and some cooking – exemplify aspects of functional precautionary ritual behavior. This minor caveat aside, B&L have powerfully illuminated underlying commonalities in ritual behavior.

Ritual: Meaningful or meaningless?

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Abstract: In conflating opposing meanings of the term "ritual," arising from historical Western cultural conflicts regarding church and state, this target article begs fundamental questions. Its appeals to cognitive science concepts such as "working memory" are poorly informed and obfuscate what could have been a far more penetrating and less biased discussion of stereotyped human action.

In English, it is not unusual for the same word to come to possess two almost opposite meanings – for example, the word "sanction" – which require careful distinction. The term "ritual" is similar, denoting pointless actions and also those with great meaning for participants. Boyer & Lienard (B&L) (and Cosmides and Tooby, whom they acknowledge as inspirations for this study) seem to have been foxed by this etymological quirk. Otherwise, their use of the term "ritual" to refer simultaneously to both opposite meanings might be regarded as disingenuous.

Much ethnography has been devoted to teasing out authentic interpretations of the rituals that are found universally in every culture (even those of university academics). Cultural anthropologists' definitions of the term "ritual" are indeed vague, for excellent reasons. Because the meanings of rituals are generally deeply embedded in the local network of social institutions and collective representations, which are to a large extent taken for granted by participants in a given culture, it is often difficult to find simple interpretations for specific component actions of any given ritual. For instance, Sperber (1975) found it quite impossible to understand why members of the tribe he studied applied butter to their hair. But absence of evidence is not evidence of absence, as all good scientists are aware.

B&L have adopted their compatriot Sperber's rationalistic bias and are content, at least at the outset of their article, to fully equate cultural ritual with the pathological and apparently irrational behaviour of humans suffering from obsessive-compulsive disorder (OCD), and with the repetitive actions of small children (who perhaps delight in their freshly-acquired ability to give order to their personal space and time). But they do not appear to appreciate that their definition of "ritualized behavior" as "stereotypy, rigidity, repetition and apparent lack of rational motivation" (target article, sect. 1), applies precisely as well to more approved, adult, and non-pathological cultural forms such as theatre, music, and poetry. It is not at all clear how these latter forms might relate to "inferred threats to fitness" arising from a "Hazard-Precaution System" (as the authors call it, perhaps using the term "system" to distance themselves from Pinker's wholesale misuse of the term "module"; see, e.g., Pinker 1997). In any case, cultural ritual clearly serves many purposes, such as worship, dedication, marking a social commitment, enacting a rite of passage, which it would be ridiculous to associate with inferred threats to fitness. Ritual is often effective in these contexts because of its dramatic power, bringing together in a choreographed and synergistic process symbols that have great resonance in the cultural understanding of its protagonists (cf. Victor Turner 1969). Perhaps B&L have had no personal experience of this power, which would explain how easily they have confused the two opposite senses of the term "ritual."

It is also important to stress that religious ritual, like other performative genres, is rarely rigidly repetitive. On the contrary, it is often tailored to suit the occasion and/or the individuals concerned, particularly in rituals that are intended to be curative. Ritual experts frequently draw from an extended repertoire of approved variants, as do Western medical practitioners (e.g., E. L. B. Turner 1992). The relatively invariant form of the proceedings can easily be seen to provide an acceptable context or frame (see Goffman 1974) for social actions, enabling the participants to interpret them appropriately.

Far from "swamping working memory," repetitive ritual actions are typically easily memorized, and thus rapidly become overlearned, relieving any potential burden on working memory and allowing a greater focus on the affective and cognitive content of the ritual context. The reader should be aware that "swamping working memory," a favourite phrase of Boyer, is not an accepted cognitive science concept – perhaps the authors mean "increased attentional load" (e.g., Lavie 2006). Over-learning is also a vital aspect of musical performance. Indeed, humans very often rely on over-learned behaviours, consciously or unconsciously fitting themselves into predictable and thus interpretable roles. Ritual action is thus a particularly striking example of role-play.

To argue that such adherence to custom results from a narrowly defined brain Hazard-Precaution System is question-begging and has limited explanatory power, like Molière's *virtus dormitiva*. In my view, this aspect of human social behaviour is supported by a more "domain-general" brain system (or systems!) for planning, scenario development, and prediction, which uses Bayesian computational algorithms to imaginatively assess the potential benefits and costs of a range of possible actions. Cognitive scientists are familiar with this system as the "central executive" (Baddeley 1990; Norman & Shallice 1980). It is obvious that the ability to acquire, learn, and represent stereotypical patterns for action greatly increases the efficiency of such neural computations by limiting the range of possibilities, and could thus increase evolutionary fitness. B&L are tendentious in separating out actions which they happen to believe are "pointless," as the products of a special evolutionary module which could give rise to the pathological behaviour of patients with OCD.

The appeals to brain science made in this target article are also unconvincing. The authors ascribe a major role in the production of ritualized behaviour to the anterior cingulate cortex (ACC), and ascribe the symptoms of OCD to its defective performance. However, this is one of the largest anatomically defined cortical areas, and recent studies (e.g., Chein & Schneider 2005) show that regions within it support a wide variety of functions, such as domain-general learning, emotional response, placebo effect, and internally directed attention. While indeed part of the subgenual ACC might possibly support the postulated Hazard-Precaution System (Van Laere et al. 2006), this area has also been firmly implicated in mood disorder (Mayberg et al. 2005). The functional anatomy of the ACC is an area of intensive research, and the authors have reached premature conclusions.

Ultimately, B&L reveal their disdain for what quite clearly gives most of us our major motivation, delight, and satisfaction – participation in social rituals such as weddings, funerals, christenings, sporting occasions, graduations, and other initiation ceremonies – by referring to them as a "waste of time" (sect. 9.3). Such an elitist viewpoint undermines the credibility of much of this article.

Ritualized behavior as a domain-general choice of actions

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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

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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

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