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PREDICTIVE PROCESSING

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It. *Processazione predittiva*; Fr. *Traitement prédictif*; Ger. *Prädiktive Verarbeitung*; Span. *Procesamiento predictivo*. Predictive Processing (henceforth, PP) is a framework in cognitive science that views the brain as an organ of prediction, constantly trying to anticipate, at different timescales, the incoming flow of sensory stimulations. Initially conceived as a general theory of brain function (Friston, 2005), PP has rapidly grown into a unified account of a broad range of mental phenomena, including perception, cognition, action, attention, learning, emotion, affect, wellbeing, and several psychopathological conditions. According to some of its leading proponents, PP represents "the first truly unifying account of perception, cognition and action" (Clark 2015: p. 2) and has the potential to "explain perception and action and everything mental in between" (Hohwy 2013: p. 1). These wide-ranging explanatory ambitions make PP one of the most discussed and actively pursued frameworks in present-day cognitive science.

In recent years, PP has caught the attention of several scholars interested in the arts and aesthetics from a variety of perspectives, including philosophy, psychology, neuroscience, history of art, and artistic practice. The result is a fast-growing interdisciplinary research programme that aims to provide important insights into our aesthetic encounters and our mental lives more generally (see Frascaroli *et al*. 2024 for an introduction). In this entry, we consider this research programme from a philosophical standpoint. We start by summarising the central tenets of the PP picture of mental functioning; we then go on to consider how this picture intersects the study of the arts and aesthetics; finally, we point to some of the issues in contemporary philosophical aesthetics that are starting to be addressed from a PP perspective.

PREDICTIVE PROCESSING: THE BASICS

The PP framework is grounded on an age-old conception of perception as a process of inference or hypothesis-testing aimed at discovering the hidden causes of our sensations (see e.g. Helmholtz 1866, and Gregory 1980 for some earlier formulations). According to this conception, to experience the meaningful, structured world that we normally encounter, we must be able to continuously identify the most likely causes of the ambiguous patterns of stimuli impinging on our sensory organs. In recent decades, this idea has been given a more formal interpretation by a broad family of approaches in cognitive science falling

within the so-called "Bayesian brain" hypothesis. According to these approaches, the brain embodies in its structures and dynamics a "generative model" of the causes of its sensory inputs and constantly tests the hypotheses of this model against the incoming input in a process that can be modelled with the tools of Bayesian probability (see Knill and Pouget 2004 for a summary).

The PP framework moves from these Bayesian premises. It offers a plausible account of how this process of probabilistic hypothesis-testing might be carried out in the brain and extends this account to explain a wide range of mental capacities. Like other Bayesian approaches, PP is grounded on the idea that the brain embodies a generative model of its environment and leverages this model to predict incoming sensations. According to the dominant PP account of neural processes (known as "predictive coding"), these predictions unfold hierarchically, across many different spatial and temporal scales, roughly following the hierarchical organisation of cortical sensory areas. Relatively high-level predictions (e.g., the prediction to see a "dog") cascade down the hierarchy in the form of lower-level predictions (about, e.g., shapes, colours, and edges) which are ultimately translated into expected patterns of stimuli on our sensory epithelia. At each level of the hierarchy, predictions are compared with the signals coming from the level below, and, to the extent that there is a mismatch between the two, "prediction error" signals are generated. These prediction errors are used to update predictions across the hierarchy, in a process that continues until prediction error is minimised and the brain has settled on the best available interpretation of the sensory input. In this way, by constantly minimising the mismatch between what it predicts and what it gets from the senses, the agent manages to make contact with a structured world full of objects, people, and orderly courses of events. PP offers therefore a unified account of perception, cognition, and learning as processes of "prediction error minimisation" spanning several temporal scales (see Friston 2005, Clark 2013, and Hohwy 2020 for handy introductions to the full PP account of these processes).

The strength of the PP framework however lies in the possibility to leverage the same apparatus to account for many other aspects of our mental life. In this framework, for example, action is seen as involving predictions about the proprioceptive and exteroceptive consequences of desired movements, predictions that are then fulfilled by moving our body in appropriate ways (see Adams *et al.* 2013; the resulting interplay between perception and action, both aiming to reduce prediction error in different ways, is sometimes called "active inference"). Emotions, on the other hand, are seen as involving predictions about the likely internal (e.g., your heart racing) and external (e.g., a dangerous animal) causes of interoceptive signals (see Seth 2013). In another important addition to the PP apparatus, the prediction errors associated with all these exteroceptive, proprioceptive and interoceptive predictive processes can be weighted according to their estimated "precision", yielding an interpretation of attention as a flexible mechanism that balances the relative influence of our predictions and the incoming sensory signal.

This rather simple PP toolkit, involving different kinds of hierarchically structured, precision-weighted predictive processes, has proven to have considerable explanatory potential. It has been used to illuminate many other important psychological phenomena, including affect, curiosity, motivation, wellbeing, and a wide range of psychopathological conditions (see Hohwy 2020 for references in all these areas). PP accounts – especially those inspired by the more general "free energy principle" (Friston 2010) – have also

been expanded beyond the level of the individual to describe interpersonal, social, and cultural dynamics. The result is a framework that aspires to account for all aspects of our individual and collective mental lives (and their disturbances) under a single explanatory principle: the brain's constant attempt to predict its sensory input to maintain a grip on its environment.

PREDICTIVE PROCESSING AND AESTHETICS

The interests that such an ambitious framework as PP is generating among scholars working in aesthetics are varied and complex, partly reflecting the broad reach and the layered structure of commitments of the PP framework itself. One of the most frequently pursued lines of research in this area uses the PP apparatus to illuminate various aspects of our experience of art. Compelling cases have been made that the picture of hierarchical predictive processes provided by PP can capture with some precision the way in which we engage with artworks, as well as the rich affective phenomenology of uncertainty, curiosity, insight and pleasure involved in such acts of engagement (Van de Cruys *et al.* 2022, Van de Cruys *et al.* 2024). In this respect, PP proponents are often confirming longstanding intuitions about the importance of expectations (and their violations) in art. Crucially, however, they add to these intuitions a Bayesian apparatus to model the unfolding of our expectations over time, as well as a framework to connect this unfolding with other important psychological and neurophysiological phenomena. PP accounts have now been proposed for several art forms, including visual art (Van de Cruys and Wagemans 2011, Kesner 2014, Seth 2019), music (Koelsch *et al.* 2019, Vuust et al. 2022), literature (Kukkonen 2020, Menninghaus *et al.* 2024), and cinema (Miller *et al.* 2023, Drew and Soto-Faraco 2024).

From this literature on PP and the arts, some general hypotheses are starting to emerge and being put forward as relevant to aesthetics at large. The most wide-ranging of these hypotheses sees aesthetic pleasure (or the perception of beauty, as some put it) as related in fundamental ways to our success in predicting our sensations. We would experience aesthetic pleasure, in other words, when we are more successful than usual in arranging our sensorium into meaningful configurations. In this picture, artworks themselves would be artifacts carefully designed to ignite our inferential capacities and keep us discovering structure in the sensory flow (see Van de Cruys *et al.* 2022 and Van de Cruys *et al.* 2024 for detailed expositions). This line of thinking makes contact with age-old philosophical intuitions about the nature of beauty, as well as with contemporary perspectives in philosophical and empirical aesthetics that connect aesthetic experience with the general process of meaning-making (see Frascaroli *et al.* 2024 on these connections).

Starting from the link that PP seems to establish between aesthetic pleasure and the processes by which we discover structure in our sensorium, some scholars are drawing even broader conclusions about the relationship between aesthetics and cognitive science. What PP allows us to see, according to these scholars, is that aesthetics and cognitive science participate in a common explanatory endeavour: clarifying the processes by which our sensations coalesce into satisfying wholes, with all the phenomenological and existential ramifications that this process entails. This opens up ways of considering not just how cognitive science might be relevant to the study of our aesthetic encounters, but

also how aesthetics can illuminate broader questions about mental functioning. Seen from a PP perspective, then, the work of aestheticians, artists, and art historians contains a wealth of theoretical and phenomenological insights into our mental lives and could contribute to illuminating, among other things, the dynamics of subpersonal and person-level experience, affect, wellbeing and psychopathology (see Frascaroli *et al*. 2024 on all these points).

OPEN ISSUES

Despite the far-reaching possibilities of interdisciplinary research that it seems to open up, the encounter between PP and aesthetics has so far been spearheaded mainly by psychologists and neuroscientists. Its implications for the contemporary philosophical debate are therefore still largely to be explored. There are however several philosophical issues that are brought into play by the PP picture of our aesthetic encounters, and some of them are starting to be addressed explicitly from a PP perspective. These include the nature of our affective responses in aesthetic contexts, the scope of aesthetic experience, and the cognitive value of art. Let us say something about each of these issues in turn (but see Frascaroli *et al*. 2024 for a more detailed exposition).

Many of the indications that PP seems to provide to the philosophical debate stem from the intuition that we should think of ourselves as embodied models of the world trying to maintain viability in a volatile environment. According to many PP proponents, this demanding task turns perception and cognition into intrinsically affective activities, constantly tinged by many different positive and negative affective undertones that signal progress or regress in predicting the sensory flow (see Van de Cruys 2017). As we noted above, in the PP picture of our aesthetic encounters, aesthetic pleasure itself has to do with these dynamics, marking moments in which we are particularly successful in predicting our sensations. In a similar fashion, PP accounts for many other affective responses crucial to our aesthetic encounters, including curiosity, confusion, boredom, and feelings of closure, suspense, (dis)fluency, and insight. Overall, therefore, PP seems to offer a picture that ties our aesthetic encounters with deep, affectively-laden existential concerns. This picture could further inform debates about the engaged or disinterested nature of such encounters, their general appeal, and their evolutionary significance.

In a similar vein, PP seems to provide a clear answer to the question of what is the scope of the aesthetic (i.e., what, if anything, sets aesthetic experiences apart from other, non-aesthetic ones), a question that underlies many debates in contemporary aesthetics. In particular, the PP view suggests that there is a fundamental continuity between aesthetic experience and experience in general, as both have to do with the ways in which we make our sensations coalesce into meaningful structures. This does not mean that all experiences are equally aesthetic, since we are not always equally successful in our meaning-making attempts. PP therefore gives us a way of understanding the deep continuities between aesthetic experience and experience tout court, while acknowledging differences in intensity that are certainly present.

Finally, the suggestion that our aesthetic encounters have to do with the successful coping with our sensorium seems also to provide useful indications to the contemporary debate on the cognitive and affective benefits of art. If really art provides us with moments where we discover the structure of our world and of ourselves as models of that world more effectively than we normally do, then they are also potent vehicles of learning and self-transformation (see Frascaroli 2022). What is more, they are also vehicles of optimal psychological functioning, as well as occasions to get affective signals that we are coping well with our environment and to build trust in our ability to cope well in the future (Van de Cruys *et al.* 2024). For this reason, PP seems also to highlight novel connections between the arts and aesthetics and the study of psychological wellbeing and psychopathology.

These and other suggestions about the relevance of PP for philosophical aesthetics are mostly only sketched in broad strokes in the existing literature, and will have to be fleshed out in detail before they can become informative. Even at this stage, however, they point to the philosophical import of the encounter between PP and aesthetics and single out this area as ripe and promising for future research.

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