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Gestalts as Predictions - Some Reflections and an Application to Art

Our aim with this paper is to demonstrate that the predictive coding framework, currently gaining support in cognitive neuroscience, can capture and elucidate important insights from Gestalt theory. Additionally, we illustrate how this approach could address a recurrent issue in the Gestalt tradition, namely aesthetic appreciation of visual art.

At first glance, predictive coding may seem very distant from Gestalt theory. Indeed, Hermann von Helmholtz' view of perception-as-inference is at the heart of this line of theorizing. Still, the predictive coding framework manages to accommodate some of the classic critique of Helmholtzian ideas, formulated first by Gestalt theorists. In what follows, we will first give the rationale for a predictive coding view and in subsequent sections we will examine how this view can illuminate several important Gestalt issues.

1. Why Predictions?

Life forms, as highly organized physical systems, have to actively construct and maintain themselves to counter entropy (the second law of thermodynamics). Organisms manage to do so by homeostasis, keeping the internal milieu in a constant condition. For stationary organisms (roughly: plants) the resources must be available locally. Animals, on the other hand, act in the world to meet their energetic requirements. They forage for resources and find shelter to conserve heat. Rather than simply reacting after the fact on stimuli that change the internal milieu, animals can predict and thus prepare for upcoming stimuli. Homeostasis urges organisms to take a predictive stance. In a primitive sense, this is already evident in E. coli, a single cell organism with a single molecule of DNA. In this simple case, the prediction is realized by an integrated protein circuit which calculates the rate of change in receptor occupancy, serves as a four second memory representation and eventually drives the flagellum (the bacterium's motor component) (Cerra & Bingham 1998). Its environmental sensors transduce information that directs behavioral responses in a way "that increases the probability of the attainment of bio-energetic resources in the next moment" (Cerra & Bingham 1998, p. 11291). The predictive capacity in

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higher animals has been greatly enhanced, but the principle remains the same: to compensate for unpredictability of resources in the environment, organisms retain information on statistical regularities in that environment, which can be used to form predictions on the when, where and what of resources in the future. Complete predictability means that an organism can fully compensate (through plasticity) for impinging circumstances that disturb internal order. Prediction can thus be regarded as just another, albeit a crucial, means to promote homeostasis. An organism can rely on numerous mechanisms to this end, ranging from low-level and purely physiological ones to those that involve cognition and behaviors. Cognitive and behavioral processes can manipulate the internal and external environment in ways that promote homeostasis of the body.

Put differently, because the meanings of different perceptual stimuli are changing too frequently, evolution could not evolve enough instinctive responses, but had to turn to an associative learning mechanism linking internal states, specific perceptual inputs, behavioral responses and the adaptive value of the outcomes of the responses (Hebb 1949). Activation of part of these assemblies, will engender a spread to other parts, in fact functioning as predictions for what comes next. Hence accurate predictions facilitate perception (*e.g.* shorter reaction times, see Huron 2006), just as Gestalts are assumed to do.

2. Predictions in Visual Perception

According to the predictive coding approach the brain actively predicts upcoming sensory input rather than passively registering it. Applied to the visual system, the idea is that, based on prior experience, our brain actively makes predictions about what visual input to expect in the current context of stimulation. Predictions generated at higher levels are used to explain away lower level representations that are compatible with the higher level interpretation of the visual input. Thus, resources at a lower level of the visual processing hierarchy can be directed at the prediction errors, that part of the input that has not been successfully predicted by higher level areas. An important part of the activity in lower level areas can therefore be considered an 'error signal' that updates the predictions at higher areas and guides learning (de-Wit, Machilsen & Putzeys 2010). Perception is a matter of constantly fine-tuning predictions by using prediction errors, *i.e.* mismatches between sensory input and generated predictions. It is an iterative matching process of top-down predictions checked against bottom-up evidence along the visual hierarchy. More specifically, each level in the visual cortical hierarchy is thought to have a twofold computational role: firstly it provides predictions (the conditional probability of a stimulus) regarding expected inputs to the next lower level and secondly it encodes the mismatch between predictions and bottom-up evidence (the 'surprise'), and propagates this prediction error to the next higher level, where representations (future predictions) are adjusted to eliminate prediction error (Friston 2005). This framework has been successfully used to explain different findings, ranging from extra-classical receptive field effects in primary visual cortex (Rao & Ballard 1999) to neural activity related to face and shape perception (Egner, Monti & Summerfield 2010; Murray, Kersten, Olshausen, Schrater & Woods 2002). The bottom line is that the brain becomes tuned to statistical regularities of our natural visual environment (Geisler 2008). Through its predictions, the visual system structures the perceptual input in patterns (Gestalts) that allow for predictability both within and across visual displays.

However, the assumptions of this model contrast sharply with more traditional views on perception as the piecemeal accumulation of evidence with visual neurons functioning primarily as feature detectors (Hubel & Wiesel 1965; Riesenhuber & Poggio 2000). In this sense the predictive coding approach incorporates and solidifies the core insight of Gestalt theory that perception is no simple sum of local stimulations of the retina. In Wolfgang Köhler's words: "The mode of appearance of each part depends not only upon the stimulation arising at *that* point but upon the conditions prevailing at other points as well" (Köhler 1920). There are emergent properties in the combinations of stimuli, which the predictive coding approach naturally accounts for through the active predictive involvement of the (visual) brain. In this way apparent motion can be explained by referring to the moment-to-moment predictions our brain generates which make the movement appear fluent. In a similar way, a predictive coding account of several visual illusions (Changizi, Hsieh, Nijhawan, Kanai & Shimojo 2008; Changizi & Widders 2002) and perceptual filling-in (Sauvé 1998) suggests that our phenomenal experience can be determined by our predictions rather than what is actually out there as visual input.

Implicit statistical learning as the basis for the difference between the whole and the sum of the parts, may not have been approved by the traditional Gestaltists, but it is increasingly supported by research (Elder & Goldberg 2002; Geisler, Perry, Super & Gallogly 2001). Statistical learning is assumed to happen almost completely without consciousness and from very early in the lifetime. Though Gestaltists were not nativists —for example they acknowledged the role of past experience in grouping (Wertheimer 1923)— they would presumably not agree with this central role of implicit statistical learning in the perception of organization. On the other hand they did not formulate a satisfying answer as to what is changed in the perception of the whole compared to the sensations of parts and what is the origin of this change. Moreover, the Gestaltists' inconsistency in their attitude with regard to the role of previous experience has been sharply criticized by Gaetano Kanizsa (1994). He remarks that after asserting that the formation of the object is

> "an autonomous process that does not depend either on the knowledge acquired through past experience or on expectations [...] many of these theorists go on theorizing as if they had forgotten it, and go on proposing that past experience (in the form of schemes, expectations, or via processes like assimilation) not only 'interprets' the objects of our perceptual world, but also contributes to creating them" (Kanizsa 1994, p. 459).

In accordance with the latter, predictive coding answers that environmental regularities have to be abstracted by our perceptual organs. One could say that what is added to the parts in the perception of the whole is the intrinsic activity of the brain, that is, the generated predictions based on partial input plus the neural structure of the brain, reflecting the correlations encountered in previous experience.

In a predictive coding approach, Gestalt laws are prime examples of very basic statistical regularities that the visual system picks up from our environment, in this case giving rise to very strong predictions. In a statistical learning view, these very basic correlations are also supposed to be learned, one could say overlearnt, and thus seemingly given as Gestaltists believe(d). Again, Gestalt theorists did not rule out a possible role of previous experience, but they did emphasize the invariant structures in perception (givenness) (Koffka 1935). Predictive coding on the other hand takes the probabilistic relationships in the world as the basis of predictions, more in the tradition of Egon Brunswik (1955). The derived predictions are only invariant insofar as the regularities in the environment are invariant. In this sense the main Gestalt laws (proximity, similarity) can be considered the limiting case, generating strongest predictions. Still, when we make grouping principles compete or try to specify the *ceteris paribus* principle, the important role of previous experience becomes obvious (Claessens & Wagemans 2008).

This view is clearly rooted in theories of perception as unconscious inference (von Helmholtz 1911) or hypothesis (Gregory, 1980) about the unknown sources in the world causing the sensory input, with the important *caveat* that we are computing probabilities on sensory input in relation to our mental model of the world and not to the actual states of the world. As pointed out by Purves *et al.* (2011), the latter information is unavailable to us. Nonetheless a mental, generative model, and the predictions it produces, can perfectly be functional or useful, without necessarily agreeing with what is actually the case in the world on every possible aspect of it. It is the predictive success that will be the ultimate judge. For example, we will perceive an input as a Gestalt if in the past it led to successful predictions, meaning successful behavior could ensue (Purves *et al.* 2011). In this regard it is important to heed Herbert Simon's (1965 p. 129) remark that "organisms adapt well enough to ‚satisfice'; they do not, in general, ‚optimize'".

3. Actively Engaged with the World

According to phenomenologists Edmund Husserl (1966) and Maurice Merleau-Ponty (1945) every moment in experience has a threefold structure comprising a primal impression, a retention and a protention. The primal impression is the now-phase of the object-directedness but it never appears in isolation from the two other components (Thompson & Zahavi 2007). Retention is the just-elapsed phase of the object and protention is the phase of the object about to happen. That our awareness extends beyond the now, is for example very clear in music perception. We do not hear a progression of single notes in consciousness but we hear a melody. We do not only perceive what is physically there at a specific moment, but in a sense also what went before and what will come. These three composites of consciousness are implicitly (unreflectively) and simultaneously present in every moment. For Husserl, they are invariant structural features that are *a priori* conditions of possibility of the flow of consciousness as we experience it. In the light of our discussion of the predictive coding approach, this sounds like a remarkably modern view. If the fundamental nature of our brain is such that it is continually looking forward based on information extracted from just-elapsed and more distant time frames, then our conscious experience too should bear the mark of this, as the phenomenologists observed. Furthermore, they emphasized that the individual is actively involved with the world, not separated from it, a notion further developed by the Gestaltists and Gibson (1979). The visual system, or better: the whole mind/brain, is fundamentally situated in and directed towards the world around it. This fits very well with the proactive role the brain plays in a predictive coding view (Bar 2007). The brain is assumed to be continuously predicting stimuli. It adds something to the input, a structure in the form of projections into the future, which in turn are based on distilled regularities from previous experience. Accordingly, Köhler and Kurt Koffka made it abundantly clear that the world that appears to us is not a literal copy of the external world but that there are events beyond the visual input, in the brain, which are responsible for the structural appearance that the world has in our consciousness (Ash 1995). The convergence of phenomenological Gestalt ideas and recent findings in cognitive neuroscience is quite striking. In general the idea that the brain is an endogenously active system, generating patterns of neural activity on its own, is gaining ground (Buzsaki 2006). If the brain autonomously generates activity, it might even be more appropriate to say that sensory input only modulates the brain's pre-existing internal dynamics, instead of classic view that sensory input causes responses in the brain (Bechtel 2009; Barrett 2009).

Our encounter with art is no different in this regard. We actively engage with a piece of art, even if this piece is not a performance but a static work. As John Dewey (2004) explains, enjoying a work of art is a full experience. It takes place when the observer ceases to be just an observer but becomes a ‚cooperator' or even an ‚adversary'. We invest something of our own in it when we build up strong predictions about the spatial or content aspects of the work, only to see them subsequently interrupted of violated. Yet a better appreciation of what goes on in aesthetic experiences evidently requires a discussion of emotion.

4. Prediction and Emotion

While several Gestalt theorists were interested in emotion (Duncker 1941; Koffka 1935; Köhler 1929; Lewin 1938), only their successors in the 'Ganzheitspsychologie' specifically drew attention to the role of emotion in perception (but see also Arnheim 1974). They argued that these emotional experiences were not mere accompanying phenomena but functionally essential to the pre-Gestalt experience (Sander 1928; see also Ash 1995). Again, predictive coding can help to elaborate this role of emotion in Gestalt formation.

Accurate predictions allow for appropriate event-readiness and consequently an increased likelihood of future positive outcomes. Thus, in an evolutionary logic it makes sense that these predictions would be reinforced with a positive feeling. Conversely, prediction errors, *i.e.* failures to correctly predict future situations, presumably are negatively valenced. In a form of neural Darwinism, this feedback on the success of predictions may be important in learning the relative success of different ways of representing information on the world (Huron 2006). The accuracy of predictions is used to select among various alternative interpretations. As an example David Huron (2006) uses absolute pitch, the ability to identify the pitch of tones without the use of external reference. Although genetics plays a role here, a critical learning period in early age seems to be decisive. If the absolute representation of tones generates functional, valuable predictions in a particular developmental context, absolute pitch will be preserved and reinforced. Otherwise, relative coding, which produces predictions that serve most purposes well, will be all that remains. A similar argument could be constructed to explain experiential outcomes when visual predictions diverge for one and the same visual display, as when grouping principles compete. At any time several competing predictions (representations) are formed. Which prediction will prevail, and thus determines our experience and behavior, will depend on the previous successes of these predictions.

Earlier we claimed that an unpredictable event (a failure of predictions) is always experienced as unpleasurable. The rationale for that is that nature tends to assume the worst, because the cost of a false negative (type II error) is potentially much larger than that of a false alarm (type I error). This means that at least the initial, quick reaction to prediction error is negatively valenced (Huron 2006). This view resonates with theories that argue that (negative) emotions originate from interruptions or discrepancies between expectations and the actual situations. These so-called conflict theories of emotion have a long history (reviewed in

Mandler 2003), but their most famous proponents are Donald Hebb (1949) and George Mandler (2003). In our view, even in cases where the actual situation is not correctly predicted but is better than expected, the initial quick response is negative. Immediately afterwards the situation is reappraised as a positive one, and in fact as more pleasurable than if it this feeling was not preceded by a negative one. The temporary unexpectedness generates part of the full joy afterwards. Similarly, even though predictability is positive as such, this experience can be intensified by a previous state of unpredictability (a negative experience). This contrast effect can be illustrated in art works where in fact prediction error or delay in prediction confirmation seems to be often used to amplify subsequent positive emotions.

Vincent van Gogh in *The Olive Trees* uses perceptual grouping by similarity (parallel waves) that transgresses the boundaries of the objects as defined by color and our top-down knowledge of what the objects are in the scene (trees, fields, sky). The violation is minimal so we can still resolve the image without problems, but arguably it is essential to the aesthetic experience we have while contemplating the work. It is part of what makes this work intriguing.

Fig. 1 The Olive Trees (1889, oil on canvas), Vincent van Gogh (MoMa, New York, Public domain).[1]

Generally, we argue that it is important to take into account both the perceptual (the moment-to-moment predictions and errors on a millisecond timescale) and the emotional dynamics to better understand pleasure associated with

[1] To find the original coloured versions of Figs 1, 2 and 4 see http://gestalttheory.net/gth/meaning.html

visual configurations. This view is reminiscent of Michael Kubovy's definition of the pleasures of the mind as "collections of emotions distributed over time whose global evaluation depends on the intensity of the peak emotion and favorability of the end" (Kubovy 1999). Similar thoughts have been expressed by Lev Vygotsky (1971) in his analyses of poetry and literature. Vygotsky uses the notion of catharsis, harking back to Aristoteles, to explain that the aesthetic experience is about transformation of feelings into opposite ones and their subsequent resolution. According to him, a work of art always includes an affective contradiction, a negatively valenced obstruction in content or form followed by a positive resolution. But to put a one-sided emphasis on the happy end (the mental closure), would miss an important, indeed essential, part. Vygotsky perceptively adds that any aesthetic experience is a creative act, in the sense that the resolving, the discovery has to be made by the observer. One must creatively, courageously even, overcome one's own negative feelings, to find one's own catharsis (Vygotsky 1971).

Together with Kubovy and Vygotsky we would say that an aesthetic experience derives from a transition rather than from a static state of stimulation. Positive emotions most intensely arise when we manage to solve the prediction error and thus to reinstate predictability, after having gone through a phase of resistance (prediction error). This is why artists deliberately create obstructions (prediction errors) in the style or content of their pieces.

Paintings are static art forms, so prediction errors often cannot be resolved, except in our minds. Hence, it seems in art we deliberately seek prediction errors. We seem intrigued by prediction error, especially when violating important default expectations. But it is only because of the 'predictive stance' of our brain that prediction errors acquire their special status. Discrepancies become salient and stimulate further processing, but only when strong predictions are first built up (clear organization). We are not indifferent to the prediction errors in art (arousal) and we keep coming back to investigate them (attentional resources are recruited). The prediction errors in Pablo Picasso's paintings are obvious. For example in his *Weeping Woman* the violated predictions involved presumably are generated by our specialized face processing systems (fusiform face area), based only on face fragments or otherwise degraded input of a face these systems generate predictions on the where and the what of the other parts (and on the face as a whole). The ‚error' here is contained in the fact that Picasso portrayed parts of the face which normally should not be visible in a face profile view (another ‚error' exists in the use of different colors for different part of the face). Enough facial cues are provided though, so the error does not really interfere with our ability to recognize a face and even its expression. The prediction error causes arousal aimed at reducing (resolving) the error.

Fig. 2 Weeping Woman (1937, oil on canvas), Pablo Picasso (© Picasso Administration – SABAM Belgium 2011).

Prediction errors urge us to question our perception and its contents, time and again. They open doors to different layers of meaning, which we so much like to discover (van Leeuwen 2007). They create ambiguity (Mamassian 2008) and multi-interpretability, which others (Biederman & Vessel 2006) have considered to be the cause of pleasure we experience while looking at art.

5. Prediction and Parsimony

The tendency to simplicity or parsimony (conciseness) of Gestalts has always been a central concern for theorists in this tradition. In the law of good Gestalt or *Prägnanz*, Gestalt theorists attempted to describe how elements tend to be grouped together if they are part of a pattern that is as simple, regular, balanced or coherent as possible, given the input. The long series of adjectives Gestaltists used to describe the good Gestalt is symptomatic for the conceptual problem which is widely considered to be one of the greatest weaknesses of Gestalt theory. Nonetheless, the intuition that the brain, as an evolved, biological system, would have a tendency towards the most efficient representation of the current visual input was very important and is also intrinsic to the predictive coding approach. The brain has evolved to code sensory information in an efficient way by using information-processing strategies optimized to the statistics of the perceptual environment (de-Wit *et al.* 2010). The predictive coding strategy is parsimonious in the sense that the brain does not need to maintain multiple versions of the same information at different levels of the processing hierarchy. In this way resources (energy) needed for representing perceptual input are minimized. In terms of brain activity this implies that predictable stimuli elicit lower responses compared to unpredictable stimuli (Alink, Schwiedrzik, Kohler, Singer & Muckli 2010; Egner *et al.* 2010).

At the same time, the brain has also evolved to maximize the relevance of prediction outcomes. Not all predictions yield the same benefits in terms of biological fitness. As we have seen, organisms developed ever more complex and fine-grained predictive systems to cope with a frequently changing environment. However, computing ever more specific predictions is costly. It follows that not all stimuli can be fully processed. Extensive sensory processing has a cost that should be incurred only in the expectation of a benefit (Cerra & Bingham 1998; Sperber 2005). Predictable stimuli are summarized in Gestalts and only the errors hold relevant information. The fact that we experience Gestalts can be thus be understood as a direct consequence of the brain trying to satisfy the joint constraints of any evolved cognitive system, namely parsimony of processing (efficiency) and relevance of outcomes.

In our section on emotion we saw that the reduction of prediction errors is pleasurable. Equivalently, gains in efficiency (the sparing use of resources) seem to be rewarding. If our visual system manages to find a sparse explanation of previously unpredictable stimuli resulting in a lesser strain on our processing resources, this is experience is pleasurable. Gustav Klimt's *Reclining Woman*, can serve as a good example here. A small struggle in our visual system precedes the discovery of the familiar silhouette. The prediction error in this collection of lines is resolved through the discovery of the Gestalt. Some mental work is necessary to discern the organization. But the aesthetic pleasure is larger as a result. We move from a multitude of seemingly unrelated lines to a coherent Gestalt.

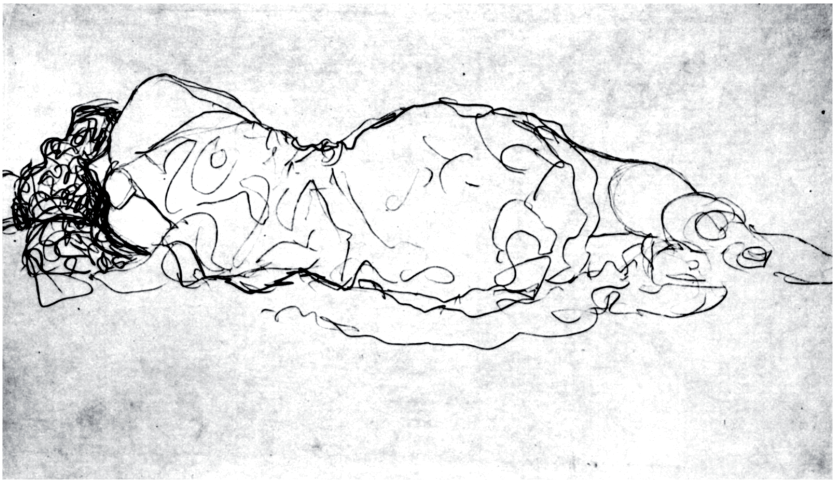

Fig. 3 Reclining Woman (1914/17, pencil), Gustav Klimt (Albertina, Vienna, Public domain).

There is a clear link with the literature on processing fluency (Reber, Schwarz & Winkielman 2004) which states that the ease of processing determines visual preference and appreciation. In this reasoning, symmetrical, clear-cut (high-contrast) and prototypical (average) stimuli are preferred. In line with this, increased liking in the mere exposure effect (Zajonc 1968) is caused by improved processing of the stimulus because of repeated experience. It accounts for what is commonly called the warm glow of familiarity. There is quite some evidence supporting the notion that visual beauty is determined by ease of processing, albeit only for simple stimuli and unconscious repetitions (Huron 2006). In terms of the predictive coding view, an increase in processing fluency corresponds to an increase in predictability (reduced prediction error). What the fluency account lacks, and in that sense it is a clear descendant of Gestalt theory, is a dynamic view, acknowledging that a (temporary) state of prediction error can be as crucial for inducing perceptual pleasure as is the predictability. This, we surmise, is especially the case in the clearest instances of beauty, namely in works of art. Again, this necessary phase of heightened processing has been hinted at by Vygotsky as he writes that the poet

> "wastes our strength and energies to the extent required by his work of art. An absolutely faithful and precise narration in prose of Shakespeare's Hamlet or Dostoevsky's The Brothers Karamazov saves much more psychic energy than the actual works of art" (Vygotsky 1971).

The phenomenon of earworms, the songs that compulsively repeat in our head, can further illustrate the important difference we are getting at. These musical pattern are great Gestalts, the ultimate predictability, but far from the most beautiful pieces we have ever heard.

6. Multiple Levels of Predictions

Gestalt theorists argued that the brain acts as a whole system and one of the strongest arguments for this was the fact that Gestalts were found at many different levels: in perceived motion, in stationary Gestalts, motor patterns, insightful problem solving in animals, memory, personality, and so on. A generalized predictive coding approach has a corresponding hypothesis in that predictions are assumed to be generated and checked against actual circumstances at every processing level in the brain. There is accumulating evidence for this position in several domains of mental functioning. Our main concern so far were predictions in perception, but they are also found in action control (Schütz-Bosbach & Prinz 2007) and computational models of reward processing (Schultz, Dayan & Montague 1997), where prediction errors serve as important signals for learning. In social and developmental psychology theorizing about predictions and their violations has an even longer tradition, namely in the context of cognitive schemata or dissonance (Kagan 2002; Proulx, Heine & Vohs 2010; Gawronski & Strack in press). Cognitive schemata are supposed to be the basis for expectations with which we interpret novel (social) situations. Both the meaning maintenance model (Proulx *et al.* 2010) and the cognitive consistency model (Gawronski & Strack in press), assume that incongruency or expectancy violation will result in negatively valenced arousal, aimed at reducing the inconsistency if at all possible. If not, this arousal presumably leads to an affirmation of any other meaning framework to which one is committed. For example, after exposure to an absurd Kafka parable subjects more strongly affirmed their cultural identity than after reading one of Aesop's meaningful parables (Proulx *et al.* 2010).

We propose the use of the term predictions instead of expectations, because it can encompass both sensory predictions as described in the predictive coding approach, and more high-level predictions arising from cognitive schemata. In addition, the term prediction has a more neutral connotation and can refer to both implicit (unconscious) predictions and explicit, ‚intellectual' prediction. The idea that the brain embodies implicit predictions of its environment can be traced back to Roger Shepard's (1984) internalization of long-enduring constraints (expected states of the external world). Apparently, the view of the brain as a prediction engine is increasingly gaining importance in several domains of mental functioning. Admittedly, a rigorous, critical comparison of the precise concepts used in these different subfields has yet to be carried out. Still, an important commonality seems to be that the brain is seen as continuously generating predictions based on prior similar experiences, while mismatches between those predictions and what is presented to the senses are significant and thus emphasized (by emotions) because they often require a response or at least an update of the current mental models though learning and plasticity.

Recently, Baingio Pinna (2010) made an interesting effort to extend the Gestalt concept to meaning. He observes that what is segregated by grouping principles (in our terms: a violation of the prediction) can be put together again in a meaningful organization (a meaning Gestalt), whose integrative, cohesive properties can be much stronger than those of perceptual layers of organization. A violation (deformation) of proper grouping at the perceptual level can be 'tolerated' by discovering a meaningful predicate, a 'happening' on the conceptual level that applies to the whole visual input and thus 'saves' the organization. Pinna (2010) uses deformed checkerboards as examples and shows that different deformations lead to phenomenally different experiences described by subjects as different happenings inflicted on the checkerboard.

Art can serve as a great example of predictive coding as a pervasive mechanism in mental functioning. Art works on different perceptual and non-perceptual levels. Clearly we do not always wind up with a coherent Gestalt. Nonetheless, it often seems the case that prediction error at the perceptual, stylistic level is in fact resolved on the content level. For example the deserting lady in Edvard Munch‘s *Separation*, ‚becomes one‘ with the road and the air. Similarly, Picasso‘s broken face in *Weeping Woman* is sad, and thus is ‚allowed to be‘ broken. In terms of meaning there is a clear congruency and thus the prediction error is mitigated. Obviously, these symbolic explanations are very speculative, but it is the kind of explanation we should expect since the interaction of style and content is what characterizes art.

Fig. 4 Separation (1896, il on canvas), Edvard Munch (© The Munch Museum/The Munch-Ellingson Group/BONO, Oslo/SABAM Belgium 2011).

7. Conclusions

The application of the predictive coding framework to art appreciation deserves a more elaborate discussion which we attempt to provide in our following paper (Van de Cruys & Wagemans in press). Other theories on the hedonic effects of perceptual organization (*e.g.* Ramachandran & Hirstein 1999) have faced the critique of being overly reductionist, which could also be raised against our theory. Therefore, a proper caveat is in place here. We do not pretend to explain the full-blown aesthetic experience in all its intricacies, if indeed such would ever be possible. But while we do not want to reduce the aesthetic experience to the mechanisms of predictive coding, we do argue that an important part of what we call an aesthetic experience (emotion) derives from our successes and failures in predicting what we are presented with. In this sense there is essentially no difference between everyday emotions and these particular aspects of aesthetic emotions, but of course a piece of art can provoke a whole range of different sentiments, some related to admiration of craftsmanship, some related to (associative) value of the contents, *etc*. Any art experience should however encompass a form of reward (otherwise we would not seek for it). It is the nature of this reward that we link to predictive coding.

In a similar way, one might object that when we reduce emotion to valence (hedonic tone) here, we set out for a very bleak, impoverished vision on aesthetic experience and emotional life in general. We think this approach is warranted though, because a) it allows us to link an important model in perception to emotion and b) there is an important ‚reductionist' current in emotion research too (*e.g.* Russell 2003; Barrett 2006), according to which emotions are socioculturally constructed but rooted in core affect (a combination of valence and activation) as a psychological primitive. Nonetheless we are familiar with the ‚richer' appraisal theories of emotion and appreciate their merits. It would be interesting to explore these theories in relation to our proposal. For example, two important appraisals (*e.g.* in Scherer 2001), the novelty check (appraisal) and the appraisal of coping potential, can be connected to our predictive coding view. Novelty, by definition unpredictable, is considered affectively negative but if used moderately a return to predictability is possible and we experience positive affect. In the latter case, the cognitive, predictive model is up to the task, in other words: it could cope with it. Thus, the positive emotion can be seen as a direct consequence of the implicit evaluation of our perceptual coping potential.

At the very start of this essay we noticed that predictive coding is ultimately grounded in a view of humans as open, self-organizing dynamical systems, an idea first formulated by a Gestalt theorist (Köhler 1920). As we progressed, a survey of the predictive coding theory felt in several ways as an effort to realize (part of the) research program of Gestalt theory. At least the ambitions seem similarly high: establishing predictions (instead of Gestalts) as general structuring principle of the brain as a whole. Karl Friston's (2005) generalization of this framework attempts to ground it in the basic task of any self-organizing system that seeks to resist a natural tendency to disorder: free energy (or surprise, in information theoretic terms) reduction. An approach that would presumably have been much applauded by Köhler, who made an effort in the same vein. To exist, that is to maintain and recreate itself (autopoesis, cf. Maturana & Varela, 1980), an organism must occupy a limited region of the physical state-space it can be in and thus avoid surprising states. Only this bounded set of states is compatible with its existence and thus constrains the interactions of the organism with the world. In dynamical systems terms, this ‚expected' set serves as an attractor for the organism's perception and behavior (for a complete overview of the free energy model, see Friston, 2010). Here we encounter spontaneous self-organizing dynamics, a explanatory concept invoked by Gestalt psychologists, in a system whose structure is constantly being updated based on experience (prediction errors). It can be argued that much work remains to be done to clarify the connection between predictive coding and self-organizing dynamics in the brain, but the same can be said of the original Gestalt concept.

In "Entropy and Art" Rudolf Arnheim (1971) attempts to reconcile the second law of Thermodynamics with the ubiquitous presence of order/organization in living (evolution) and nonliving nature, in search for a continuity between his theory on art and the mechanisms of natural science. Because he writes at a time in which Prigogine's work on far-from-equilibrium systems and Maturana & Varela's work on autopoesis was not yet published, he had to resort to positing new ‚cosmic tendencies' to account for the tendency towards order in art and nature. He too may have been interested in the current account of art, using predictions and prediction errors instead of vague pulls, pushes and tensions (Arnheim, 1971). It is based in biology (homeostasis) and in the organism's efforts to resist thermodynamic entropy, but it may make a theory of art appreciation more tractable in the lab.

While for Gestaltists the ultimate goal of organisms was the good Gestalt, for advocates of predictive coding it is the reduction of prediction error (complete predictability). As we reviewed, this is a dynamic concept. Organisms aimed at minimizing prediction errors can follow two strategies: changing the generated predictions (perceptual-cognitive mechanisms) or changing the things predicted (the environment) or its sampling of it (behavioral mechanisms) (Friston, 2010). Changing our mental model in perception and changing our behavior in the world serve the same goal. In both cases, the sense of mastery we derive from it is remarkable. Discovering a Gestalt, where there was none before, amounts to discovering that our mental model (prediction) agrees with what we find out there in the world. We managed to increase our ‚grasp' on reality and this seems to be genuinely, intrinsically pleasurable. Friston (2010) notes that minimizing prediction errors is equivalent to maximizing the sensory evidence for the agent's existence, if we consider the agent as a model of its world. Any progress in tuning the self to the world in this way seems to be deeply satisfying. There is a holism in this view that would have appealed to many a Gestaltist.

Summary

The predictive coding framework is increasingly used to explain behavioral and neural data in visual perception. The broader view that the brain is continuously generating predictions based on previous experience is also powerful in accounting for findings in other domains of mental functioning. We attempt to demonstrate that several insights from the Gestalt tradition are incorporated in this view, although typically not acknowledged. Additionally, we illustrate the explanatory power of this account with a discussion of aesthetic appreciation in visual art. In their works of art, artists often meticulously build up strong perceptual and conceptual predictions by using (and sometimes repeating) a familiar perceptual pattern or conceptual domain — only to subsequently either interrupt or blatantly destroy this ‚order'. The latter they often do by violating one or more of the strongest predictions of the pattern or domain used. In case of an interruption, the viewer often manages to fill in where the artist left off. In case of a violation, often a new order emerges, possibly on a different level. But in both cases the viewer is left with a positive feeling, which presumably is part of what we call an aesthetic experience.

Keywords: Aesthetic emotion, art appreciation, Gestalt, perceptual organization, predictive coding, prediction error, psychoaesthetics.

Zusammenfassung

Zur Interpretation behavioraler und neuraler Daten im Bereich der visuellen Wahrnehmung wird zunehmend der predictive coding-Ansatz herangezogen. Die allgemeine Sichtweise, dass das Gehirn auf Basis vorheriger Erfahrungen kontinuierlich Vorhersagen generiert, hat auch für Befunde in anderen kognitiven Funktionsbereichen großes Erklärungspotential. Wir versuchen zu zeigen, dass sich in diesem Ansatz verschiedene Ideen der Gestalt-Tradition wiederfinden, auch wenn dem üblicherweise nicht Rechnung getragen wird. Des Weiteren illustrieren wir das Erklärungspotential dieses Ansatzes anhand einer Diskussion der Ästhetik bildender Kunst. In ihren Kunstwerken erzeugen Künstler oft bewusst perzeptuelle und konzeptuelle Erwartungen, indem sie ein vertrautes perzeptuelles Muster oder einen Konzeptbereich verwenden (und z.T. wiederholen) — nur um diese „Ordnung" daraufhin abrupt zu unterbrechen oder klar zu zerstören. Letzteres wird oft durch Verletzung einer oder mehrerer der stärksten Erwartungen hinsichtlich des verwendeten Musters bzw. Konzeptbereiches erreicht. Im Falle einer Unterbrechung ist der Betrachter oft in der Lage, das zu ergänzen, was der Künstler ausgelassen hat. Im Falle einer kompletten Zerstörung dagegen ergibt sich häufig eine neue Ordnung, z. B. auf einer anderen Ebene. In beiden Fällen jedoch bleibt beim Betrachter ein positives Gefühl zurück, das vermutlich Teil dessen ist, was wir als ästhetisches Erleben bezeichnen.

Schlüsselwörter: Ästhetisches Gefühl, Kunstverständnis, Gestalt, Wahrnehmungsorganisation, Predictive coding, Vorhersagefehler, Psychoästhetik.

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