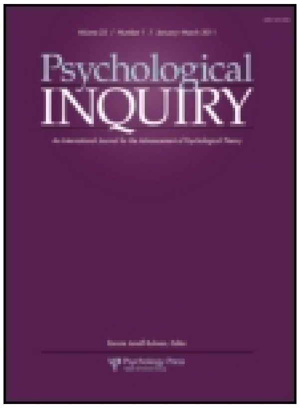

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COMMENTARIES

Turning Two Uninvited Guests Into Prominent Speakers: Toward a Dynamic Culture Neuroscience

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> "Is it language which influences culture? Is it culture which influences language? But we have not been sufficiently aware of the fact that both language and culture are the products of activities which are basically similar. I am now referring to this uninvited guest which has been seated during this Conference behind us and is the human mind."—Lévi-Strauss (1963/2008, p. 71)

It is with assurance that we can state that Lévi-Strauss would have been more than satisfied by reading the target article by Chiao and colleagues (this issue). The authors review and outline the most recent advances in the burgeoning field of cultural neuroscience (CN). The article provides convincing evidence demonstrating the interplay between biology, behavior, and culture as a response to evolutionary and societal pressures. The human mind is no longer an uninvited guest; in fact, it is a prominent speaker.

But Chiao et al. (this issue) move a step forward to right another injustice. If the human mind had been an uninvited guest to culture conferences, then culture was sitting outside of closed doors in neuroscience meetings. To be fair, one of the main reasons pertaining to the weakened recognition of the role of culture in neuroscience studies could be purely financial, as the cost of neuroimaging studies limited the possibilities for cross-cultural research. However, potentially following the psychological tradition, neuroscientists in general are quick to assign universality to their conclusions. Yet the present report demonstrates that there is a deep change in neuroscience circles.

There is yet more light and truth. Here is what we think should be one of the principal considerations stemming from the rich conclusions offered by Chiao et al. (this issue): It is not only neuroscience helping us understand the cultural phenomenon but, critically, *the tools provided by CN hold a matchless potential to understand the human mind, brain, and behavior, and their links to evolution.* De jure, CN emerges as a potentially unique discipline that can offer a common platform for understanding and, possibly, *testing* the mechanisms through which the human mind, brain, and behavior dynamically integrate to adjust to a changing environment.

In the next paragraphs, we explain our interpretation of Chiao et al.'s (this issue) message and offer our opinion on the directions that CN could take to boldly move on to answer more global questions. Specifically, we claim that research in CN would greatly benefit if the following concepts are integrated in the research rationale:

1. *Dynamic (over static) mechanisms*: Both words are significant. CN needs to address phenomena as they evolve and, critically, find the mechanisms that drive change.
2. *Computational and algorithmic approaches*: This comes as an immediate necessity from the previous concept. Dynamic mechanisms imply learning and adaptation, which can be more efficiently described by computational approaches.
3. *Parameterization*: Describing global behaviors and/or employing general theoretical debates might not be sufficiently efficient. An optimal utilization of the powerful neuroscience methods would necessitate the identification of key factors shaping the cultural phenomenon.

We elaborate on these concepts in the subsequent paragraphs. Before that, to put the ideas in perspective, it is useful to review the foundations of cognitive science and culture science in order to understand where CN stands.

First, Gardner (1985) provided probably one of the most famous, detailed, and widely accepted accounts of cognitive science. Gardner envisioned cognitive science as the unification of different disciplines, represented in his now-famous hexagon (Figure 1). Twenty-eight years later, we can safely state that Gardner was, to a great extent, correct in his predictions:

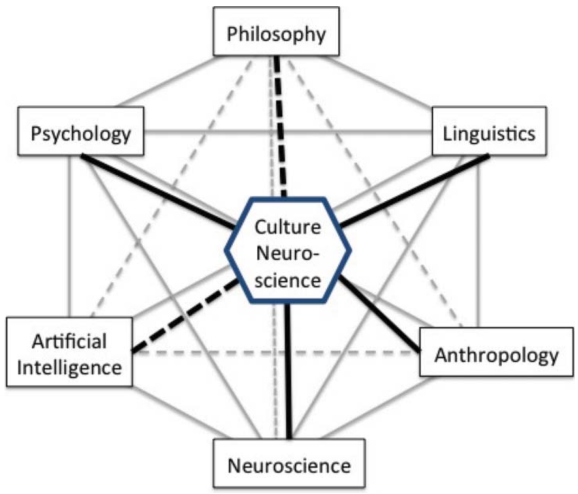

Figure 1. Gardner's original hexagon with culture neuroscience superimposed. *Note.* Dashed lines imply that connections are not strong (both for the original hexagon and our superimposition). Here we note the weak connection between culture neuroscience and artificial intelligence (color figure available online).

Psychology and linguistics are the most significant hubs having strong connections with all other nodes. Gardner also potentially suspected that neuroscience (and biology in general) would aggressively adapt the concepts of all other disciplines, thus offering the possibility of a "common language" and allowing communication between all other nodes. Of interest, what was less expected was that other disciplines would enthusiastically come into play. The principal example is economics, in relation to neuroscience: Neuroscientists found all the necessary quantitative tools to explain the decision process in the formal microeconomics theories, whereas economists eventually identified a way to understand utility (a quest going back to Edgeworth's, 1881/1961, "hedinometers"). A second example is game theory: The methodical formalization of social exchanges proved extremely useful to psychologists, neuroscientists, and philosophers alike (see Camerer, 1997; King-Casas et al., 2005; Ross, 2008).

Second, within culture science, debates continue on whether it is possible to study culture using a "common language." Oftentimes these debates predicate on a dichotomy that, on one end, cultures are incommensurable entities (i.e., each culture can be understood only in terms of its own indigenous concepts or construals), whereas on the other end, cultures are entities that can be indexed by average scores on universal dimensions (e.g., collectivism vs. individualism). Moving beyond this arguably false dichotomy, Richard Shweder and colleagues (1998) espoused the notion of "one mind, many mentalities." Accordingly, we can study culture in terms of both universal processes and particular mentalities in a given society. This dynamic approach is remarkably analogous to the cognitive science rationale, and mounting evidence demonstrates its epistemological plausibility—if not necessity. A theoretical basis was set up by Hong and colleagues (Hong, Morris, Chiu, & Benet-Martinez, 2000) where the focus was established on dynamic cultural influences within an individual—culture is internalized in the form of a loose network of domain-specific knowledge structures (Bruner, 1990; D'Andrade, 1984; Shore, 1996; Strauss, 1992). That is, culture impacts on individuals via its shared meaning systems (including norms, values, lay beliefs, and lay theories); the activation of these shared meaning systems renders certain responses more likely. Cognitive neuroscience offered further support to this approach: For instance, activating an interdependent self-construal via priming was associated with increased medial prefrontal cortex responses when participants were asked to evaluate self-statements in social relational contexts compared to evaluating self-statements in general; the reverse patterns were observed when an independent self-construal was activated (Chiao et al., 2010, this issue). This implies that individuals can possess more than one set of shared meaning systems and can dynamically apply one set of the shared meaning systems in a particular context (see review in Hong, 2009). This account strongly suggests that behavioral differences observed across racial/ethnic/national groups are modulated by the accessibility of different shared meaning systems, rather than an unalterable essence of race/ethnicity/nationality. As such, these results not only have helped CN to avoid the trap of "essentializing" human groups but also supported the significance of a dynamic framework for research on human social cognition.

What are then the next steps that would facilitate the epistemological integration of CN to human cognition research? Observing Gardner's hexagon indicates that, in a similar fashion to one of its epistemological progenitors (Anthropology), CN needs stronger connections with artificial intelligence (AI) methods. Indeed, there is an increasing interest in modeling cultural exchanges via agent-based modeling or other computational approaches (Epstein & Axtell, 1996; see Lansing & Cox, 2011). Remember that economics, psychology, neuroscience, and game theory principally communicate via computational representations, which, at the very end, are based in or inspired by AI. Therefore, approaching CN problems from a computational perspective will facilitate communication with other parent disciplines of cognitive science.

But there is a more critical reason that CN needs to adopt such paradigms. As Chiao et al. (this issue) state, "Culture is a dynamical system of bidirectional influences within the individual, including psychological and biological processes that facilitate social interaction (Vogeley & Roepstorff, 2009)" (p. 2). We would like to emphasize the word *dynamical*. Culture has

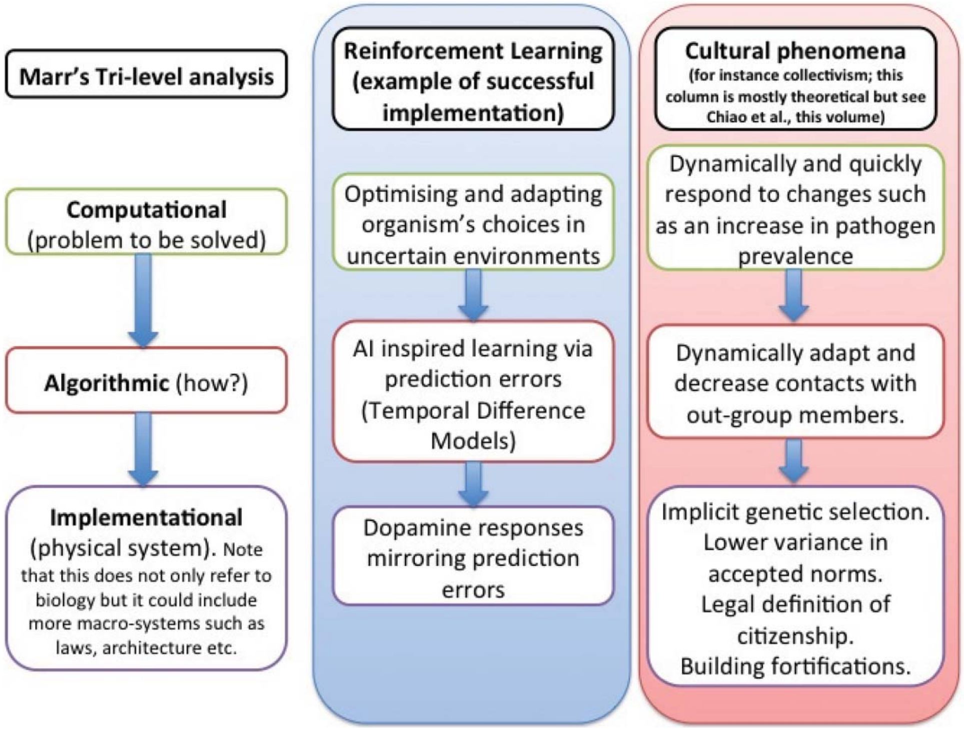

Figure 2. Applying Marr's tri-level analysis. *Note.* Second column: Successful implementation of Marr's tri-level analysis in reinforcement learning (serving as an example). Third example: Theoretical implementation on a key concept of culture science (collectivism) (color figure available online).

a bidirectional relationship with environmental influences: Culture adapts to environmental demands but can also dynamically change the environment. This notion has challenged traditional cross-cultural psychology as it has often taken "static" approaches to culture.[1] Traditional cross-cultural psychology has indeed been proven very useful, but we need to understand not only how cultures *are* but also how cultures *respond* and *change*. To this end, we have envisioned two broad future directions for CN. The first one is inspired by Marr's Tri-Level Hypothesis, and the second one is related to the links between brain plasticity and niche construction.

Studying Adaptive and Dynamic Responses: Marr's Tri-Level Hypothesis

Cognitive and, to some extent, social neuroscience already have the tools (borrowed from AI) to study adaptive responses of organisms. These tools, concepts, and methods have very successfully described adaptive behaviors in computational terms (for instance, a successful example is reinforcement learning); the biological representation has been found (in the case of reinforcement learning, dopamine responses representing "prediction errors") and behavioral manifestations have been explicitly described (e.g., speed of learning or reversal learning capacity). We suggest that if CN wants to address questions such as the mechanisms underlying the dynamic updating of cultures, then such a framework—which is described immediately next—would be the most efficient one.

Let us go back to the fundamentals again and explain our framework with additional reasoning. David Marr, the founding father of cognitive science, provided a comprehensive and practical framework for explaining cognitive phenomena. He suggested the famous Marr's Tri-Level Hypothesis (Marr, 1982), stating that a complete understanding of systems entails three levels of analysis:

- Computational level (i.e., what is the problem that needs to be solved?)
- Algorithmic representation level (i.e., the processes, the symbols and the mechanisms used)
- Implementational/Physical level (i.e., how the processes are realized at the physical level)

In Figure 2 we explain how these levels are realized in the case of reinforcement learning. We have also added how we think the culture phenomenon could be analyzed using these levels of analysis by providing a

[1]Research on cultural transmission (Mace & Jordan, 2011) is a characteristic, but somehow isolated, exception

tri-level analysis of collectivism. However, these are just suggestions, and the figure is mostly positioned as a question to be answered by future research.

This approach is a principal example on how AI, neuroscience, and psychology can be efficiently combined to address key questions of cognitive science. Notice that Marr originally formulated his tri-level analysis as a way to analyze *information-processing systems*. By all means, culture is much more than an information-processing system (as it can produce information itself) and definitely includes more than one layer of processors. It is therefore evident that such an analysis might miss some components of culture; yet remember that this was and is the case with many cognitive phenomena that cognitive neuroscience examines. Therefore, in a way similar to other complex topics, understanding culture at this level is extremely useful as it approaches the cultural *phenomenon* and tries to identify common *mechanisms* underlying different cultures instead of merely comparing behavioral manifestations of cross-cultural differences.

In practical terms, this approach is not a terra incognita. CN can benefit by adopting the methods that neighboring sciences developed in order to address similar questions under the proposed framework. Take, for instance, decision neuroscience or social neuroscience. One useful modus is *parameterization*: to understand the decision mechanisms, instead of examining the decision process as a whole, decision neuroscientists chose to explore behavioral and biological underpinnings of separate individual parameters (such as probability, value, time, risk aversion; see, e.g., Christopoulos, Tobler, Bossaerts, Dolan, & Schultz, 2010). In this way, we are able to identify the exact parameters influencing the behavioral outcome. In other words, saying that "these two groups made different choices" is less informative compared to "these two groups made different choices because they represent probabilities in a different way, and this is also supported by their differences in brain responses" (cf. Hong, 2009).

Moreover, such a parametric approach could help in identifying the most basic mechanisms, the "building blocks" of the culture phenomenon. For instance, in social neuroscience there is some evidence that risk aversion and trust are related (Lauharatanahirun, Christopoulos, & King-Casas, 2012) and any differences between social and nonsocial decision making could be attributed to additional concepts such as betrayal aversion. Cultures are diverse, but the mechanisms that guide their development, adaptive responses, and overall behavior could be subserved by similar mechanisms (akin to Shweder's notion of "one mind, many mentalities"). Identifying these mechanisms could be facilitated by this dynamic proposed framework and should be one of the principal directions of future CN research.

Some examples could be useful. Remember that any kind of system is *accumulating* information in order to understand the world: The human visual system employs probabilistic inference mechanisms to form expectations; the human reward system updates values attached to alternatives; acculturation involves observing and testing behaviors in order to constantly update an agent's beliefs about the statistical properties of shared meanings. Cultural parameters such as laws, language, or norms have to respond when there are threats. The basic premise of computational neuroscience is to analyze how the brain (and generally systems) processes new units of information in order to reduce uncertainty. CN research could examine the largely unexplored question of how individuals, groups, and cultures respond to new information, resulting in actions facilitating or resisting change.

Brain Plasticity and Niche Construction

Neuroscience studies have shown that people's activities and learning experiences can change their brain structure. For instance, it is found that experienced taxi drivers have a larger hippocampus (the area of the brain that stores spatial representations) as compared with less experienced drivers (Maguire et al., 1999), and people who juggle regularly develop denser gray matter than participants who do not juggle; the longer the participants have juggled, the more gray matter develops (Draganski et al., 2004). In short, people's activities and experiences can change brain biology.

People around the world often engage in different cultural practices and hence have different cultural experiences. For example, East Asians tend to process information in a more holistic way than do North Americans, whereas North Americans tend to process information in a more analytic way than do East Asians (Chua, Boland, & Nisbett, 2005). These cross-cultural differences have been shown to associate with different patterns of neural responses (Jenkins, Yang, Goh, Hong, & Park, 2010). Could the different cultural practices alter brain biology? This is certainly a plausible hypothesis to be tested. Indeed, meditation, a practice that originated in Eastern cultures, has shown to alter the integrity of white matter fibers in the brain (Tang, Lu, Fan, Yang, & Posner, 2012). Taken as a whole, findings from CN (see Chiao et al., this issue) imply a strong interplay between culture and human biology; these changes in human biology can, in turn, create a new niche for people to thrive in. That is to say, brain plasticity may guide human into creating new environments (niches) that favor certain human characteristics while disfavor others, thereby shifting the kinds of human characteristics that are being selected (cf. Olding-Smee, Laland, & Feldman, 2003). As such, brain plasticity can underlie niche construction. CN has the potential to shed light on these processes.

That being said, even if cultural practices can indeed alter brain biology, the cultural background of individuals does not necessarily determine brain biology. Why? It is because both people and cultures are, again, dynamic and can change their practices and/or mix them. For example, some Westerners are taking up Eastern practices (e.g., learning meditation, Eastern languages); likewise, some Easterners are westernized (e.g., endorsing more independent than interdependent self-construal). These cultural mixing and adaptation have become ever more common as a result of globalization.

Of interest, recent research has shown that the magnitude of neural responses vary as a function of individuals' degree of culture-typical identity—the more acculturated the East Asian participants are to American culture, the stronger they show the "American" pattern of neural responses (Hedden, Ketay, Aron, Markus, & Gabrieli, 2008). Therefore, it is the dynamic identification process rather than the static race/ethnicity/nationality that matters in brain plasticity. Moreover, people's lay beliefs of race further affect the identification process and its attendant cultural adaptations (see review in Hong, Chao, & No, 2009). Precisely because of these dynamic processes, the cultural background of individuals does not determine human biology inevitably.

In conclusion, Chiao et al.'s (this issue) target article provides ample evidence supporting not only the interplay between biology, behavior, and culture but also the idea that CN can play a pivotal role in leading and reshaping cognitive science and culture science. CN can provide the framework for identifying, explaining, and translating adaptive mechanisms from the biological and behavioral level to the social and cultural level. In a broad sense, understanding the reciprocal relations between brain plasticity and niche construction can shed light on the future direction of human race. Would the cultural mixing and adaptation lead to a more harmonious or discordant world? The findings of intergroup empathy and intergroup biases in the CN literature (as reviewed by Chao et al., this issue) have the potential to address this broad question. The two uninvited guests have brought gifts that exceeded everybody's expectations.

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Note

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