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Comment

Chills, aesthetic experience, and new versus old knowledge — What do chills actually portend? Comment on "Physics of mind: Experimental confirmations of theoretical predictions" by Schoeller et al.

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Schoeller, Perlovsky, and Areniev (this issue) present an ambitious proposal for a unifying theory of a number of topics at the base of psychology — perception, cognition, "concepts and emotions," "conscious and unconscious aspects," reactions to music, and, perhaps most intriguing, information encoding, learning instincts, and accompanying physiological responses. The authors attempt to target these issues by introducing a "Physics of the mind". Picking up where behaviorists from the 60s left off, they strive to put psychological theories on a basis of mathematic formulas that aim to concisely capture universal mechanisms of the human mind. Of course, they go beyond the behaviorist's black box and actually propose functional principles of cognitive processes which are not directly measurable but which underlie and determine human behavior itself. Although not explicitly noted, this idea also appears to coincide with current arguments in psychological science for "predictive coding," which similarly describes hierarchical organization of internal models used to guide and adjust perception and which is currently seeing a renewed interest (e.g., McClelland and Rumelhart [15]; see Clark [3]; Friston [5] for reviews). It is important to note here as well that despite being backed by some empirical evidence, it is far from trivial to match mathematical formulation into actual practical neurophysiological parameters, and for predictive coding this to date has not been convincingly achieved [11]. Thus, it is particularly important that Schoeller et al. [26] provide parsimonious explanations that, as they argue, can be used to predict cognitive events and in future can and must be tested with empirically observed data.

To this end, in this commentary we will keep to our own expertise and interests in empirical aesthetics and focus on one factor — chills, or more broadly, aesthetic emotions — which we believe does raise interesting implications regarding both their specific explanation and regarding their more general model placement. We suggest that chills might provide an interesting point of entry for empirical testing of the proposed physiological and cognitive mechanisms of learning and aesthetic responses noted by Schoeller et al., especially as this relates to the brain.

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A theory of chills by way of schema-matching, emotions, and knowledge

The authors propose a theory relating to chills as an output, beginning from a very general idea of human experience. They take the basic argument that humans have multiple instincts — or "drives" — which guide behavior. Tied by the authors to biochemical functions (such as glucose levels with satiation of hunger, etc.), these may exist on a gradient from very basic to more complex. Notable among more complex motivations, they highlight an instinct toward *seeking* knowledge. This is "a special instinctual mechanism related to the acquisition of knowledge and to the evolution and improvement of concepts" which "involves sensor-like neural mechanisms measuring similarities between patterns in sensor data and mental models, or more generally the similarity between bottom–up and top–down signals." This to us does seem to jive with our own working idea of psychological and neurofunctioning (e.g., Pelowski and Akiba [20]; Pelowski et al. [22]), holding that we indeed have a range of schema, which we encode, store, and apply to new sensory information.

In turn, the authors suggest that this knowledge instinct is a guide for most human behavior — "both perception and cognition depend on the knowledge instinct. . . it plays a fundamental role" (p. 6). Interestingly, they also suggest that it is explicitly connected to "aesthetic emotions," presumably involving situations when one finds themselves in an art or aesthetic context [21]. "Aesthetic emotions measure the satisfaction or dissatisfaction of the knowledge instinct" (p. 6). They are "modelled mathematically as the rate of change of the similarity function" (p. 6) or "any change in the likelihood that sensory signals match their corresponding cognitive models" (p. 20). This would mean, if our reading is correct, that the higher the match of schema to environment — increasing similarity — the more intense the aesthetic emotion, at least on the positive end, and presumably the better the satisfaction of the knowledge instinct.

This theory itself raises numerous interesting ideas, relating basic human drives to aesthetic experience, as well as introducing a (possibly) distinct set of emotions confined to aesthetics. Finally, the authors also go further and again connect this explicitly to a distinct physiological (chill) response. The authors suggest that the above knowledge seeking process might work on a number of levels, however, "at the top of the hierarchy, the highest aesthetic emotions are perceived as emotions of the beautiful, sometimes these emotions can be strong enough to produce various physiological effects such as tears or *shivering*" (p. 20, emphasis ours). "Aesthetic chills are fundamentally related to meaning and understanding, in particular when subjects understand something important for the cognitive system" (p. 19). Chills correspond to a "satiation of the knowledge instinct" (p. 20).

Chills and knowledge — do these aspects fit together?

Chills are an intriguing and instructive phenomenon in and of themselves. Recent papers [13,22,23,29] point out a lack of clarity in defining chill states — as well as other responses commonly affixed to aesthetic experiences such as awe, being moved, etc. On the other hand, especially when put into a comprehensive cognitive, physiological and presumably neurobiological theory, employing elements of predictive coding, their framing of chills is particularly intriguing for the following reasons:

Throughout most of the authors' discussion, chills, and by extension the aesthetic experience, coincide with reconfirming existing information or finding a good match of one's schema — a minimization of change. This coincides with the general underlying notion of predictive coding theories, which stress the importance for a (cognitive) system to be able to efficiently reduce the amount of uncertainty of its predictions. This also tends to match most empirical evidence and current chill theories, which suggest that it is cases where an individual *anticipates* a coming harmony or strong emotion (in a song, movie, or art) and where this is eventually provided which create the chill response. For example in music, Sloboda [28] suggests that chills tend to occur at "dramatic crescendos" while McCrae [16] also suggests that these can arise through anticipated emotion, occurring at the moment when a desired emotion is at a peak, and tend to coincide with being moved [18]. We ourselves [22] recently put forth an argument that includes chills, suggesting such an outcome coincides with cases — what we called "emotional resonance" (see also Funch [6]) — where one's prior schema are such a good match to the world, and thus show low discrepancy, that they fit like a glove or 'drop into place,' which can be quite pleasurable. This in turn may also be an outcome that indeed is often championed as *the* "Aesthetic Experience".

The suggestion for chills occurring *only* sans discrepancy/high schema-match was also supported by recent empirical studies by Schoeller and Perlovsky [25] who found that chills are inhibited by exposing participants to incoherent

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