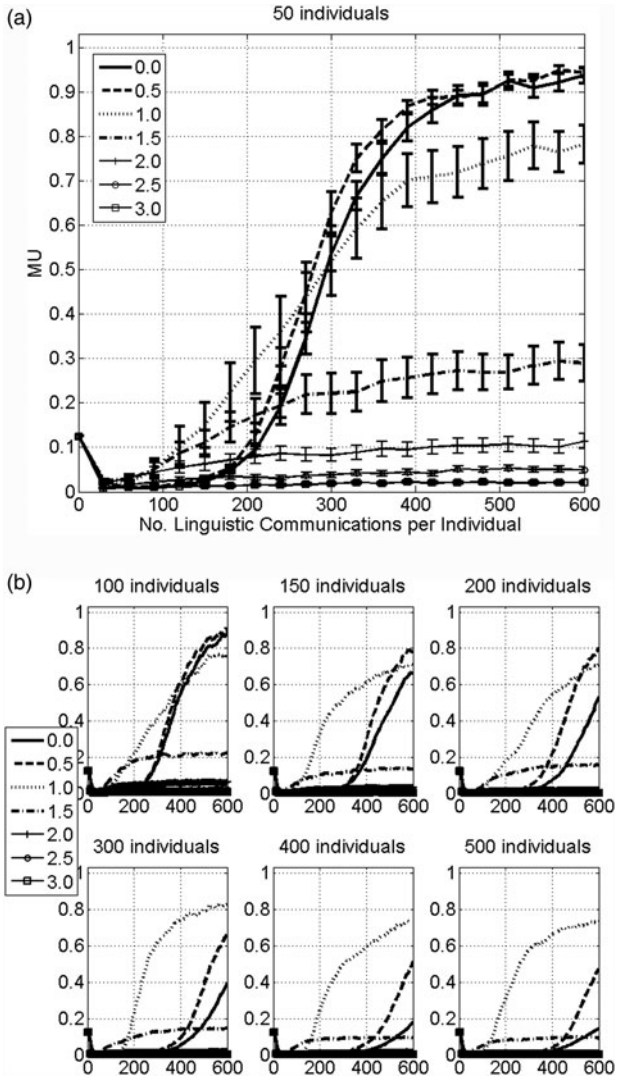

Figure 1 (Shuai & Gong). Mutual understandability (*MU*) under Various Social Popularities in a 50-individual Population (a) and Populations Having Other Sizes (b). Each line denotes the average *MU* (over 20 simulations) under a social popularity with a particular λ. Error bars denote standard errors (because of size, error bars in (b) are omitted). It is shown that when λ = 1.0, the dynamics of language origin (indicated by *MU*) is not only similar across different population sizes, but also optimal compared to those under other λ values.

effects of structural features on language evolution (e.g., Baronchelli et al. 2009; Dall'Asta et al. 2006; Gong et al. 2012a; 2012b). Apart from social interactions, it is shown that combinations of different forms of cultural transmission can also affect language evolution across generations of individuals (e.g., Gong 2010). Moreover, models of other social activities (e.g., cooperation, collaboration, labor division, leadership formation, etc.) can also be adopted in those simulation studies. Exploring the dynamic correlation between sociocultural organization and language (or other group-level traits), these studies offer a general computational framework to evaluate whether a sociocultural phenomenon is qualified as an emergent group-level trait. This framework focuses on individual behaviors and group structures, as well as on the correlation between emergent group-level traits and sociocultural organization patterns. According to Smaldino, this framework is very promising for the future work concerning group-level traits in ecological and evolutionary contexts.

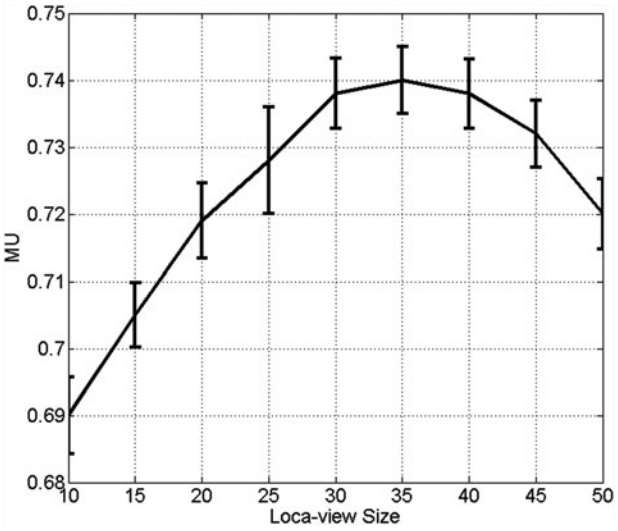

Figure 2 (Shuai & Gong). Mutual understandability (*MU*) vs. Local-view Size (when local-view size = 50, each individual can view all members in the group). Each simulation has 50 individuals and 500 communications, and the adjustment on link weight is 0.01. The results are averaged over 20 simulations. Error bars denote standard errors.

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Why religion is better conceived as a complex system than a norm-enforcing institution

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Abstract: Although religions, as Smaldino demonstrates, provide informative examples of culturally evolved group-level traits, they are more accurately analyzed as complex adaptive systems than as norm-enforcing institutions. An adaptive systems approach to religion not only avoids various shortcomings of institutional approaches, but also offers additional explanatory advantages regarding the cultural evolution of group-level traits that emerge from religion.

The target article is an important contribution to the study of cultural evolution and an impressive account of the emergence of group-level traits. In Smaldino's view, norm-enforcing institutions and cultural narratives are necessary for maintaining suites of cultural traits, such as organizational patterns, behavioral norms, and cooperative decision-making heuristics. If these traits are maintained over time, they will potentially contribute to the emergence of group-level traits. These are the phenotypic effects of social organization and interdependent collaborations that are made possible only when individuals with differentiated roles are structurally cooperative and socially coordinated. Furthermore, because religion is one of the most effective mechanisms for transmitting whole suites of cultural traits, such as hierarchies that reinforce the group's social organization, it is one of the most important constituents of traits at the group level.

We are in general agreement with Smaldino's account, but we think he has overlooked two crucial points about religion: its unique role in stabilizing prosocial norms and its distinct

effectiveness at transmitting suites of cultural traits. Approaching religion as an institution, as Smaldino does, can lead to worthwhile insights about the social structures that support religion and the function of religion as a cultural organization. However, analyzing religions as complex systems more accurately reveals the structures that maintain religions, as well as the traits that emerge from them. Religious systems consist of core interdependent features, such as rituals, supernatural agent beliefs, and myths, which evolved independently but at some point in human history began to co-occur and coevolve regularly and cross-culturally (Alcorta & Sosis 2005; Purzycki & Sosis 2009; Sosis 2009). As anthropologists observe, elements of religious systems interact in complex ways, resulting in emergent properties (e.g., Geertz 1973) and creating communities with shared customs, cognitive schemas, historical memories, and identities.

Although we are critical of Smaldino's characterization of religion as a norm-enforcing institution, we believe that an adaptive systems approach is consistent with his argument for the emergence of group-level traits and provides various explanatory advances to his conception of religion. We address each of these advantages in what follows. In doing so, we hope to show that, from a cultural evolutionary perspective, religion is better conceived as a complex adaptive system rather than a norm-enforcing institution.

First, understanding religion as a complex adaptive system clarifies how religions succeed at transmitting suites of cultural behaviors while concurrently adapting to varying socioenvironmental conditions. Religious systems achieve this apparent opposition by maintaining hierarchies of religious discourse, in which adherents focus on core statements of belief that remain unchanged, even as interpretations of those statements change over time. Accordingly, adherents typically accept novel interpretations of fundamental postulates as being reifications of eternal or personally relevant truths, while taking little notice of the modifications to religious rules and social norms with each generation (Rappaport 1999; Sosis 2011).

Second, the complex adaptive systems approach exposes the mechanisms by which religious systems achieve extensive cooperation and coordination, as observed experimentally and ethnographically (e.g., McKay et al. 2013; Sosis & Ruffle 2003; Xygalatas 2013). One such mechanism is religious signaling systems: religious activities are costly and thus serve as honest signals that enable and sustain trust, allowing groups to cooperate and coordinate socially (Irons 2001). In other words, by performing religious activities, adherents reinforce cooperative norms and signal their commitments to the group, which in turn provides the necessary levels of trust to overcome collective action problems and to maintain group-level traits. However, signaling theory advances Smaldino's argument on other fronts as well. Because signaling theory recognizes that systems can remain stable despite some deceptive signalers (Johnstone 1997), it anticipates the inherent variation within and across religious communities that Smaldino presumes (Wildman & Sosis 2011). It also explains why adherents are highly attuned to signaling variations: they carry respective fitness consequences. Finally, given that signals require arenas of display and reception, signaling theory emphasizes the importance of social and cognitive niches created by religious communities (Bulbulia & Sosis 2011).

Third, the complex systems approach can explain the variation in social structures across religious systems, including religious variations among bands, tribes, chiefdoms, and states. Although religious systems consist of a core set of recurring features, cultural variation arises from how these elements interact within local ecologies to produce specific practices, beliefs, and structures. For example, although many Christian groups maintain an office of ministry, as Smaldino describes, it is hardly a universal or even a common feature of most religious systems. Rather, ministries emerge under specific conditions, such as when groups can benefit from economies of scale (Sosis 2003, p. 115), which are more common in state systems.

In addition to these three advances, the complex systems approach also overcomes several inherent limitations to Smaldino's understanding of religion as a norm-enforcing institution. First, Smaldino situates social norms outside of religious systems, such that religious institutions act on norms that emerge independently, which is unreflective of human history. The systems approach, in contrast, recognizes that religion was not a separate and well-defined arena of social activity for most of human existence. Rather, religious systems permeated all aspects of social life, and thus norms coevolved with the system itself. Second, religious systems not only enforce norms, but they also naturalize them (Rappaport 1999). Because religion is comprised of cognitive, behavioral, and developmental elements – and regularly activates human senses – it fully engages practitioners, making social norms feel correct and natural. Lastly, although we share Smaldino's concerns about reductionism, it is necessary to recognize that reductionism is nevertheless essential for uncovering the constituents of religion. However, the complex systems approach avoids the pitfalls of reductionism by emphasizing that selection operates on the system itself, not its constituent parts (Sosis 2009).

To conclude, we stress that we are not offering a competing alternative to Smaldino's account, but rather a helpful extension of his approach. Indeed, we are curious to hear from Smaldino whether the complex adaptive systems approach can complement the valuable extensions to cultural evolutionary theory that he has offered in the target article.

Replicators, lineages, and interactors

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Abstract: The target article argues that whole groups can act as interactors in an evolutionary process. We believe that Smaldino's discussion would be advanced by a more thorough analysis of the appropriate replicators and lineages for this model. We show that cultural evolution is necessarily a separate process from cultural group selection, and we also illustrate that the two processes may influence each other as demonstrated by an agent-based model of communicating food-processing skills.

Smaldino argues that human groups can act as cohesive units to the extent that they can be considered interactors in an evolutionary model. To briefly review standard evolutionary theory, an evolutionary process requires three things – replicators, interactors, and lineages. Replicators are entities that pass on their structure intact into successive generations. Interactors are entities that interact as a whole with their environment, leading to differential replication (selection). Lineages are entities that persist indefinitely whether in the same state or in one altered by the process of replication.

We believe that Smaldino's discussion can be advanced by a more thorough analysis of the appropriate replicators and lineages for this model. In human cultural evolution, there are at least two sets of things that might form lineages. The first is a set of humans who interact at a specific location, for example, a company or a village. The second is the components of the culture itself – for example, the set of ideas and practices that make up biology or physics. Obviously these two sorts of lineages will not always be perfectly aligned.

Cultural group selection by standard definition is about the first sort of lineage (sets of people at a location). However, the notion of memetics suggests that there may also be a second replicator system – the lineage formed by the memes themselves. These might sensibly be expected to produce "emergent, group-level traits" and would be mostly independent of cultural group selection, although sets of people might well exploit its consequences as a defining feature of their group identity.

organization for human social behavior, but I agree with **Mattei** that an explicit evolutionary perspective on those properties and behaviors that are properly defined at the group level can lead to advances in a number of the human sciences, including social neuroscience, game theory, linguistics, and economics, as well as more applied fields like marketing and law.

Shuai & Gong highlight the study of language evolution, and point out that the language of a group is an emergent group-level trait. Language also clearly facilitates group organization and coordination and is therefore essential in many other group-level traits in humans. Moreover, Shuai & Gong are right that understanding the roles of complex organization and the competitive advantage of group-level traits is probably crucial for a better understanding of the coevolution of language and human social complexity. As an example, they highlight the importance of language in the formation of social bonds. What else would explain why teenage friends or separated lovers often spend hours on the phone discussing their feelings, their hopes, and their fears? Characterizing human social complexity will probably require more than the simple analyses of static social networks and summary statistics (such as power-law degree distributions) presented by Shuai & Gong. For example, it is clear that to *whom* we are tied matters (Granovetter 1973; Hill et al. 2011), as do the dynamics of those ties. Nonetheless, complex models that incorporate social structure with the evolution of language represent a good direction.

R8. Conclusion

Sitting alone at our desks, it is easy to focus on the aspects of human existence that are best described at the level of the individual. Consider the very process of writing, often characterized as a very solitary activity. I write something. I struggle, alone, and finally manage something I am satisfied with. I send it to the editor. The editor reads it, and gives it his approval. The publisher prints it, and the reader reads it. These are actions with social consequences but individual-level descriptions. Yet this is a false picture of the writing-to-reading process. In reality, I write standing on the shoulders of giants, with the influence of the many articles and books I have read, filtered through my mental models and biases shaped by years of explicit learning and cultural indoctrination. I discuss my piece with friends and colleagues, who shape it further. I submit it to the editor, who solicits the advice of experts, and makes recommendations upon which I base a revision. Upon acceptance, the piece is inspected and refined by a team of proofreaders and editorial assistants. Printers, internet service providers, IT support staff, and mail carriers are all involved in the dissemination of the piece to its readers, who choose whether to read it based on a host of factors of personal history and circumstance, and who interpret it similarly. In the case of the unique structure of this particular journal, a new process starts at this point, as readers become writers, and beget an academic dialogue. The production of this very issue is not something that is produced by any individual, nor is it coordinated by a supreme leader with a host of underlings. Instead, the journal, along with many of its properties, are group-level traits, produced by the complex coordination of organized, differentiated individuals. So too are many, many other aspects of the lives of humans best described.

The role of group-level traits in human evolution is at present poorly understood. Changing that will be a vastly interdisciplinary undertaking, with contributions needed from across those fields concerned with human behavior, evolution, and the dynamics of complex systems. It is an imposing challenge, but one that is surmountable when we work together.

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[The letters "a" and "r" before author's initials stand for target article and response references, respectively]

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