Abstract: Although we agree that ritualized behavior is a mystery that calls out for an explanation, we do not think that the proposed domain-specific two-component system offers an empirically well-justified and theoretically parsimonious description of the phenomena. Instead, we believe that the deployment of domain-general mechanisms based on choice of actions could also explain the essential features of ritualized behavior.

Fully recognizing that ritualized behavior manifests itself in vastly diversified forms, Boyer & Lienard (B&L) have taken a bold and admirable step in proposing to find a common mechanism that is capable of explaining what they claim to be "core features" across different manifestations of ritual: from pathology in obsessive-compulsive disorder (OCD) to routinely invasive thoughts in adults to various elaborate cultural rituals. Based on various pieces of neuropsychological evidence that link the ritualized behavior observed in OCD sufferers to specific brain pathology in the basal ganglia and cortico-striatal loops, a domain-specific two-component system account has been suggested.

While the account seems quite reasonable in the case of OCD (as well as in other motor and cognitive disorders such as Parkinson's disease), we wonder how far it can be extended to explain ritualized behavior in more complex personal and cultural rituals. In particular, we are not fully convinced by the suggestion that the relatively low-level motor control functions of basal ganglia are primarily responsible for the higher-level ritualized behavior demonstrated in various cultural rituals such as religious ceremonies, ancestor worship, and death rituals. Even the authors constrain their definition of "ritualized behavior" to be "a precisely defined way of organizing a limited range of action" (sect. 1, last para.) (i.e., action ritualization); the gap between motor control functions and ritualized behavior seems too wide to be easily filled. Ritualized behavior in various social scenarios clearly involves more than a failure of motor control, though it may be manifested by rigid, stereotypic, and aimless action sequences.

The authors' proposal for a domain-specific "Hazard Precaution System" for ritualization is also partially based on their observation that most, if not all, ritualized actions have to do with dangers, threats, and hazards that somehow impair individuals' fitness or survival. They argue, for example, that "washers" compulsively seek purity while "checkers" desire security. On their account, when adequate satiation of these desired states is not perceived to have been achieved, precautionary actions have to be taken to correct the situation and from this ritual behavior often arises. Although intuitively appealing, these arguments are difficult (if not impossible) to falsify. First, even from an evolutionary point of view, fitness-related features are quite diversified – food, sex, and pleasure-seeking, to name a few of many, can all be motivating forces for certain types of behavior. It seems that those most commonly observed ritualized actions, such as "washing" and "checking," only cover a tiny subset of these features. To adequately link fitness and ritualized actions, one has to explain this "asymmetry," that is, why some types of fitness features (e.g., "purity" for "washers") are more important (and thus more commonly ritualized) than others. Second, it seems that there is a conflict in the authors' arguments that ritualized actions are often fitness-driven, on one hand, and goal-demoted, on the other. Seeking health and security, which arguably motivates ritualization in the first place, is clearly goal-oriented. The compulsiveness and rigidity demonstrated in ritualized actions may seem senseless on the surface but may not be so beneath. A theory of ritualization has to strike a balance between ultimate fitness-seeking and superficial goal-demotion.

Finally, hazard detection and precaution taking are basic and general neuropsychological mechanisms. In a certain sense, all forms of human behavior can be cast as results of this detection-and-reaction operation. Supplementing this point, many production rule based cognitive architectures, such as ACT-R (Anderson & Lebiere 1998) and Soar (Newell 1990), actually model large domains of human cognitive functions using domain-general rules that are just condition-action pairs. If we conceive of conditions as hazard-related features and actions as precautions plans, these systems, with certain additional constraints, seem to be capable of explaining most of the ritualized behavior mentioned by the authors. In order to claim that hazard detection and precaution generation are specialized systems responsible for ritualized actions, one has to explain why such domain-general mechanisms are insufficient or implausible explanatory devices.

We tend to believe that such domain-general mechanisms are sufficient and may offer a more parsimonious and flexible account for ritualization than the domain-specific two-system proposal. A large body of neuropsychological evidence has suggested that the human brain be viewed as a holistic modular system – while individual modules possess functional specialties embodying rich cognitive functions, causing behavior to emerge when all modules are unified in principled and constrained ways (Farah 2000; O'Reilly & Munakata 2000). The difficulty lies in defining sufficiently rigorous criteria for claiming that some of these modules are part of our evolutionary inheritance, rather than using them as convenient explanatory devices when one doesn't sufficiently consider other alternatives. A striking example concerns the function of Broca's area. Whereas it has long been accepted that Broca's area is specialized for language, it has recently been discovered that the area also plays a role in hierarchical event processing and planning (Koechlin & Jubault 2006). Therefore, it is at least conceivable that contextualized usage of domain-general mechanisms implicated in reasoning and making decisions about simple (but survival-necessary) domains, such as navigating the physical world, could adequately account for ritualization behaviors without sacrificing parsimony. In particular, if we accept that human behavior is generally goal-oriented and that goals are naturally multifaceted due to genetic, evolutionary, social, and cultural constraints, then it is plausible to assume that different modules are evolved to emphasize different types of goals and therefore value actions differently. When the choice of actions preferred by different systems differs, they compete to determine the final decision. Note that this account has been the essence of reinforcement learning (Sutton & Barto 1998) and is supported by a body of neuropsychological and neurocomputational studies (Daw et al. 2005; Sanfey et al. 2003; Wang et al. 2006). Since this account emphasizes the role of executive control in choice of actions, it more closely associates ritualized behavior with the domain-general functions of executive control rather than domain-specific mechanisms.

Uncertainty and rituals

DOI: 10.1017/S0140525X06009563

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Abstract: Boyer & Lienard (B&L) elegantly elaborate the links between normal motivational systems and psychopathology and address the evolutionary and cultural context of ritualized behaviors. However, their model omits a key property of the security-motivation (hazard-precaution) system, and this property suggests that ritualized behavior may generate an alternate satiety signal by substituting, in place of uncertainty, a problem that is verifiably solvable.

In the target article, Boyer & Lienard (B&L) build elegantly on our theory that absence of negative feedback in a

security-motivation system generates the symptoms of obsessive-compulsive disorder (OCD) (Szechtman & Woody 2004; Woody & Szechtman 2005). Their article makes contributions to the important theme of conceptualizing psychopathological disorders as dysfunctions of motivational systems (Szechtman & Woody 2006). It does so by elaborating on the normal properties of the security motivation system. In particular, the authors address several important issues, including the evolutionary context of potential danger cues and relevant species-typical behaviors, the developmental and cultural origins of relevant variations in normal behavior, and the importance of learning and cognitive processes in elaborating the workings of the motivational system.

The authors frame their article with the intriguing question, "Why ritualized behavior?" From our perspective, a crucial part of the answer stems from what we consider to be a key property of the security motivation system, but one that was not featured in the authors' interpretation of this system. Namely, the problem addressed by the security motivation system is potential threat, and this problem is inherently open-ended in the following sense: Once the system is activated, there are no stimuli in the external world that provide unequivocal assurance that potential danger is absent. In fact, it is logically impossible to demonstrate that there is no potential danger. Hence, the external environment cannot provide cues for terminating the activity of the security motivation system. It is for this reason that we proposed that the system relies on the performance of security-related behavior itself to provide a satiety signal (which we termed *yedasentience)* as feedback to shut down the system.

The problem of potential threat is also open-ended in the sense that it concerns the prospect of future events, which are inherently uncertain. The issue of uncertainty provides a perspective on the reasons for ritualization that contrasts with those advanced in the target article. In particular, rather than serving to demote goals and swamp working memory, as emphasized by the authors, ritualized behavior may serve to substitute a clearly defined, closed-ended task for the uncertain, open-ended problem of potential threat. A crucial aspect of ritualized behavior is that the question of whether it was performed "just right" is logically answerable, because there are clearly defined rules governing performance of the behavior. Working memory is fully engaged to make sure the behavior is being done correctly, accounting for the high level of concentration during the ritual. In essence, when security-related behaviors do not readily generate the satiety signal in the usual fashion, ritualized behavior may substitute a goal that is verifiably solvable, and thereby generate a substitute satiety signal.

What empirical tests would differentiate the view we are advancing from the authors' interpretation of ritualized behavior? If the function of ritualized behavior is to swamp working memory, then deviations from the ritual should not reduce the effectiveness of the ritual or interrupt its flow. In contrast, if ritualized behavior functions to generate a "just right" satiety signal (yedasentience), then deviations from the ritual should interfere with its effectiveness and provoke starting over from the beginning.

The issue of uncertainty inherent in managing potential danger raises some unique challenges for any organism. One important challenge is how much time to allot to security-related behavior rather than to other survival-related activities. This trade-off admits of no straightforward solution, because it is always possible that further investment in security-related behavior would have been worthwhile, given future events. And yet, an overinvestment in security-related activity may deplete resources necessary to cope with danger when actual danger does materialize. For example, consider a grazing animal. The more time it spends being vigilant for potential predators, the less time it has to graze and nourish itself (Mooring et al. 2004). Paradoxically, if it over-invests in vigilance, it may be insufficiently nourished to cope when real danger does materialize.

Humans are faced with similar uncertainties and a similar trade-off in the allocation of time and resources to being vigilant for potential dangers versus engaging in other survival-related endeavors. Although a rational analysis of potential dangers would take account of their probabilities, our natural, intuitive evaluations are quite different from this (Kahneman et al. 1982). For example, according to Suskind (2006, p. 62), Vice-President Cheney articulated the position that potential threats, rather than being evaluated on the basis of "our analysis, or finding a preponderance of evidence," should instead be evaluated according to a one-percent doctrine: If there is a one percent chance of the reality of the threat, "we have to treat it as a certainty in terms of our response." In essence, if the probability of the threat is more than zero, we need to respond as if it were a certainty. Such a doctrine seems to be a misappropriation of the security motivation system, in the sense that it indicates we should act, once the system is activated, as if the danger were real rather than potential.

It is a trap to seek a sure answer to the question of the absence of potential danger. Nonetheless, in the face of stimuli suggesting potential threat, the security motivation system is readily activated. In this context, we would propose that rituals are more important than B&L suggest in their summary characterization of them as an "occasional byproduct," involving a "waste of time and resources" (sect. 9.3, Epilogue). Rather, rituals, both individual and collective, may serve a necessary role in limiting counterproductive vigilance toward potential threats and providing closure in response to a security-motivation-driven focus on unresolvable uncertainty. We need rituals, even today. Moreover, this potential usefulness of rituals lends considerable importance to further research on the issues advanced in the target article.

Authors' Response

Precaution systems and ritualized behavior

DOI: 10.1017/S0140525X06009575

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Abstract: In reply to commentary on our target article, we supply further evidence and hypotheses in the description of ritualized behaviors in humans. Reactions to indirect fitness threats probably activate specialized precaution systems rather than a unified form of danger-avoidance or causal reasoning. Impairment of precaution systems may be present in pathologies other than obsessive-compulsive disorder (OCD), autism in particular. Ritualized behavior is attention-grabbing enough to be culturally transmitted whether or not it is associated with group identity, cohesion, or with any other social aspect of collective ceremonies.

R1. Introduction

Apart from uncertainties caused by the word "ritual," most commentators provided useful suggestions and much-needed additions to our theory of ritualized behavior on several fronts, in particular with regard to the computational and neural requirements of a hazard-management system; the process of ritualization in patients; the