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

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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

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question of a possible comparison between ritualized behavior in obsessive-compulsive disorder (OCD) and in other pathologies; and the dynamics of cultural ceremonies that include ritualized behavior. We discuss each of these themes in turn.

R2. Why no theory of "rituals"?

From the outset, we knew that it would be of some importance to characterize in the most precise terms the domain of behavior we were trying to explain in the target article. This is why we clearly stated (sect. 1 of the target article) that our model was not at all about the vague category of "rituals" but about "ritualized behavior," a precisely identified form of behavior. It is not too uncommon in empirical research programs to abandon ordinary language and create terms that cut across its common categories. So we thought that particular move should be unproblematic – especially given how heavily, explicitly, and repeatedly we labored the point. But the lure of ordinary language is powerful, perhaps irresistible, together with the illusion that its categories must correspond to genuine kinds of objects in the world. This may explain why, for instance, **Turner** sets great store by the etymology of the word "ritual," admittedly a topic of immense interest, although perhaps not for us as we tried to explain behavior. Also, **Hageman** and **Turner** chide us for saying that (cultural) rituals are meaningless, while **Merker**, **Hageman**, and **Foss** are appalled by the notion that all rituals are about fear and anxiety. But, again, we did not make any claims about "rituals." We do not even believe it is possible to say anything specific and explanatory about this vague and confusing category.

Let us just reiterate, then, that "ritual" is a category we can and should dispense with. Instead, we chose to focus on a set of behaviors characterized by goal-demotion, scriptedness, redundancy, and compulsion. These behaviors may or may not be present in any particular situation that we want to call "ritual." What matters to us is why ritualized behavior is compelling and intuitively natural, why it appears at particular points in typical child development, why it becomes pathologically inflated in some conditions, and, most important, why it centers around recurrent themes such as contagion-contamination, assault-predation, and coalitional psychology. Whether a model of this intriguing phenomenon squares with standard or historical understandings of the word "ritual" is a question that can be safely ignored, or left to the philologically minded.

R3. The functional logic of hazard-management

The Hazard-Precaution model starts with the assumption that indirect threats to fitness create a specific adaptive problem: (1) they are quite diverse – as **Eilam** and others point out, it is difficult to see where such threats begin and end; (2) there is no straightforward feedback demonstrating that a threat has been removed, as **Woody & Szechtman** point out, since it is in the nature of such threats that they are not directly observable; (3) appropriate measures cannot be mapped one-to-one on to physically different classes of threats, since each of the latter may require very different precautions depending on the situation, as **Tooby & Cosmides** emphasize. The cognitive systems underpinning such appropriate responses must be (a) smart and (b) specialized, two points that we should emphasize here.

The responses should be smart. In our view, precautionary behavior requires complex computation rather than simply a collection of "instincts" (in the sense of straightforward, unsophisticated reactions to restricted classes of stimuli) as **Behrendt** suggests. Avoiding charging predators may require a unique response, but avoiding potential detection by predators requires context-dependent measures. The same applies, a fortiori, to more complex sources of fitness-threats like contaminated substances or social threats.

The responses should be specialized. It is a consequence of their ecology and fitness effects. A distinction between specific precautions systems may be necessary, as they may have different learning logics and calibration processes during cognitive development. For instance, there seems to be in humans a general preference for open landscapes with plenty of potential refuge and escape routes but also good visibility, which may be interpreted as an evolved precaution against predators (Orians & Heerwagen 1992; Silverman & Choi 2005). There is also a general distaste for festering meats, most probably as a prevention against pathogen ingestion (Fessler 2002; Fessler & Navarrete 2003b). We would assume that these two forms of precautionary processes are handled by distinct specific systems, which orient attention to different cues, trigger specific reactions, and allow learning of associated aspects of situations in different ways. More generally, precautionary behaviors probably correspond to the operation of a variety of systems geared to such special threats as, for example, predation by large animals, assault by conspecifics, social exclusion and status-loss, contamination, and others (we are obviously in no position at this stage to determine the exact contents of this "catalogue"). These different systems have different input formats, follow inferential principles, and produce different outputs.

So, to reformulate what may have been ambiguous in the target article, we did not assume that one should expect to find a unique, integrated Precaution-System in the cognitive architecture of our species. We use the term "precaution system" in the same general way as one would talk about a "mating preference system" or a "foraging system," without specific presumptions as to the diverse neuro-cognitive systems that may support such large functions.

As **Tooby & Cosmides** emphasize, it may make sense to start by considering two encompassing repertoires, of all represented hazards and all represented countermeasures, respectively. But the role of specific inference systems is to establish the particular connections between these repertoires. Functional diversity may be relevant to explaining differences in the extent to which precaution systems are flexible, context-dependent, and open to cultural input. In particular, while some systems seem to take environmental cues as input (e.g., a position in a landscape is intuitively perceived as protected or vulnerable), others require vast amounts of calibration to local conditions or norms (e.g., preserving friendships and coalitions).

Importantly, as **Tooby & Cosmides** point out, each domain of threat is *cognitively* defined. That is, there are no definite physical features that would necessarily mark

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off social exclusion threats from assault threats. It is only by interpreting accessible information in a specific way that the organism can identify a particular situation as an example of the former or latter kinds of threat. So the different precaution systems are *not* specialized in physically distinct types of situations, but in types of situations that represent different kinds of threat and require different appropriate counter-measures *for agents at specific stages of their development and belonging to specific social categories*. As such we should expect systematic variations in agents' appraisal, between females and males (**Saad**), infants, children, adolescents, and adults. Social threats, for instance, may consist in a huge variety of utterances, gestures (or in the absence thereof), which only a long chain of inferences can convert into threats to the person's fitness. There may be an infinite number of ways to diminish someone's status – ways that, moreover, differ according to the person's status – but an efficient precaution system should associate them with the unique threat of status-loss. This is why, as **Huppert & Cahill** point out, some pathological obsessions and their normal counterparts often include "modern" themes (e.g., car accidents), which shows that precaution systems are learning systems, not situation-driven fixed responses.

Such flexibility and complexity does not entail the operation of domain-general, all-purpose reasoning processes, as **Wang & Bello** propose. In our view, the general reasoning models proposed are less than compelling descriptions of the computations required. Production-rules are only as good as their fit to particular domains of action, and the problem here is, precisely, that specific rules are required to nudge organisms towards the most appropriate precautions. Moreover, our aim was to model, not the way computational systems in general could handle information about threats and precaution, but how specific biological systems actually do it. Evidence from selective phobias and obsessions, as well as neuro-functional evidence, suggest specialization rather that the operation of general reasoning.

R4. Ritualization process and satiation in OCD

The Hazard-Precaution model does not require a strict demarcation between normal and pathological situations, contrary to what **Foss** contends. Indeed, we emphasized the continuum between normal, sub-clinical, and clinical manifestations. We are content with the assumption that ritualization is pathological to the extent that it constitutes "harmful dysfunction" (Wakefield 1992; 2003), which implies no straightforward demarcation between pathology and the normal case. Also, it is certainly true, as **Huppert & Cahill** point out, that ritualized behavior as described here is not the sole component of OCD symptomatology. But our aim was to describe a specific form of behavior, not to provide a unified account of "OCD" as a clinical construct (which may be a futile pursuit in any case). However, these confusions may result from our own description, as we did not specify to what extend ritualized behaviors could be expected as outcome of the activation of precaution systems.

The main point in the model is that precaution systems trigger particular, species-specific, and contextually appropriate precautionary behaviors. Among these could be included a great many intrusive thoughts and other apparently "irrational" manifestations common in non-clinical populations (Rachman & de Silva 1978). In general, these behaviors span the entire range from elementary actions to highly scripted precautionary sequences. Humans perform many precautionary behaviors on account of the socially transmitted information that such behaviors are appropriate (e.g., burning the sheets and clothes of infected patients), and they often take care to perform these actions in the precise way prescribed. People do not care to modify the established recipes, either because it is simply efficient to adopt the process without much scrutiny or because there is no effective means of verification. What marks off the pathological extreme of precautionary behavior from intricate precautionary behavior recipe are such features as the intensity of the compulsion, the anxiety level in case of non-performance, the compulsion to repeat the precautionary behaviors, and the extend to which the behavior's ritualization is felt as intrusive and overbearing. Obviously, the pathology can include many other responses to obsessive intrusions, as **Huppert & Cahill** emphasize. Those symptoms that do not include ritualized behavior fall outside the scope of this model. In the case of OCD, Huppert & Cahill also point out that the compulsive aspect of ritualized behavior is often driven by hyper-responsibility, typical in the "thought-action fusion" observed in many patients (Foa et al. 1993). This last feature, in precaution-based interpretations, may well be an outcome rather than a cause of the pathology. To the extent that precaution systems orient attention and motivation to potential unwanted effects of own actions, their impairment might result in such inflated construals of one's responsibility.

As we noted above, precautionary behaviors, by their nature, cannot be terminated by the perception that the precaution has been effective. You cannot decide through observation that you have reduced the probability of an event that never happened, as **Eilam**, **Woody & Szechtman**, **Rutherford**, and **Tooby & Cosmides** point out. So it is likely that precaution systems include some termination mechanism, which limits the fitness cost of taking excessive precaution. In principle, this may reside in the precaution scripts themselves as self-terminating processes. However, it would then be difficult to understand why OCD patients, who have the same scripts as normal individuals for precaution actions, still cannot help repeating the actions.

On the basis of animal models and neuro-psychological evidence, Szechtman and Woody proposed that a special circuit provides a satiety signal (Szechtman & Woody 2004) which itself allows a shift to other, non-precaution-related goals. We did include this in our model of the neural circuitry involved in ritual, but perhaps did not do justice to this important component of the neural processes involved.

This may be why **Woody & Szechtman** criticize us for not providing a clear explanation of the use of ritualized behaviors. They also highlight the contrast between the respective predictions of their model and ours. In our view, there is not such a great discrepancy. We accept the central contention of the Szechtman-Woody (henceforth SW) model, that security motivation results (in the normal case) in behaviors that themselves trigger some satiety or just-right signal. We also accept that this signal

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is *not* produced by feedback about the objective elimination of threats, since the system's only possible effect is to reduce the likelihood of threats. We agree that the absence or weakness of such a signal is a fundamental piece of the OCD pathology. The real contrast is in the account of the ritualization process in OCD pathologies. In the SW model, the ordinary satiety signal is provided by visceral systems, with input to the limbic system. In cases of excessive ritualization, SW suggest that there is displacement, in the sense that a controllable routine is substituted for the appropriate precaution behaviors, and the fact that it is accomplished as planned triggers the satiety signal. The picture we propose is both a refinement of this idea and a slightly different interpretation.

In our view, the OCD pathology comprises two manifestations that are not usually distinguished in the theoretical models:

(a) Unstoppable reiteration. The behaviors cannot be stopped because they are not felt to be completed: for example, as with patients who incessantly wash their hands or check their door locks. The action is reiterated until (usually) some external occurrence forces the patient to stop, or the satiety signal finally saturates the appraisal system.

(b) Scripted behavior, for example, tapping several pieces of furniture with a particular hand in a particular order, before leaving the room, or washing each body part a certain number of times in a certain order. In this case, the action is terminated once the script is properly performed.

Obviously, the actual symptomatology in most cases includes many combinations of these two types. But it is important to keep this distinction in mind, because it may provide the elements of a (speculative) reconstruction of the dynamics of ritualization. The evidence suggests that unstoppable reiteration is generally concentrated on actions (washing, checking) that are directly relevant to the security concerns of hazard-management systems, such as assault-predation and contamination. On the other hand, at least some of the scripted behaviors escape from this domain. This is why, for instance, some patients have rituals in which the prescribed behavior (e.g., tying one's shoe laces a certain number of times) ends up being detached from the usual precautionary repertoire.

Woody & Szechtman are of course right that one should explain why patients persist in their rituals and why performance must be rigid. In our view, this is not because a substitute satiety signal is provided. Indeed, in cases of unstoppable reiteration, there is no just-right feeling (or it exists in an inefficient or too attenuated form to succeed in decreasing at once the level of anxiety). A solution might be at hand if we follow **Swain** in suggesting the involvement of a reward. What ritualized behavior produces, on the other hand, seems to be a specific reward, in the form of a lowered anxiety level, which we interpreted as the result of making intrusive thoughts less accessible for the duration of the precaution system's activation. So in our view the "substitution" is the replacement of a (absent or inefficient) just-right or satiety signal by a positive reward. The latter is associated with attentional focus on the rules governing exact performance, and therefore reinforces adherence to these rules. In this sense, then, we would include in the model decision-making considerations of the kind suggested by Cavedini and colleagues, consistent with excessive discounting observed in many OCD patients (Cavedini et al. 2006).

R5. Comparison of ritualistic pathologies

Since OCD is characterized by compulsive repetition of apparently unmotivated behaviors, it makes sense to compare it to other pathologies with unwanted or purposeless repetition and stereotypy, notably autism and Gilles de la Tourette's syndrome as well as some forms of Parkinson's disease and schizophrenia. This seems all the more relevant as there is a clear comorbidity between some of these conditions and OCD.

However, we should introduce a caveat here, concerning the use of such terms as "stereotypic" or "ritualistic" in the clinical literature. These terms, when used for symptomatologies as diverse as Huntington's chorea, Tourette's syndrome, and OCD, denote vastly different ways of organizing action. For instance, stereotypy in Tourette's syndrome concerns an idiosyncratic but restricted domain of gestures and utterances, repeated in various situations, outside the patient's control. Autistic repetition also concerns gestures and utterances, but within a larger repertoire, and these are not perceived as alien by the patient. Both Tourette's syndrome and autism contrast with the unstoppable behaviors of OCD patients (generally about evolutionary threats) and their scripted rituals (with high cognitive control). To bring together these disparate phenomena under the umbrella term "stereotypy" may be more misleading than illuminating.

This being said, the problem of stereotypy in autism, underlined by **Kirov**, **Rothenberger, Roessner, & Banaschewski** (**Rothenberger et al.**), **Benga & Benga,** and **Rutherford**, is of great interest to models of OCD. About 90% of adolescent and adult autistic patients display abnormal repetitive behaviors, both stereotyped and purposeless (Seltzer et al. 2003). Do these constitute ritualized behavior in the sense describe in our model? Autistic stereotyped behavior (and to some extent similar behaviors in schizophrenia) differs from typical OCD manifestations: (1) The former are highly variable (all sorts of gestures or movements are used) rather than concentrated (on such themes as checking and cleaning). (2) They are non-motivated (the subject is not aware of any reason for acting stereotypically) rather than motivated (e.g., to prevent accidents or disasters). And, (3) as we discuss further on in this response, though the autistic patient might often be motivated to rehearse precise sets of acts in particular situations felt as threatening or challenging, behaviors and threats seem not to be conceptually linked in autism, whereas the linkage is more often than not the case in OCD. Despite these differences, it makes sense to notice the overlap in the compulsion and repetition and to try and make sense of its possible neural correlates in both disorders.

This is difficult because the neural underpinnings of the autism spectrum are much less circumscribed than those of OCD. In terms of anatomical differences, structural imaging has shown differences between autistic patients and controls in the orbitofrontal cortex (Carper & Courchesne 2000; 2005) and in the cerebellum (Allen et al. 2004).

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Functional differences are also numerous, from the orbitofrontal-amygdala connection (Bachevalier & Loveland 2006) and the activation of the Broca and Wernicke language areas (Harris et al. 2006), to more clearly social circuits like medial prefrontal areas (Frith 1996; Happe et al. 1996) and superior temporal sulcus (STS) (Pelphrey et al. 2005). That functional imaging finds so many specific activations in autism is not surprising as the condition typically develops from infancy and therefore affects the overall brain development. In comparison, OCD is often a late developing condition in a partly- or fully-formed brain.

Despite all this, the comparison is highly informative. There are relevant differences between autistic patients and controls in caudate volumes (Sears et al. 1999), as well as hemispheric differences in the caudate in patients (Hollander et al. 2005). Furthermore, the divergence from controls in basal ganglia volume correlates with the severity of stereotypic behavior (Hollander et al. 2005). Specific alteration of the striatum would be consistent with stereotypy symptoms. This would suggest that part of the typical impairments associated with autism might consist in a similar failure to reach closure after performance of particular actions.

There may be deeper similarities, too. The evidence suggests that some aspects of autistic stereotypy may be very close to an impairment of security systems. **Benga & Benga** state that in autism rituals seem to be performed without any clear connection to threat avoidance. In terms of conceptual content, it seems indeed that behaviors and threats are not linked. Note, however, that stereotyped behavior in many autistic patients is triggered or intensified in anxiogenic situations, such as the presence of strangers or forced social interaction (Ahearn et al. 2003). Systematic studies of the onset of stereotypy show that it generally follows the occurrence of an aversive stimulus, and the offset correlates with appearance of attractive stimuli (Gal et al. 2002). Also, one of the major symptoms of autism is reduced exploration of the environment, correlated with restricted growth in particular cortical structures and the cerebellum (Pierce & Courchesne 2001). This would suggest that, for the autistic patient, at least a subset of the stereotypy symptoms are proximally triggered by situations we identified as typical of indirect fitness threats: the presence of strangers, and the need to explore one's environments beyond familiar confines. This certainly does not contribute to an explanation of autism, but may help clarify the true and the misleading similarities.

In this view, then, stereotypy may be a specific distortion of behavior that may or may not be associated with the other features typical of OCD. This also makes it easier to understand the presence of stereotypy in other animal species. Similar pathologies are observed in animals, especially in caged animals that develop stereotypic and purposeless behaviors. One interesting point is that these behaviors are invariable taken from the normal range of (predatory, exploratory, sexual, precautionary) behavior typical of the species. Second, the appearance and severity of the symptoms depend on external factors. For instance, stereotypy is greatly reduced when caged animals are provided with security cues (a covered place out of sight) and with later weaning (in lab rats) (Wurbel et al. 1998).

R6. Ritualized behavior and cultural material

Many commentators focused on our description of ritualized behavior in the context of what are generally called collective ceremonies or rituals. Since this was the least-developed part of the model, we welcome the opportunity to make it more specific. First, we must reiterate that the model is not about "cultural rituals" in general, for the same reason that it is not about "rituals" in general, as explained earlier. According to **Hageman,** and to some extent by **Alcorta & Sosis** and **Merker**, the model proposed carries the assumption that collective ceremonies (to use a fairly neutral term) in general consist in ritualized behavior. But we are only concerned with the occurrence of ritualized behavior, its effects, and its conditions of transmission.

Now, one feature of ritualized behavior is goal-demotion, a disconnection between action-sequences and goal-representations. To the extent that ceremonies include ritualized behavior, they include actions for which an overall goal can be formulated but without the hierarchy of sub-goals that usually accompany parts of the action (Zacks & Tversky 2001). While a sequence of actions is associated with a goal, its components or sub-actions are *not* related to sub-goals. Consider a typical blessing ritual among the Turkana of Eastern Africa, in which the elders smear chyme on the bodies of juniors (Liénard & Boyer 2006). By such smearing elders are said to bestow their protection unto the young men. But why would the operation have to follow a very specific and precise sequence (ritualized behavior) to make that person safer? The overall goal, to protect a person, is not accompanied by sub-goals that would correspond to each of the sub-actions required, namely smearing the forehead first, then the shoulders and the chest repeatedly, then plucking a small quantity of chyme between the big toe and the next toe. The overall goal of the ceremony does not explain why all this should be precisely scripted and rigidly performed. Nor will it be of much use, as most anthropologists know, to invoke the idiosyncratic rationalizations for ritual sequences – rationalizations that people in small-scale societies sometimes provide after much prodding – or the literate theological justifications produced by literate theologians. These justification and rationalizations are fascinating cultural creations, but they do not explain the scriptedness and rigidity which are our object.

Goal-demotion is difficult to understand and may easily lend itself to misinterpretation, if one tries to frame it within everyday categories. For instance, **Turner** seemed distressed by our alleged description of collective rituals as "meaningless," apparently under the influence of our "compatriot" [sic] Dan Sperber. This would be very bad indeed. But we certainly eschew any claims about "meaning" or its absence – the sort of issues we would rather leave to professional philosophers. To ask whether any action has "meaning" or not seems to us even more nebulous than asking whether or not the action belongs to a "ritual." What people understand by the "meaning" of actions is so unconstrained that participants in ceremonies can state either that their actions are extremely meaningful (Bell 1992), or that they are utterly meaningless (Humphrey & Laidlaw 1993); and both can be right, as it is unclear what these claims amount to in terms of cognitive processes, the object of our model.

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Features of ritualized behavior include not just goal-demotion and compulsion, but also internal redundancy and rigidity in repetition. In our view, the co-presence of these different features suggests a specific way of processing action-representations. This is why we would resist analogies with other forms of behavior in which we find, singly, either rigidity, or goal-demotion, or other features. For instance, as **Fessler** points out, many recipe-like behaviors would seem to show goal-demotion. True, most people who follow long cooking recipes may do so without representing the particular goals achieved by each step of the recipes. This might count as goal-demotion, but the comparison between cooking and ritualized behavior is not very informative, as it does not say much about the crucial differences: the presence of compulsion, rigidity and internal redundancy in the latter, but not in the former.

This is also why we beg to differ from **Fessler**'s tempting suggestion that most cultural ceremonies may be founded on "magical" associations. The anthropological evidence does suggest that many ceremonies do trigger some spurious causal associations. That is, some action is presented and its result is assumed to obtain. Fessler sees this as a fundamental feature of ritualized action. This would suggest an alternative to our model. In that view, people would be likely to represent spurious causation for uncertain outcomes, and act accordingly (in a "magical" way). The presence of precaution themes would be only a consequence of that process, unsurprising since precautionary thinking is itself generally based on imagined (if not imaginary) causation. However, a problem for that view is to explain why the spurious associations represented should invariably center on the themes of predation, attack, social threat, and contagion.

From our point of view, it seems more parsimonious to see the "magical" flavor of many ceremonies as a predictable consequence of the activation of precaution systems, in itself triggered by precaution themes (invisible danger, for instance). Since precaution systems *always* combine the representation of a distant threat with the representation of a preventative action, they necessarily suggest courses of action for which there is no easy demonstration of efficacy. You cannot demonstrate that the absence of predator attacks was caused by your camouflage, since the former is a null effect, as it were.

This goes to the heart of the distinction between "rituals," a loosely organized category of actions, situations, and behaviors, and the specific phenomenon of ritualized behavior that we described in our model. Note that ritualized behaviors can be found outside of the realm of cultural ritual, for example, in sport, as a way of alleviating anxiety prior to a competition, as **Jackson & Masters** propose. Interactions that comprise ritualized behavior may also include all sorts of other phenomena. Indeed, some forms of cultural transmission may easily piggyback on the attention-grabbing potential of ritualized behavior, and even share some features with it. As **Pyysiäinen** points out, the effects of ritualized behavior on working memory may be found in a whole variety of techniques, including some forms of meditation and mysticism. We certainly concur that the cultural effects of ritualized behavior – for instance, enhancing the salience of particular associations, or making particular events memorable if not explicable – are usually accompanied by a host of other manipulations of mental processes, from music to dancing to alterations of consciousness. These, however, are secondary from the point of view of our discussion in the target article and here: that is, to provide an explanation for the recurrence of ritualized behavior. The fact that ritualized behavior is associated with, for example, magical claims, or hierarchy displays, or the reinforcement of ethnic affiliation, does not explain the compelling nature and rigidity of the ritualized behavior itself.

Our model suggests that ritualization is really diametrical to routinization. In actual ceremonies, one is bound to find *both* highly routinized and highly ritualized behavior. The Precaution model also suggests that, *inasmuch as* there is ritualized behavior in collective ceremonies, one would find activation of precaution systems. Now, as **McCauley** points out, the commitment of some participants in most ceremonies or of most participants in some of them is minimal. This entails that, as far as those participants are concerned, the sequence of behavior does not constitute ritualized behavior as defined here, and is therefore outside the scope of this model. For that same reason, the model does not entail that collective ceremonies in general are about "anxiety" or "precaution," as **Foss** and **Turner** imagined. Many forms of collective action are indeed a source of innocent merriment as much as anguished precaution. But that is clearly irrelevant. What our model implies, in a more precise manner, is that, *inasmuch as* there is ritualized behavior in rituals and ceremonies, it is liable to activate precaution systems in at least some of the participants, and thereby enjoy some transmission advantage.

This is intrinsically an epidemiological claim (Sperber 1996). We are not making claims about the "origins" of particular cultural institutions or the ultimate "reason" why people perform ceremonies – indeed we are not sure that these questions make much sense. We are only considering transmission, and arguing that transmission is intrinsically entropic, as it depends on imperfect acquisition and communication processes. Against this, the presence of highly recurrent features in many collective ceremonies (Dulaney & Fiske 1994) requires an explanation.

We proposed that ceremonies that include such precaution-relevant themes would be more likely to be transmitted than those that do not. Also, as **Orrock** points out, an important effect of ritualized behavior may be to allow recalibration of defenses against indirect threats, which is why we should and do observe connections between particular points in the life-cycle and particular forms of individual and collective ritualization. As **Schipper, Easton, & Shackelford** (**Schipper et al.**) suggest, the specific stage of the life-cycle at which an agent is indeed predicts that agent's sensitivity to specific problems. All this, obviously, is not the same as saying that "low-level motor control functions of basal ganglia are primarily responsible for higher-level ritualized behavior demonstrated in various cultural rituals," a claim that **Wang & Bello** find odd – perhaps because it could not be found in the target article.

R7. Ritualized behavior as adaptation

A central question is whether evolved mental capacities are specifically geared to the production of collective

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action with ritualized behavior. As we said in the target article, most functionalist accounts of ritualized behavior so far flounder because they provide an account of social or cognitive outcomes that would be optimally provided *without* scripted, rigid, goal-demoted, et cetera, action-sequences. If "rituals" convey religious knowledge or maintain social identity, many non-ritual forms of interaction do that just as well.

By contrast, **Merker** and **Alcorta & Sosis** offer a more refined explanation, centered on the costly nature of many ceremonies – costly not only in terms of resources but also in pain and danger – suggesting that a deliberate diminution of one's own fitness is the point of the whole exercise. In this sense human ceremonies could be compared to various traits and behaviors that impose a handicap on their bearers and therefore advertise a surplus of fitness potential (Zahavi & Zahavi 1997). They could be more precisely defined as a strategic form of costly signaling (Grafen 1990).

We briefly – perhaps too briefly – discussed this possible interpretation. We think **Merker** and **Alcorta & Sosis** suggest something both plausible and important, namely, that some forms of social behavior may constitute self-imposed fitness-losses, and that we may have evolved dispositions for identifying such behaviors and interpreting them as paradoxical fitness-signals, according to the handicap principles (Zahavi & Zahavi 1997). However, we have reservations on two fronts.

First, the association between ritualized behavior and costly performances do not explain the features of ritualized behavior. We agree that ritualized behavior may be co-present with various forms of signaling, including costly, handicap-based signaling, in a great many social ceremonies. However, as we said in the target article, a whole variety of social interaction processes are contingently associated with specific episodes of ritualized behavior in specific groups. That is, it is certainly impossible to engage in ritualized behavior with other people without, at the same time, communicating some information about status, or about commitment, or about conflicts, and so forth. In our view, however, these processes – including the occurrence of costly signaling – are not good candidates for a general model of ritualized behavior because (a) they are not invariably associated with the latter, and (b) even if they were frequent enough, they would not explain why the behavior is *ritualzed*. For example, blood letting (through penile incisions, for instance) can be done ritualistically (in the precise sense adopted here) or matter-of-factly in front of everyone. Both behaviors could be conceived of as costly signaling. But this would not account for the differences between the two kinds of behavior.

Second, our challenge was to explain why ritualized behavior is so consistently associated with such themes as contagion, assault, and other fitness threats. This is where the association with signaling, even if it was general, would be of little explanatory help, without additional specific hypotheses.

We have similar reservations about the various uses of "ritual" as described in cultural anthropology. For instance, **Alcorta & Sosis** are probably right in suggesting that, in many cases, an outcome of ritualized behavior is that particular conceptual associations are strengthened as a result of attention-grabbing experience. However, we should also note that in many situations of ritualized behavior, the main focus of possible query would be the connection between goals and recipes, and that is precisely what remains obscure to most participants. Most rituals do not communicate much or communicate very well, in terms of transmitting unambiguous norms or concepts (see reviews in Bloch 1974; Lawson & McCauley 1990; Liénard & Boyer 2006; Sperber 1975; Staal 1990).

R8. Outstanding questions

Our aim was to contribute to an integrated explanation of ritualized behavior, starting from deep models of neurocognitive function (Szechtman & Woody 2004) and of hazard-management (Cosmides & Tooby 1999). Although there has been substantial progress in the neuropsychology and neurophysiology of such conditions as OCD, there remain great lacunae in our understanding of normal and pathological threat-management. Some of these uncertainties stem from a lack of relevant evidence, particularly in the description of OCD (and other conditions') symptomatology.

First, theoretical models, such as the one put forward in our target article but also most current interpretations of ritualization, would require specific descriptions of symptomatic evolution in patients, from the first manifestations to the clinical presentation observed by the therapist or neuropsychologist. The paucity of detailed case histories makes it very difficult to test any claims about the dynamics of ritualization, which is crucial to validating models in terms of security-motivation or working memory processes.

Second, we have only rather vague, impressionistic descriptions of what we call ritualized or stereotypic behaviors in the various pathologies, from Tourette's syndrome to OCD, schizophrenia, and autism. As noted above, there are important differences between purposeless reiterated gestures, unstoppable goal-directed behaviors, and complexly scripted precautionary measures. But this distinction is only the beginning. Very few clinical descriptions provide us with a detailed account of who does what, when, and how often. A brilliant exception is **Eilam**'s research into the parameters of ritualized behavior in some OCD patients (Eilam et al. 2006). We consider that such highly specific ethological descriptions of patient presentation should constitute a major element in our understanding of the underlying impairment.

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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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