the location and scale parameters for the Gumbel distribution assumed by Henrich for the distribution of skills in the population. Henrich implicitly assumes α is fixed as N varies since in his model the only term in $\Delta \bar{z}$ that varies with population size is z_h. Under this assumption, $z_h - \alpha$ increases monotonically with N, hence the sign and magnitude of $\Delta \bar{z}$ are determined by the population size. But assuming α constant as N varies implies that imitators will do better – measured by the imitation bias, α, as a percentage of the skill level for the target that is being imitated – when imitating a target requiring higher skill than when imitating a target requiring less skill.

To see this, suppose that the imitators from a population of size N have a mean skill level, L, and when imitating a target with skill level z_h they have imitation bias α. The magnitude of z_h depends on the population size. Assume the current population size is such that $\Delta \bar{z} = 0$ with imitation bias α; that is, the imitators currently do not succeed in improving their average skill level through imitating a target with skill level z_h. Suppose the population size increases from N to N^*, hence z_h increases to z_h^* and so the most skilled person in the larger population is now doing a task requiring skill level $z_h^* > z_h$. Under the assumption that the most skilled person is the target for the imitators, they now imitate the new target person who is doing a task requiring skill z_h^*. (The imitators in this larger population would still have bias α if they imitated a target requiring just skill z_h.) Under the assumption that α is constant, it follows that when they now imitate the target requiring skill $z_h^* > z_h$ (that is, a target that requires greater skill than was the case when the population size was smaller), their average skill level will increase since $\Delta \bar{z}^* = (z_h^* - \alpha + \bar{e}) - \bar{z} > (z_h - \alpha + \bar{e}) - \bar{z} = \Delta \bar{z} = 0$ and so $\Delta \bar{z}^* > 0$ when $z_h^* > z_h$ under the assumption that α remains constant. This implies that the imitators are more successful in learning skills when the target requires greater skill than when it requires less skill. If that were true, then it would imply, for example, that if we tried to teach reading skills to first graders using books written with a 6th grade level of reading skills and the first graders fail to learn reading skills from these books, hence $\Delta \bar{z}_{grade\ 6\ books} = 0$, then if we switch to books requiring a 12th grade level of reading skills the first graders would now learn some reading skills since, according to Henrich's assumption, $\Delta \bar{z}_{grade\ 12\ books} > \Delta \bar{z}_{grade\ 6\ books} = 0$ for the books requiring a 12th

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[2] Powell et al. 2009 use a simulation approach in which they make Henrich's model more realistic by dividing the population into subpopulations wherein a novice imitates the most skilled person in a subpopulation rather than one's parents only when that person has greater skill then the parents of the novice. Random migration of a portion of each subpopulation to its nearest subpopulation provides the larger interacting group in Henrich's model. Their model arrives at a similar conclusion regarding the effect of increasing the population size as it uses the same invalid assumptions that appear in Henrich's model. Hence the criticisms made here regarding Henrich's model apply equally to their modified model.

grade level of reading skills. The assumption is obviously not valid – if the imitators fail to learn through imitation with target at skill level z_h, then they will still fail to learn through imitation when the target requires a still higher level of skills. Instead of being constant as z_h increases, α will also increase even for the same set of imitators. Henrich, though, is not consistent in his assumptions as he also assumes α is not constant but varies with the skill level of the target: "If something is easy to imitate [then] α … will be small …. If something is hard to imitate … then α will be large" (2004: 201).

Without the assumption that α remains constant, there is no basis for the claim that $\Delta\bar{z}$ varies positively and monotonically with population size. Instead, the effect of a larger population is to increase the number of potentially highly skilled persons in the population who may, in fact, imitate z_h with good success, which implies that assuming α is constant across all imitators is the second assumption that is not valid.

Second Invalid Assumption: Imitation bias α is independent of imitator skill level

Instead of α being a constant determined by the skill level of the target, α will vary, for the same target, in accordance with the learning ability of the imitator based on her or his native abilities. Consider Isaac Newton's development of calculus that he subsequently published in his 3-volume book, *Philosophiæ Naturalis Principia Mathematica*. His *Principia Mathematica* will be the target for the imitators. Let us use IQ as the measure of skill level that a person can achieve (admittedly unrealistic, but satisfactory here for heuristic purposes), with IQ scores having a normal N($\mu = 100$, $\sigma = 15$) distribution. Assume that the skill level needed to initially develop calculus is greater than the skill level needed to master *Principia Mathematica* once calculus has been formulated. Accordingly, assume Newton had, say, IQ = 190 and assume the skill level needed to master calculus is, say, IQ = 160.

For a person with IQ = 100, the mean IQ level for the population, *Principia Mathematica* would make little sense and so $\alpha \sim 60$ for this person. However, someone with IQ = 160 is able to master calculus by reading *Principia Mathematica*. For this person, $\alpha = 0$. When comparing these two persons, the target has not changed, only the native skills of the imitator. In other words, α values are distributed in accordance with the relationship between native ability and the level of skill that can be achieved by such a person when imitating

the target. In this case, the mean achieved skill level of those with IQ = 160 will be that of mastering calculus by reading *Principia Mathematica* – the target – and α = 0 for these individuals.

Individuals with IQ = 160 will vary in their actual achieved skill level. Some, for a variety of reasons may not master calculus completely and others may achieve more than a mastery of calculus. Thus the achieved skill level, z, of those with IQ = 160 will be given by $z = \alpha_{160} + e$, where e are individual error terms with, say, an N(0, σ) distribution and $\alpha_{160} = 0$ is the measure of the imitation bias under the assumption that individuals with IQ = 0 are able to master calculus by reading *Principia Mathematica*. In general, assume that there are I native skill levels and the ith skill level, $1 \leq i \leq I$, has imitation bias, α_i. Thus the achieved skill level, z, for each imitator will be given by $z = z_h - \alpha_i + e$, where z_h is the skill level of the target, α_i is the imitation bias associated with the native skill corresponding to the ith skill level, and e is an imitator specific error term.

Consequently, a more plausible assumption than a fixed imitation bias α regardless of the native skill level of the imitator is to allow for imitation bias that varies with the native skill level of the imitator. Accordingly, let α_i vary monotonically with the difference between the target and imitator native skill levels. Under this assumption, the population size need not lead to change in mean skill level through imitation. To see this, model the imitator who achieves skill level z by imitating the most skilled person with skill level z_h by: $z = (z_h - \alpha_1) - \alpha_i + e$, where α_1 is the maximum skill level for a target such that with that skill level there will only be negligible imitation bias among the imitators (that is, α_1 is the maximum skill level that can be achieved by all imitators), and (following Henrich's assumptions) e is an imitator specific error term from a Gumbel (0, β) distribution (that is, a Gumbel distribution with mode 0). It follows that $\bar{\alpha}_i = z_h - \bar{z} - \alpha_1 + \beta\varepsilon$, where ε is Euler's constant, since the mean of the Gumbel (0, β) distribution is $\beta\varepsilon$.

Now use $\bar{\alpha}_i$ in place of α in Henrich's derivation for the value of $\Delta\bar{z}$. We find that $\Delta\bar{z} = \alpha_1$ regardless of the population size. In other words, change in the average skill level through imitation is independent of N and is measured by the largest skill level possible for a

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target without incurring imitation bias on the part of any of the imitators.[3]

Third Invalid Assumption: There is no teaching effect modifying the value of the imitation bias α

A third assumption is that there is no teaching effect whereby the skill level achieved by the imitators is incrementally increased and the current increase in skill level builds on the skill level achieved in a previous round of imitation. However, consider the following example. Public schools have as their target a skill complexity level, call it L_{12}, for all students by the time they graduate from high school. If a cohort of first graders initially with skill levels L_1 were presented with materials to be learned with skill complexity at the L_{12} level as their target for learning, then, in accordance with the imperfect learning assumption, we would expect a negative learning bias $\alpha = L_{12} - L_1$ since none of the L_{12} level materials would be learned by the first graders and there will be no increase in their average skill level. In actuality, first graders are presented with material at, say, an L_2 level as their target and for this target α is small and the mean skill level increases to L_2. Then the same cohort is presented with materials at an L_3 level, again with α small, and the mean skill level increases and so on until the mean skill level of the cohort increases until it reaches (hopefully!) the L_{12} level. Thus whether the target skill level is accessible to the imitator is not measured just by the value of α based on imitating the highest skill level directly and without any intermediate steps. The possibility of there being a step-based learning procedure must also be taken into account.

In addition, the learning process increases the pool of potential target persons (in this case, teachers) in the learning process since the target person only needs to have the skill level of the current target; i.e., the person teaching counting and adding to first graders only needs to have the L_2 skill level, not the mathematical abilities needed, say for college level mathematics courses. Consequently once a learning process is established, the value of α for the target when there is no

learning process cannot be used to determine the skill level for the most skilled target person needed in the population to keep $\Delta \bar{z} \geq 0$ so that the skill is maintained in the population.

For the context of, for example, the Upper Paleolithic, it may have required a highly skilled person to develop a technology such as the prismatic blade production that flourished in the Upper Paleolithic. If a novice flint knapper simply observed a skilled flint knapper and there was no teaching, then α would be large and the mean skill level might only increase slightly. Absent a highly skilled imitator capable of repeating the prismatic blade production technology, the skill would be lost to the population. But if the skilled flint knapper teaches novices by breaking the learning process down into steps, each of which has a small α value, then a cohort of novices are able to learn the skill of flint knapping (Ferguson 2008). In addition, once the learning process is in place, teaching can be done by less skilled targets, hence maintaining blade production skills in the population is no longer dependent upon having for a target a person with the skill level that will only be found in a large population and simultaneously having imitators with high, native skill levels.

The proposed effect of population size on losing a skill thus depends upon absence of a learning process that reduces the value of α through small steps in the learning process. To see how loss of a skill would take place absent a learning process, let us continue with the calculus example and assume a reader of *Principia Mathematica* needs an IQ = 145 to be able to understand (though not necessarily master) and use calculus. In order for the expected number of persons with IQ = 145 (3σ above the mean IQ = 100) to be at least 1, we need a population with $N \sim 800$ for normally distributed IQ scores. If the population size decreases to, say, $N = 400$, most likely there is no longer any person in the population capable of learning calculus from *Principia Mathematica* and the knowledge of calculus would be lost to this population if that is the only target.

If, instead the population size increases to, say, $N = 1600$, we would double the expected number of persons with IQ $\geq$ 145 compared to $N = 800$ and now we would have 2 persons who understand and can use calculus. However, increasing the population size does not, by itself, lead to the calculus skill being disseminated to persons in the population with IQ < 145. Further, though those with IQ $\geq$ 145 now have an in-

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[3] Skill levels that can be achieved are ultimately bounded by the cognitive and/or motor skill abilities of the imitators. For example, in chimpanzee groups that have learned to crack nuts, 25% of them are unable to learn the task of nut cracking even through imitation of other chimpanzees that crack nuts. The failure is due to those chimpanzees with a working memory too small to conceptualize the relationships among anvil, nut and hammer stone necessary for successful nut cracking (Read 2008c).

creased mean skill level through learning calculus and while this may lead to their development of new, skilled tools in the form of variants on the basic ideas of calculus, the distribution of these new tools will remain within the cohort of persons with IQ ≥ 145. (Consider the development of mathematical concepts known and understood only by academic mathematicians. Only when the α value is decreased do those concepts disseminate outside the narrow pool of academic mathematicians.) Diffusion into the population as a whole depends on reducing α, not increasing the population size. The stepwise learning process discussed above can decrease the value of α. When that happens, even though the skill level represented by calculus, for example, has not changed (that is, the concepts of integration and differentiation have not changed, though the methods for teaching those skills have changed and thereby decreased the magnitude of α for the same level of native skills) the skill level required for someone to be a target person will decrease. Today, those who teach calculus need not be persons with extremely high IQ.

Conceptual Problems with Henrich's Model

The assumptions and implications of Henrich's model that will now be considered are: (1) the expected range of skills in a population increases monotonically with population size, hence the expected skill level z_h for the most skilled individual in the population increases monotonically with the population size, (2) imitation need not be perfect, hence the average skill level, $\bar{z}$, in the population even when all individuals imitate the most skilled individual may be less than z_h, (3) behavior tasks vary with regard to the skill level required to perform the task effectively, and (4) behavior tasks are maintained in the population in accordance with the skill level required for the task in comparison to the average skill level for all individuals in the population. From these assumptions, Henrich derives the implication that with imitation of the most skilled individual in the population each generation, the range of tasks that can be maintained in the population is directly related to the population size, N, as discussed above. If there is decrease in the population size, the expected skill level of the most skilled individual in the population available as a target for imitation will decrease due to the decrease in the expected range of skills in the population (see Assumption 1), hence in his model the average skill level will decrease and any task requiring a skill level above the new, decreased average skill level can no longer be maintained

in the population. The maladaptive argument arises from this last observation in the following manner.

Suppose task, T, was part of the population's adaptation and requires a high, average skill level for its performance, a skill level that can be maintained through imitation of the currently most skilled individual each generation when the population has N individuals. If the population size decreases from N to N^* < N, the skill level for most skilled individual in subsequent generations will decrease. This will lead to a decline in the average skill level and if the decline is sufficient, then task T will be lost to the population through an adaptive process (average skill level adjusting to the effect change in population size has on the degree of skill of the most skilled individual available as a target for imitation), thereby leading to a maladaptive loss of task T when the functionality achieved through task T is still needed by the group in question. For the Tasmanian case, Henrich assumes clothing was still needed even after bone points were no longer made, given the weather conditions of Tasmania, but could no longer be made without the bone points and so the alleged loss of the skill to make bone points (see Figure 1) due to reduction in population size would be maladaptive.

A number of recent publications have cited Henrich uncritically to this effect (Edinborough 2005, Richerson and Boyd 2005, Mesoudi, Whiten, and Laland 2006, Ramsey 2006, Roebroeks 2006, Sterelny 2006, Bentley 2007, Lewens 2007, Mesoudi 2007, Mesoudi and Laland 2007, Newson, Richerson, and Boyd 2007, Sterelny 2007, Caldwell and Millen 2008, Richerson and Boyd 2008, Riede and Bentley 2008, Lyman, VanPool, and O'Brien 2009, Nunn 2009, Ridley 2009, among others). These authors refer to his conclusions about the large population size needed for maintaining complex tools as part of a hunter-gatherer group's tool-kit as if they are well-validated despite obvious contradictions with data on hunter-gatherer groups. For example, Newson, Richerson, and Boyd (2007) comment: "The number of people needed to support cultures of hunter-gatherers is surprisingly large, as Henrich (2004) shows ... [Tasmanians] had a very limited tool kit compared to that of mainland aborigines … rising sea levels caused Tasmania to be cut off from the mainland, the isolated islanders gradually lost many skills their ancestors had possessed, including fishing and the making of clothes" (p. 461). In a similar vein Richerson and Boyd (2008) observe: "Worse yet, as anthropologist Joe Henrich has argued, to get complex traditions, just a few individuals with

the necessary cognitive complexity aren't enough; the cultural evolution of complex adaptations may require a fairly large population of imitative minds.... Henrich's work suggests that *only fairly sizable populations can sustain complex, culturally evolved artifacts and behaviors*. This result is consistent with the loss of tool complexity on Tasmania…" (p. 138, emphasis added). Yet, as noted above, one only has to consider the complexity of the Inuit tool-kits in comparison to their population size to see that data on hunter-gatherer groups contradicts the predictions Henrich makes from his model. In addition, the reference to "loss of tool complexity on Tasmania" misrepresents the fact that the only archaeologically documented tool loss in Tasmania consists of the bone points (Hiscock 2008). In addition, the invalid assumptions identified in the previous section negate the conclusions drawn from his model.

Even if we stay within the confines of his argument, Henrich's claim for an evolutionary "maladaptive response" is conceptually flawed. Consider a population growing to size N, where N is the size required, according to Henrich's model, for maintaining the skill level needed to make and use a complex tool effectively. Presumably, as the population grows, additional tools to be used for resource procurement are incorporated into the repertoire of the population as part of its adaptation. Had we observed the population at size N^* prior to when it grew to size N, we would not have identified the population as being maladaptive even if behavior trait T was not yet incorporated into the population. Trait T would not yet be incorporated since $N^* < N$, where N is the population size needed to maintain the skill levels for T to be included in the group's repertoire of behaviors. The group first incorporates trait T only after the population increases in size to N. It is only when they subsequently lose this trait due to the reduction of the population size back to N^* that Henrich's argument for maladaptive loss of a trait is applicable.

For his argument to make sense, we must assume that the presence of trait T when the group was of size N made possible some aspect of the population's adaptation that could not occur absent T; e.g., the population at size N was able to exploit resources in environmental or ecological conditions using trait T that it previously could not exploit absent T. When the population experiences a decline in size from N to N^* and thereby, according to Henrich's argument, loses the trait T since the population can no longer maintain the skill level required to engage in behavior using trait T

effectively, the loss of T will not, however, be maladaptive if the population simply reverts back to its previous state when it had population size N^* and did not yet have trait T. For the maladaptation argument to hold, the population must not be able to revert to its earlier condition of an effectively adapted group with population size N^*, otherwise there is no basis for saying that an adaptive process has led the population to a maladaptive loss. Thus the smaller population must continue, for example, to exploit the same environmental/ecological resources and conditions as it was doing with population size N, yet must do so without having trait T.

It is not easy to hypothesize general situations where this argument might hold since it is unclear why the population, when it reverts back to size N^*, must still need T for its adaptation, even though previously when it had the smaller population size N^* it did not need T. One possibility is that after the population increases to size N, it also experiences changed conditions that did not exist previously and the changed conditions required the introduction of T. Then, when the population size declined and, according to Henrich's argument, could no longer maintain trait T, it no longer had the ability (or had reduced ability) to cope with the changed conditions.

Even this scenario does not apply to Tasmania, though, for the change in conditions is from colder to warmer around 8-10,000 *ya* after which bone points were no longer being made, with the exception of a single bone point found at Louisa Bay on the southern coast of Tasmania dating to about 3,000 *ya* (Gilligan 2009: personal communication).   Skin clothing was needed prior to the population growing to size N, even though, according to Henrich's argument, they did not yet have the population size needed for making bone points to be used in making clothing, hence they must have used some other means to make clothing before, allegedly, the population size was sufficiently large to be able to make bone points on a regular basis. Unexplained in Henrich's argument is why they did not simply revert back to the earlier method for making clothing when they allegedly lost the skills for making bone points due to a decrease in population size. In fact, though, the Tasmanians did not stop making clothing when they no longer made bone points; rather, based on reports of early travelers to Tasmania, it was the males who frequently did not wear clothing whereas women were often reported as wearing clothing (Gilligan 2008: Figure 4). Further, for all Tasmanians the percentage of those wearing clothing increased

in the winter months in comparison to the summer months (Gilligan 2008: Figure 5) as would be expected if they were still making clothing to deal with colder weather. But even prior to when the climate ameliorated in the Holocene, "thermal conditions required only simple clothing and technological requirements correspond to Mode 3 [flake rather than blade artifacts]. With respect to bone points or awls, the need arose because small wallaby hides had to be joined together to make adequate cloaks. Other typical signatures of complex clothing (such as blade tools and eyed needles) remained conspicuously absent" (Gilligan 2007a: 511).

Simple clothing of the kind made by the Tasmanians before the climate ameliorated only provides limited protection against wind chill and thus promotes selection for cold tolerance in contrast to complex clothing (Gilligan 2007a:Table 1). Since the percentage of reports with Tasmanians wearing little or no clothing is substantially greater than for reports on the southern Australian mainland at a latitude just to the north of Tasmania, Gilligan (2008) concludes that the Tasmanians had become cold adapted before they stopped making bone points and attributes the disappearance of bone points to the decreased need of Tasmanians for clothing: "these signatures [bone points] begin to disappear from the archaeological record with the onset of warmer climates in the early Holocene, since the Tasmanians were free largely to dispense with simple clothing after the Ice Age" (Gilligan 2007a:511; see Figure 2).
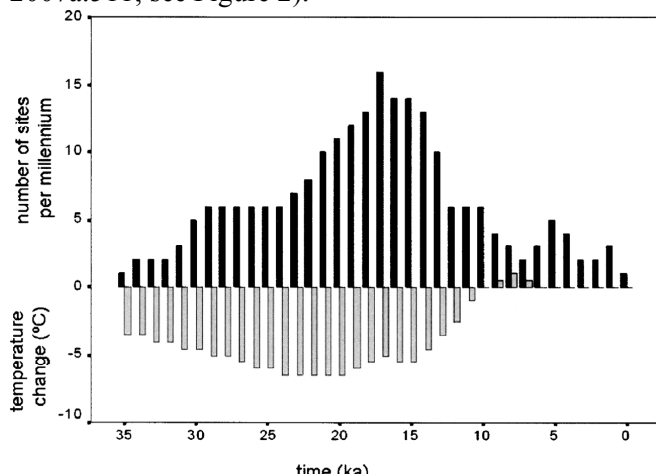

Figure 2: Onset of warmer climate occurs around 8-10,000 *ya* (bottom part of figure). Bone points disappear with the onset of a warmer climate. (Reproduced from Gilligan 2007b: Figure 2 by permission of *Antiquity*.)

All of Henrich's claims about skills and loss of bone points are hypothetical and difficult to translate into an archaeological context for verification since "We have no clear archaeological measures of 'skill'" (Bleed 2006: 5), though a number of measures for indicating when high skill levels are involved have been proposed for lithic artifacts (Bamforth and Finlay 2008:Table 1). None of these measures have even remote analogues for the bone points, indicating that the points (see Figure 1) did not take much skill to produce. Yet Henrich's argument, when applied to the Tasmanian data, requires assuming that the bone points needed more skill for their manufacture than the stone tools made by the Tasmanians since they continued to both make and elaborate upon stone tools even after they stopped making bone points. Henrich does not provide any evidence justifying his claim about the limited skills needed for making stone tools versus bone points and it is contradicted by studies made of the skills needed in flint knapping. For example, "it can take as long as 2–3 years to become skilled at even just retouching a worn edge (Weedman   2002)" (Bamforth and Finlay 2008:4). In contrast, the Tasmanian bone points are described as "simple bone points" (Habgood and Franklin 2008: 207; see Figure 1) and are about as far as is possible from being a complex tool such as the Angmaksalik toggle-headed harpoon with 33 parts that required a high degree of skill to manufacture and use. Further, he must assume that the Tasmanians could not have made a "cruder" bone point (or even a wood point) when their average skill level had allegedly decreased due to the claimed change in population size when Tasmania was isolated from the Australian mainland due to rising sea levels.

But even if the bone points were lost to the Tasmanians in the manner modeled by Henrich, his assertion that the Tasmanian "tool kit" is impoverished when compared to other hunter-gatherer groups – a claim that does not stand up to careful analysis (Read 2008a) – would still not be resolved by his model. Their tool kit + bone point would still be impoverished in comparison to other hunter-gatherers since his proposed measure of tool kit complexity, namely the sum of the number of parts for the most complex tool in each of the four tool categories used by Oswalt (1973, 1976), would be exactly the same with the bone points included in the Tasmanian tool kit since a bone point has just 1 part and so would be the least complex tool in its tool category and hence would not contribute to Henrich's measure of complexity. More problematic, though, is the model's prediction that the complexity

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of a tool kit should scale with the population size. Yet, as noted above, the most complex tool kits occur with Inuit groups who both have small population sizes and low population densities.[4]

Though Henrich agrees with my assertion that the assumption of each person imitating the most skilled person in the population of size N is unrealistic, his defense (see below) misses the point at issue. What is the population size, call it N_e, within which imitation takes place? For his Tasmanian argument to work, Henrich must assume that N_e is much larger than 4000, the estimated population of pre-contact Tasmania, oth-

erwise when Tasmania was isolated from the Australian mainland the population size necessary to have a person sufficiently skilled so as to maintain the average skill level through imitation that was needed for making bone points would not have changed. For his model to have its predicted results, N_e must be the population of imitators interacting directly with a skilled target person, not the population size for a network of interconnected individuals through whom goods and ideas might be transmitted as he asserts in his response to my critique.

Henrich confounds the network of possibly interconnected persons with the pool of interacting persons among whom imitation may take place. These are not likely to be of the same magnitude. The "small world" research (Watts 1999) does demonstrate that for a wide variety of empirical networks the number of links needed to go from one person to another need only be a handful even when the individuals in question do not have direct knowledge of each other. Thus information can potentially flow throughout such a network even when most persons in the network are isolated from each other from the viewpoint of who knows whom. This implies that information flow through a network, on the one hand, and transmittal of skills based on face-to-face interaction (the condition for imitation), on the other hand, involve non-comparable topologies and non-comparable scales for group size. In addition, objects and information can spread through networks activated by trade and other forms of contact without the knowledge and skills necessary for producing those objects being transmitted as well. The archaeological literature is full of examples of archaeological sites containing "exotic" items brought in through trade from distant locations without *in situ* counterparts.

Henrich's model has to do with imitation of an expert by a novice – "interacting social learners" in his words – and not trade networks. Hence the population size for his model is that of the pool of interacting social learners, not the number of persons connected through networks. Henrich is disingenuous when he writes: "the applicability of my model does require that *either* culture (ideas, practices, skills or knowledge) *or* people move among the smaller subpopulations scattered around the island" (my emphasis), which implies that his model applies to communication transmission from one person to another, despite the fact that his model deals exclusively with transmittal through imitation based on face-to-face interaction and not the diffusion of ideas by other means. He is right, of course, when he states that "If, for example, Paleolithic Tas-

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[4] Henrich questions my use of density in lieu of population size, where the latter refers to the pool of "interacting social learners" and is assumed by Henrich to be much greater than simply the society in which an individual is located. In the absence of population data of the kind required by Henrich's model, I (2006) regressed tool kit complexity on population density since density translates into the number of persons with whom an individual can potentially interact over a specified radius and the degree of interaction is constrained by distance. Although population (and density) estimates for hunter-gatherer groups are subject to considerable error as Henrich notes for the Andaman Islanders and as can be seen more generally when comparing data given by Kelly (1995) versus Binford (2001) for the same groups, nonetheless, the data show unequivocally that the relationship between complexity of tool kits and population size/density contradicts what the model predicts. If $N = 8000$ persons were required to maintain the skill level needed for making simple bone points as argued by Henrich, then the population size required for making the far larger and far more complex Inuit tool kits (complex both with regard to individual artifacts such as harpoon points as well as having complex weapons, complex tended facilities and complex untended facilities [Oswalt 1973]) must be substantially larger than $N = 8000$. Yet the Inuit have a population density at least an order of magnitude smaller than the Tasmanians and so for Henrich's argument to work, social learning among the Inuit must have taken place over an area more than an order of magnitude larger than the 140,000 km^2 exploited by the $N = 8000$ persons in pre-Holocene Tasmania (based on 68,000 km^2 for the area of Tasmania with 4000 persons plus an equivalent area extending into southeastern Australia for the other 4000 persons making up the population with $N = 8000$ persons). Thus, Henrich's model requires the implausible claim that Inuit groups scattered over more than 1,400,000 km^2, or approximately the area of Alaska, constitute the population of social learners who learn from the most skilled tool maker in that region each generation. Yet in fact the skills needed for the making (and use) of complex tools were learned within families in a single Inuit group such as the Netsilik Inuit who totaled around 300 - 500 persons.

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manian bands were not linked through social networks … then cutting off Tasmania from mainland Australia would not have influenced the size of the intercon-nected pool of social learners—and thus my model could not explain the losses." But a large population determined by linkage of persons through social net-works is not a sufficient condition for his model to be applicable.

Lack of Evidence for Specific Claims

Henrich (2006) begins by claiming that I assert that his "model--and Dual Inheritance Theory more gener-ally--applies only to the 'imitation' of 'motor skills,' and not to the cultural transmission of knowledge". His comment baffles me as I specifically stated that trans-mission of knowledge can "take the form of imitation" (p. 165); i.e., imitation is one way, though obviously not the only way, by which knowledge can be transmit-ted from one individual to another – as he readily ad-mits in the quote in the previous paragraph. Nowhere, contrary to his claim, do I discuss the domain for the application of Dual Inheritance Theory as I was not critiquing Dual Inheritance Theory. Nor do I lead "the reader to believe by 'skills' I [Henrich] mean 'motor skills'--which I [Henrich] did not mean" as he claims. I specifically stated that "Henrich has confounded three distinct aspects of *task performance* as if they are one and the same: (1) the knowledge needed to do the task, (2) the level of motor skills that can be achieved … and (3) phenotypic differences in motor skill level arising from genotypic differences …" (p. 165, emphasis added). Task performance involves skills, including, but not limited to, motor skills.

I supposedly continue in the same misleading vein, allegedly making Henrich's 'skills' synonymous with 'motor skills' by "sliding the word 'motor' in front of 'skill' in describing my [Henrich's] model, [but] the word 'motor' never appears in my [Henrich's] paper." Let us look at the facts of what I wrote. In the first part of my paper there are two places where I use the ex-pression 'motor skills': (A) "maintenance of motor skill levels needed to make and use tools" – clearly I am not referring to what Henrich means by skills and my use of the word 'motor' is necessary for what I am referring to in this phrase – and (B) "Conceptually, Henrich has confounded three distinct aspects of task performance as if they are one and the same: (1) the knowledge needed to do the task, (2) the level of motor skills that can be achieved by most individuals through practice and training and (3) phenotypic differences in motor skill level arising from genotypic differences

that either cannot be overcome by practice and training or would require inordinately long periods of practice and training to do so." In this quote I am saying that Henrich treats skill as if it were a unitary phenomenon and thereby makes it difficult to distinguish between two aspects of what he refers to as skill, namely knowledge and motor skills. Henrich agrees that this is what he means by skill: "he [Read] uses the word 'skill' in the same way I [Henrich] did" and he goes on to show this by quoting my comment referring to "skill (both in terms of motor development and knowledge about effective task performance)" (p. 181). Nowhere else in my discussion of his model do I use the word motor other than in the two quotes given above. Hen-rich then spends pages refuting what is essentially his egregious misreading of what I actually wrote. In con-trast to Henrich, I find it useful to deconstruct 'skill' into at least the three component parts listed in the above quote rather than treating skill as a single, sum-mary dimension that incorporates knowledge, learned motor skills, and genetically based phenotypic differ-ences. But deconstruction is not the same as claiming that when Henrich says "skills" he means "motor skills."

Henrich continues his response by asserting that I mischaracterized Dual Inheritance Theory, but I merely quoted Robert Boyd's characterization of Dual Inheri-tance Theory, hence his disagreement is with Boyd and not with me. Then Henrich spends several pages dis-cussing Dual Inheritance Theory and its domain of ap-plication, all based on what he imagines I wrote as op-posed to what I actually wrote. Dual Inheritance The-ory and its domain of application has no bearing in my critique of Henrich's argument as I am not disagreeing with the notion that skills (in the sense of a covering term for both knowledge about how to do a task and the motor skills necessary for carrying out the task) may come under the rubric of what can be imitated as set forth by Robert Boyd and Peter Richerson. My cri-tique relates to the model as formulated by Henrich.

Henrich agrees that his model's assumption of all persons imitating the most skilled individual is unreal-istic, but somehow that is not relevant since "Every useful model is loaded with unrealistic assumptions." Apparently unrealistic models are acceptable if they are "useful" – but useful for what? As Bamforth and Finlay observe (2008), in so doing one ends up with idealized predictions without empirical reality. Surely Henrich is not advocating that explanation of pattern-ing in phenomena should be made with invalid as-sumptions.

Henrich tries to bolster his position by referring to the fact that "models from evolutionary biology typically assume random mating within large (infinite!) populations" as if no one has ever criticized such models for unrealistic assumptions. Under the random mating, infinite population genetic model, for example, there are no inbreeding or assortative mating effects, yet inbreeding and assortative mating effects are well-documented in human populations.   To study these effects, the unrealistic assumptions of these population genetics models are discarded, regardless of how elegant they may be as mathematical models. Or, to say that one wants the simplest model that captures the evolutionary process of interest – namely what Henrich refers to as: "capture the governing dynamics of a process, while at the same time stripping the process to the bone" – is not equivalent to saying one introduces unrealistic assumptions just as a way to make a more tractable model.

Unrealistic assumptions may be useful heuristically to explore the consequences of a hypothetical set of conditions, but before any model is applied to real world data the assumptions of that model must be shown to hold or, possibly in some situations, it may be sufficient to show that the invalid assumptions do not qualitatively affect the model outcomes. But Henrich wants quantitative results and obviously whether there is a single most skilled person who is the target for all imitators does not give the same quantitative results for the same population size when, as he discusses, one partitions the population into those who learn vertically from parents (a proportion 1- p of the population) and those who learn from the most skilled person (a proportion p of the population).

Even with this partitioning, it is still the case that the model assumes there is a most skilled person in the population as a whole who is the target person for the subpopulation of non-parent imitators and the same problem remains as to whether, in fact, such a model could ever be realized. How is such a person identified and how do all imitators have access to this person? There are contexts where the first part of the assumption can be met, such as our system of higher education in which research universities compete over hiring "star" faculty and a student can use the reputation of the university as a proxy measure for the skill level of the faculty, though the second part of the assumption will not be met since only a few students will be admitted to the university. Access can be accommodated if the target is in the form of a book such as *Principia Mathematica* in the calculus example discussed above.

But nothing like this characterizes the situation in pre-contact Tasmania.

Further, his assertion that the partitioning has no qualitative effect so long as $p > 0$ makes no sense, for if all persons but one imitated their parents and only one person imitated the most skilled person the model would give different qualitative results. In brief, Henrich never addresses the question of whether his critical model assumption of a single target person for all imitators can actually be realized in a real population of the size he proposes for Tasmania.

In his response to my critique, Henrich goes on to modify his model by partitioning skill into knowledge and motor skill (or technique) and concludes that it makes no difference to the outcome of the model. But that is a foregone conclusion since he simply changes skill into a linear combination of knowledge and technique and does not address the fact that the way knowledge is transmitted and the way technique is transmitted are likely to be qualitatively different. In effect, Henrich assumes knowledge and motor skill are transmitted in the same way, but the point I was making in my critique is that there are good reasons to consider that the process of knowledge transmission has more to do with networks of interconnected persons, whereas transmission of motor skills has more to do with one-on-one interactions such as apprenticeships. Henrich, however, assumes that knowledge transmission and motor skill transmission are structurally equivalent and thereby assumes away precisely what is at issue.

His reply to my pointing out that his model requires unrealistic parameter values equally avoids the issue. First, he asserts that imitation can be of someone less than the most skilled and the same qualitative results can arise. But that's beside the point. At issue is how the α value (difference in skill level between the target person and the modal skill level of the imitators) and the β value (a scale parameter for the Gumbel distribution) relate to the model outcomes. The qualitative results that he obtains for maladaptive adaptation requires $\alpha \geq 9\beta$; that is, $\alpha/\beta \geq 9$ (see Figure 3 in Henrich 2004). His archery example, rather than contradicting my statement about unrealistic parameter values, shows the problem precisely. The Grand Master archer in his example has a skill level of 150 and the population of imitators have a skill level (after extensive practice and imitation) that ranges from 20 to 40, so $\alpha = 150 - 30$ (assuming the mean and modal skill levels are the same in the imitators) = 120. Henrich

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asserts that $\beta = 20$, the range in skill levels for the imitators. This is not correct as discussed below. Nonetheless, using his interpretation of β, $\alpha/\beta = 6$.

Now consider the imitators to be a (random) sample from a population and, for simplicity of calculation of σ for this population from these data (but excluding the Grand Master as an outlier), let us assume skill levels are approximately normally distributed in the population. Assuming (again for simplicity of calculation) that the range of skill levels among the novices represents the middle 95% of the population distribution, we conclude that $\sigma \approx 5$ for archery skills in this population. The Grand Master is then 24σ above the mean skill level of $\mu = 30$! We would have to reduce α/β to 0.75 for the Grand Master to obtain a more realistic $\alpha = 3\sigma$ above the population mean using Henrich's assertion as to what β measures. For $\alpha/\beta = 0.75$, only 1.2 = $N^* = e^{(\alpha/\beta - .577)}$ imitators are needed (see Henrich 2004 for the derivation of this equation for the number of imitators needed to keep the average skill level constant).

The unrealistically low value of 1.2 persons lies in Henrich's incorrect assumption that β measures the range of skill levels in the sample of imitators. For the Gumbel Distribution assumed by Henrich for skill levels in the population, we can relate β to the population standard deviation via $\sigma = \pi\beta/\sqrt{6}$, hence $\beta = \sqrt{6}\sigma/\pi$. If we measure α in units of σ, so that $\alpha = k\sigma$, then $N^* = e^{(\alpha/\beta - .577)} = e^{(k\pi/\sqrt{6} - .577)}$. For $k = 3$, $\alpha = 3\sigma$ and $N^* \approx 26$, indicating that, even if we ignore the invalid assumptions in the model, a population size equivalent to a hunter-gatherer camp is sufficient for maintaining a high level of skills in the population, not the 8,000 persons Henrich claims were needed to maintain the skills to make simple bone points.

For the values used by Henrich and to have a Grand Master 24σ above the mean, a population of $N^* > 1$ trillion persons would be required! Obviously assuming the most skilled person in a population is 24σ above the mean skill level that can be maintained in the population is hardly realistic for any real population. Henrich's maladaptive loss of a trait due to decrease in population size fares no better. Maladaptive loss requires $\alpha/\beta \geq 9$ (see Henrich 2004:Figure 3), which implies that the trait in question would require someone with skill level $\alpha = 7\sigma$ above the average skill level that can be maintained in the population – an unbelievably high level of skill that would be required for

the trait in question to have been introduced into the population in the first place.[5]

My choice of $\alpha = 3\sigma$ derives from using IQ as a model for distribution of skills. With IQ as a model (and using Henrich's assumption of a Gumbel distribution for skills), we would expect to find a highly skilled person (IQ $\geq 145 = \mu + 3\sigma$) in a population of 500 persons and a skilled person (IQ $\geq 130 = \mu + 2\sigma$) in a population of 45 persons. This means that we should find a highly skilled person in a single hunter-gatherer society and a skilled person in virtually every residence camp of that society; i.e., each hunter-gatherer society, and most likely each residence group in a hunter-gatherer society, has persons with the skill levels necessary to maintain the average skill levels, according to Henrich's model, without access to individuals in other societies. This conclusion is corroborated by the fact that "Shennan and Steele's (1999) review of ethnographic information indicates that artisans in traditional societies *overwhelmingly learn their crafts within their family*" (Bamforth and Finlay 2008:12, emphasis added). The change in population size discussed by Henrich for isolation of Tasmania due to a rising sea level would only affect the number of hunter-gatherer societies, not the size of each hunter-gatherer society, hence the change in population size he discusses would have no or little effect on the complexity of the tools and tasks undertaken by the members of each society.

The next section of Henrich's response relates to my use of data on hunter-gatherers and their tool complexity. His complaint about some of the corrections I made in data values misses the point that when we have evidence that a reported value is incorrect, we should correct by estimation, if possible, the incorrect value before proceeding with the analysis. With regard to his concerns about the ET value for Tasmania, even though I pointed out in my 2006 paper that the ET

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[5] The reference, average skill level, for measuring the distance of the skill level of the most skilled person must be the average skill level that can be maintained in the population with that skilled person as imitator, not the skill level before the population had any skilled person as a target. Obviously for a brand new trait or behavior not yet engaged in by anyone, the initial value of σ for persons engaged in doing that trait or behavior is, be definition, 0 since there is no such person in the population. Anyone now introducing that trait is an infinite number of standard deviations above the initial mean skill level of 0 with $\sigma = 0$. What Henrich is measuring with α is the distance from the average skill level that would arise among the imitators after imitating the skill level of the target person and the skill level of that target person.

value for Tasmania (and only the ET value for Tasmania) is misleading due to the fact that "the mean temperature for Tasmania is cool but Tasmania has an unusually stable weather pattern with a 9 month growing season" (2006:168), Henrich opines: "Mysteriously, Read decided that the Tasmanian ET value from Binford, *and only the Tasmanian value*, did not capture what ET is supposed to measure" (his emphasis). There is no mystery. The low ET value due to the low temperature value is misleading since it implies that Tasmania should have the same risk as a region with a short growing season, but Tasmania has a long growing season. In my 2008a paper, I show how a corrected value could be computed directly from the extremely high correlation between ET and length of the growing season, but for reasons I discuss in that paper (such as ET is a twice-removed measure of risk), the length of the growing season is a better measure of risk than the ET values and so the length of the growing season is used in that paper. (I also include the uncorrected ET values so as to satisfy Henrich's concern, but the ET variable drops out of the analysis once the length of growing season is included as a variable.)

The other complaints he makes about use of data on hunter-gatherer groups arise only because of his egregious misreading of what I wrote. Henrich asserts "I [Henrich] prefer Collard's data to Read's, as the former has been synthesized and crosschecked across a variety of sources, including but not limited to Binford and Oswalt" but one only has to read Collard's paper to know that the cross-checking led Collard to exclude all data *except* the data from Binford and Oswalt. Collard used precisely the same data set I used in my 2006 paper.

Henrich goes on say "that the real challenge for those who strictly adhere to ecological and economic models is to explain why the Tasmanians were so different--in terms of technological complexity—from their aboriginal cousins 150 miles across the Bass strait in Victoria. Read reaffirms my challenge when he writes: 'As can be seen in Table 2, these two regions [Victoria and Tasmania] are comparable with regard to ET and TEMP, and have similar *predicted* numbers of tools and technounits/tools'" (his emphasis). The only problem is that his inserted editorial comment in square brackets, [Victoria and Tasmania], is contradicted by what I wrote: "A comparison can be made between *Tierra del Fuego* and *Victoria* on the Australian mainland across the strait from Tasmania. As can be seen in Table 2, *these two regions* are comparable with regard to ET and TEMP…" (2006:170, emphasis

added). Further, Henrich's editorializing is contradicted by the very next sentence he quotes from me: "'Australian groups in *Victoria* had a *more complex tool assemblages* than was the case for the *Tasmanians*'" (emphasis added). How could Victoria and Tasmania have "'similar *predicted* numbers of tools and technounits'" (his emphasis) according to his reading, yet he doesn't see the contradiction with his editorializing and what he next quotes from me: "'groups in Victoria had a more complex tool assemblages than was the case for Tasmania'"? It is obvious from the wording that the "two regions" refer to Tierra del Fuego and Victoria, not Henrich's imagined Victoria and Tasmania. I stated clearly that Victoria had a predicted tool assemblage more complex than that of the Tasmanians and in my Table 2 Victoria is similar to Tierra del Fuego and not to Tasmania.

Henrich's editorializing thereby changes entirely the meaning of what I wrote: "That the Australian groups in Victoria had a more complex tool assemblage than was the case for the Tasmanians may thus be explicable through the difference in climatic conditions between the two regions, taking into account the manner in which differences in climatic conditions affected the seasonality and spatial distribution of both fauna and flora" (2006:170). I was making the factual observation that since Victoria is climatically similar to Tierra del Fuego and different from Tasmania, and since the predicted size of a tool kit for Victoria – larger than the tool kit predicted for Tasmania – is similar to that for Tierra del Fuego, it follows that the difference between the tool kit sizes for Tasmania and Victoria lies in the differences in the climatic conditions between Tasmania and Victoria. So rather than, as Henrich claims, "Read reaffirms my challenge," the only real challenge is for Henrich to respond to what has been written and not to what he imagines has been written.

Henrich argues for a different measure of tool complexity than the one I used (based on Oswalt's [1973, 1976] characterization of tool complexity), but that makes no difference in the results. The results I obtain (2008a) are robust across all the different measures of complexity that have been used in the literature for measuring the complexity of hunter-gatherer tools, including the one introduced by Henrich in his response. As I discuss (2008a), Henrich's use of stepwise backward regression in his response is inadequate as the results he presents are an artifact of that particular method for selecting which variables to include in a linear regression model (along with problems arising

from the distribution of ET values across different habitats, also discussed in Read [2008a]), despite his claim to the contrary: "any approach will yield the same result." Henrich seems to be ignorant of the extensive statistical literature on problems with variable selection in multivariate regression analyses. When done properly, instead of population size relating to tool complexity, it is evident that variation in the complexity of hunter-gatherer tools is due to an interaction effect between risk of successfully obtaining resources and the number of times a group moves in its annual round, with risk being the major factor. The Tasmanians are well within the pattern found for other hunter-gatherer groups, with or without the bone tools included in their tool kit, when this interaction effect is taken into account. The interested reader can refer to Read (2008a) for the data and details of the argument.

The last part of Henrich's response deals with the alternative model I develop. His initial criticism is that I did not model the origin of a new trait. I agree – and there are many other things that I did not include in my model as well. None of this is relevant, though, to what I wrote since I was providing an alternative to Henrich's model of skill maintenance in a population through imitation and his model equally does not deal with the origin of a trait. That imitation may play a role, even perhaps a central role, in how one person's invention spreads and becomes an innovation may be valid, but that is not the whole story for the appearance of innovations (see the papers in [Lane et al. 2009] for an extended discussion of innovation in human societies) and was not the issue at hand.

Lastly, Henrich writes: "The final problem with Read's model … is that there's no evolution. The model has no endogenous dynamics. If costs and benefits change, does the entire population shift instantaneously to the new optimal technology?" This is an odd objection since Henrich admits the same is true of his model: "I highlighted the possibility that a drop in the size of the pool of interacting social learners *could initiate* a process of cultural loss…" (my emphasis). What that process would be and how it would play out is unstated in his model. When the population size decreases and so the likelihood of maintaining the skilled task is in jeopardy, does everyone in the population simultaneously stop doing the skilled task? Neither model is designed to address the dynamics of how a population will respond to changed conditions as both models are addressing another matter: What is the relationship between learning skill levels and the complexity of tasks or behaviors that can be maintained as part of the behavioral repertoire of a group? Both models address the evolutionary question Henrich poses in his response in the same way, namely by providing a means to identify if a disconnect will arise in past behavior due to changed conditions, though each does this in a different manner. Henrich's model links the source for a disconnect to change in population size; my model links the source for a disconnect to whether "the time investment needed to gain the necessary skills are worth the cost of the time investment when averaged over the number of units that is anticipated will be produced" (p. 179) and obviously that assessment may lead to different outcomes when external conditions change.

Conclusion

The model developed by Henrich (2004) is flawed by virtue of making unwarranted assumptions regarding imitation bias. When these assumptions are corrected, the direct relationship between average skills in a population and population size drops out. This is not to say that there is no relationship between population size and average skill level, for clearly there is an indirect relationship relating to the cost of maintaining the subsidiary skills, technologies, and knowledge necessary for highly skilled activities to be maintained in a population. High costs are more likely to be borne by a large population than by a small population. When the group in question no longer is willing or no longer is able (possibly through decrease in population size), to maintain the cost of these subsidiary, support activities the skills will be lost. The problem in the model lies in attempting to directly relate the population size to the average skill level via the skill level of the most skilled person in the population who is the target for the imitators. The claimed monotonic increase of average skill level with population size only holds in the model if the imitation bias when imitating a task requiring a higher skill level is constant and that assumption is not valid.[6]

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[6] If the task being imitated remains constant, then the fact that the most skilled person in a population will have higher skills when comparing a larger population with a smaller one has no effect since it is the task being imitated that is driving skill transfer, not the skill of the person doing the task. It makes no difference to the imitator if one is imitating the same task done by a skilled person or by a highly skilled person. Henrich's model requires that the more skilled person is also doing a task that requires more skill for its performance.

The alternative model that I presented takes the cost aspect into account by assuming that potential imitators amortize the cost over the expected return over the time span one will be using the task in question. It is worth investing in learning the skills needed to make and use a bow and arrow effectively when one anticipates using it to procure meat over one's lifespan, but not if one anticipates access to meat by other means or only has need for meat over a very short time period. In my field work with the !Kung san in the early 1970's, an example of this difference in calculations was evident in the case of a man with a son around 25-30 years of age. While I was there, the father spent his time in the camp preparing his poison arrows for hunting, whereas the son appeared indifferent to the matter and happily sold his quiver and arrows to me – it was clear that he anticipated obtaining food through working for the Herero pastoralists who lived near his camp rather than through hunting and was not interested in maintaining hunting skills.

In presenting an alternative model, I was trying to determine conditions when Henrich's model might apply, such as situations where one needs to develop skills through something like apprenticeship to a highly skilled person: "the role of imitation appears to be more relevant when considering tasks that require a high degree of motor skills and expert knowledge for their effective performance" (p. 181). I noted that this kind of apprenticeship behavior does not apply to all tasks: "With the exception of tasks requiring a high level of skill (both in terms of motor development and knowledge about effective task performance), target individuals with the requisite level of skills are likely to be frequent and skill levels are developed not only by imitation, but through repeated performance of a task and through self-evaluation of one's performance level in comparison to the desired outcome." (p. 181). This lead me to conclude: "The Tasmanians may have simply worked out an adaptation that was sufficient for their needs and in the context of isolation and a stabilized population size change in the direction of new and more complex technologies was simply unnecessary," (p. 181) a conclusion Henrich does not address in his response.

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