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Comparison of the determinants for positive and negative affect proposed by appraisal theories, goal-directed theories, and predictive processing theories

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The determinants of affect proposed by the appraisal theory, the goal-directed theory, and the predictive processing theory are compared. The first theory attaches a role to multiple factors (goal-related factors, expectation-related factors, and control), the second theory only focuses on goal-related factors, and the third theory only focuses on expectation-related factors. We hold each of the theories against the light of (some) empirical evidence and examine whether the increase in parsimony of the second and third theories comes at a cost of scope or whether there are ways around it.

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What is the origin of affect? This question has been addressed by many theories, of which we will discuss the following three: the appraisal theory [1], the goal-directed theory (in particular the version developed by Moors [2••,3••]), and the predictive processing theory [4,5]. Although these theories take as their primary explanandum emotion, behavior, and perception/behavior, respectively, they do also offer an account of affect. Here, we understand affect in the narrow sense as valence, a bipolar dimension of feelings ranging from extremely negative to extremely positive. Thus, a complete account of affect understood in this sense should propose factors that determine the direction or polarity (positive versus negative) and extremity or intensity of affect (more to less positive/negative). Another implication of understanding affect as a bipolar dimension (and not as two independent dimensions) is that positive affect, the topic of the current special issue, cannot be understood in isolation from its negative counterpart as they are two sides of the same coin. An increase in positive affect entails a decrease in negative affect. Mixed affect is only possible if different entities are evaluated. Further, by restricting affect to the valence dimension, we do not include the arousal dimension (as Russell [6], does in his notion of 'core affect'). Thus, the extremity or intensity of valence should not be conflated with arousal. Arousal is physiological activity that supports bodily functions such as homeostasis and behavior. Conspicuous changes in arousal can also be felt, but this is true for anything that is perceived and becomes the content of a representation [2••].

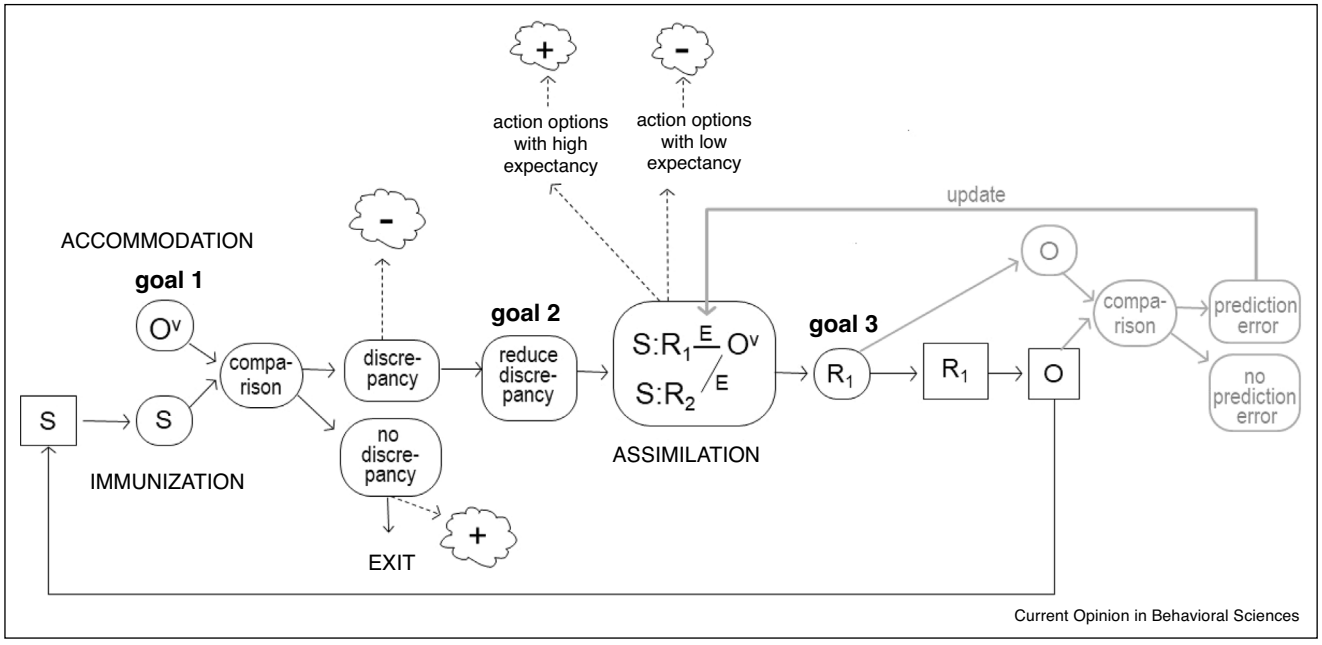
After describing the basic assumptions of each of the three theories in a nutshell, we compare the factors that they propose for the direction and extremity of affect to identify the overlap and divergence among them. After that, we evaluate their accounts of affect in light of the criteria of parsimony and scope [7], that is, the least number of factors they require to explain the widest range of findings.

Determinants of affect proposed by theories: overlap and divergence

Appraisal theory

In the appraisal theory of emotion [1], emotions are collections of the following components: appraisals, action tendencies, physiological responses, expressive behavior, and feelings. Feelings (of which affect is one aspect) thus have a part-whole relation to emotions. An emotion starts when an incoming stimulus is appraised on a number of appraisal criteria such as goal relevance, goal in/congruence, un/expectedness, ease/difficulty to control, and internal/external cause. The resulting representation of appraisal values (e.g. goal relevant, goal incongruent, unexpected, difficult to control, and externally caused) activates the representation of a response (i.e. an action tendency, e.g. tendency to flee), which in turn produces physiological responses, which prepare and support behavior (e.g. actual flight). Aspects of appraisals, action tendencies, and (physiological and motor) responses emerge into consciousness as the emotion

Figure 1



Goal-directed cycle.
Note: squared boxes stand for observable (overt/physical) entities, rounded boxes for non-observable (covert/mental) entities, and clouds for affect (positive/negative). S = stimulus; O^V = valued outcome or goal; O = outcome; R = response or behavior; E = expectancy. Adapted from Ref. [38].

unfolds, and together these aspects form the content of feelings.

Appraisals have been shown to be the primary determinant of (the reportable part of) feelings [8] with the appraisal criteria of goal relevance, goal in/congruence, un/expectedness, and ease/difficulty to control as the prime determinants of positive and negative affect specifically. Stimuli appraised as in/congruent with one's goals or needs produce negative/positive affect. This affect is enhanced when the stimuli are appraised as more goal relevant and as more unexpected [9••]. In addition, the negative affect produced by goal-incongruent stimuli is enhanced when the stimuli are also appraised as difficult to control. Put simply, rewards feel better when they are bigger and more unexpected whereas non-rewards feel worse when they are bigger and more unexpected and when they are more difficult to overcome. Note that the hypotheses about goal in/congruence and un/expectedness are also shared by reinforcement learning theories [10•]

Goal-directed theory

The goal-directed theory of behavior recently developed by Moors [2••,3••] (Figure 1) proposes that most of our behavior (both so-called emotional and non-emotional behavior) is part of a goal-directed cycle that starts with a comparison between the representation of a (actual or anticipated) stimulus and a goal (i.e. representation of a valued outcome). If a discrepancy is detected, a second goal to undo the discrepancy is activated, which can be achieved via the broad strategies of (a) assimilation (i.e. acting to bring the stimulus in line with the goal), (b) accommodation (i.e. choosing a different goal that is more in line with the stimulus), and (c) immunization (i.e. reinterpreting the stimulus so that it is more in line with the goal [11]). In the case of assimilation, a concrete behavior option is selected from the behavioral repertoire if it has the highest expected utility. The expected utility of a behavior option depends on the value of the outcomes of this option and the expectancy that the option will lead to these outcomes.[4] The selected behavior option activates its corresponding action tendency, which in turn translates into overt behavior and produces an actual outcome. This outcome is a novel stimulus, which is fed back as the input to the next cycle where it is again compared with the goal. The cycle is repeated until there is no discrepancy left or until other goals take over. The outcome of the behavior not only serves as the input to a new goal-directed cycle, but is also compared with the outcome that was expected to result from the selected action. If the latter comparison yields a discrepancy (i.e.

[4] This is different from the appraisal theory, which postulates fixed associations between specific patterns of appraisal values (representations of stimulus features) and specific action tendencies (response representations), irrespective of the expected utilities of the action tendencies in the current context. This qualifies as a sophisticated stimulus-driven process [2••,13].

prediction errror), this may lead to an updating of the expectancies of the behavior options in the repertoire (in line with reinforcement learning theory). Each of the steps in the cycle can leave traces in consciousness, which together, form the content of feelings (similar to what appraisal theory proposes). Cycles for subordinate goals are embedded in cycles for higher-order goals [see also Ref. 12]. Just like an action option is chosen if it has the highest expected utility for reaching a goal, a subordinate goal is chosen if it has the highest expected utility for reaching a superordinate goal.

This cycle presents at least two occasions for the production of positive/negative affect: during (a) stimulus-goal comparison and (b) behavior selection. The goal-directed theory has partial overlap with the appraisal theory in that it explains the direction of affect by the presence/absence of a stimulus-goal discrepancy (i.e. goal in/congruence in appraisal parlance) and the extremity of affect by the magnitude of this discrepancy (i.e. goal relevance in appraisal parlance).[5]

Both theories differ, however, in that the appraisal theory adds un/expectedness of the stimulus and ease/difficulty to control the stimulus to the set of determinants for affect whereas the goal-directed theory takes (the presence/absence and magnitude of) the stimulus-goal discrepancy to be the sole determinant of affect. We are quick to note, however, that discrepancies in the goal-directed theory need not be actual (i.e. between a goal and an actual stimulus) but may also be impending (i.e. between a goal and an impending stimulus). Both actual and impending non/discrepancies may produce positive/negative affect. This allows to explain why affect is not only produced during the phase of stimulus-goal comparison but also during the phase of action selection. Indeed, during the latter phase, the presence/absence of behavior options with a high expected utility signals an impending non/discrepancy. Simply put, a person not only feels happy when she gets what she wants, but also when she anticipates getting what she wants.[6]

In the goal-directed theory, the strategies of assimilation, accommodation, and immunization are only generated if the organism detects a discrepancy between a stimulus and a goal, which forms the basis of negative affect. At the same time, these strategies are also only generated when they have an above-zero expected utility, which forms the basis of positive affect. This means that whenever an organism engages in overt/physical behavior (as in assimilation) or covert/mental actions (as in accommodation or immunization) negative and positive affect are deeply intertwined. Negative affect can still occur alone, when a discrepancy is detected but no strategy is expected to yield a solution (i.e. the person does not see any behavior option, is unable to replace the goal with another goal, and is unable to see the stimulus in a different light). Positive affect can also occur in the absence of negative affect, at the time of goal satisfaction. This positive affect is local (i.e. tied to a single goal) and its influence on the person's overall affective state is likely fleeting. This is because a person has multiple goals and these will rarely all be satisfied at the same time. When one goal is satisfied, the discrepancies with other goals may start to loom, or formulated more positively, the person may open up to explore opportunities for the satisfaction of other goals.

Predictive processing theory

The predictive processing theory of perception/behavior [4,5] proposes that an organism approaches the world with predictions of what it will encounter (i.e. expected stimuli) and that when a stimulus forms a discrepancy with a prediction—called a prediction error—two strategies can be taken: (a) accommodation (i.e. updating the prediction in line with the stimulus) and (b) assimilation (i.e. acting to get the stimulus in line with the prediction and make the prediction come true). The choice between accommodation and assimilation is determined by stability as a function of expected uncertainty (precision): The element that is least resistant to change will change. Predictions are generated at every level of the visual/motor hierarchy (sensory, configural, conceptual). Higher levels form predictions about lower levels and prediction errors at lower levels travel back to the higher levels.

Applying this theory to affect, Van de Cruys [15••] proposed three varieties of affect that can contribute to the total experienced affect: A first variety stems from absolute prediction errors (with presence/absence leading to negative/positive affect, and larger ones leading to more negative affect). A second variety stems from the increase/decrease of prediction errors (with increase/decrease leading to negative/positive affect [16]). A third variety stems from second-order prediction errors regarding the rate of increase/decrease of first-order prediction errors (with a lower/higher than expected rate leading to more negative/positive affect).

Although the predictive processing theory is reminiscent of the goal-directed theory in several respects (the notions of discrepancy, accommodation, and assimilation), the key difference is that the discrepancy in the predictive processing theory is between an actual stimulus and a

[5] By tying affect to the degree of goal dis/satisfaction, both theories can explain why people can have mixed feelings, as shown by an independence (instead of interdependence) between reports of affect on unipolar rating scales (one for positive and one for negative affect [14]): A single stimulus can touch on multiple goals, thereby satisfying some goals (thus generating positive affect) but dissatisfying others (thus generating negative affect).

[6] Note that in the case of an impending non/discrepancy, the certainty of this non/discrepancy pops up as an additional factor next to its presence/absence and magnitude. This certainty is tied to the expectancy of the to-be-chosen behavior option.

predicted or *expected* stimulus (i.e. an *expectation*), whereas in the goal-directed theory it is between an (actual or impending) stimulus and a *desired* stimulus (i.e. a *goal*). In predictive processing theory, non-valued states (expectations) can breed value (affect) whereas in the goal-directed theory, only valued states (goals) can do so. Therefore, predictive processing theory can be said to explain away goals and values whereas the goal-directed theory can be said to leave an unexplained residual or a form of circularity [17]. Note that while the goal-directed theory does have a role for discrepancies with expectations (prediction errors), they are not immediate causes of affect. Because expectations are entirely at the service of goal satisfaction, non/discrepancies with expectations produce positive/negative affect only insofar as they signal impending non/discrepancies with goals.[7]

The predictive processing theory has partial overlap with the appraisal theory in that it postulates a role for expectation-related factors as determinants of affect, albeit a somewhat different role: a stand-alone determinant in the predictive processing theory, a moderator of the influence of goal-related factors in the appraisal theory.

Evaluating the proposed accounts in light of parsimony and scope

The focus on a single type of determinants in both the goal-directed theory and the predictive processing theory is more parsimonious than the inclusion of multiple determinants in the appraisal theory. The question is whether this parsimony comes at a cost of scope when we hold these accounts against the light of certain well-established findings (and intuitions).

The appraisal theory and the goal-directed theory share the factors of the presence/absence and magnitude of the discrepancy between stimuli and goals as determinants of affect. This allows them to explain the well-established finding that gains lead to positive affect and losses to negative affect [e.g. Refs. 18,19].

In the appraisal theory, un/expectedness acts as a moderator of the relation between goal in/congruence and affect. At first blush, postulating such a role is required to explain the robust (but not ubiquitous) findings that (a) unexpected gains/losses lead to more positive/negative affect than expected gains/losses [20–23 but see Refs. 24,25] and (b) better/worse-than-expected outcomes lead to more positive/negative affect than equal-than-expected outcomes [26]. Yet there are ways in which the goal-directed theory can make sense of both types of findings without having to include un/expectedness as a moderator.

In studies that examine the first effect ('un/expectedness boosts affect'), expectations of outcomes are either manipulated by informing participants about the probabilities of these outcomes (e.g. in lotteries [22]) or by manipulating the actual probability or frequency of these outcomes (e.g. in performance tasks [27]). Outcomes that mis/match the most probable outcomes are considered un/expected. Based on the idea that scarcity or difficulty breeds value, less probable outcomes may have a higher value, and this may be the reason why reaching them generates more positive affect [28,29]. Such an explanation of the purported findings rests entirely on the values of goals and does not require invoking the un/expectedness of a stimulus as a moderator.

Also the second effect ('better/worse-than-expected outcomes boost affect') still fits in the goal-directed account. The problem can be stated as follows: A reward that is better-than-expected on a certain trial is most often also better-than-wanted and thus forms a discrepancy with a goal on that trial, and a discrepancy should lead to negative affect. Keeping in mind the hierarchical organization of goal-directed cycles, a possible solution is to argue that this goal is a subordinate goal that is itself instrumental to the superordinate goal to gain as much as possible. A reward that is better than, and hence discrepant with, the subordinate goal, would then still entail progress towards the superordinate goal.

The predictive processing theory fits like a glove to another set of affective phenomena. There is evidence that prediction errors indeed produce (short-lived) negative affect (i.e. first variety of affect [30]) and that a reduction of prediction error produces positive affect (i.e. second variety of affect [31]). The finding that people have a preference for medium complex and medium novel stimuli (i.e. with medium prediction error [32]) has been taken by some as evidence for a curvilinear instead of a linear relationship between the magnitude of the prediction error and affect. An alternative explanation (also in line with the second variety of affect), however, is that people prefer these stimuli because they hold the promise (i.e. expectation) of a (positively valenced) reduction in prediction error [15••]. In addition, studies on laughter [33,34] and on positive affect created by unexpected fluency [35] support the idea that higher than expected rates of prediction error have a particularly positive affective mark (in line with the third variety).

In most studies, however, it cannot be ascertained that the prediction errors were pure predictions errors, that is, that they were only discrepancies with expectations and not also with goals. More problematic perhaps is that the predictive processing theory has difficulty to explain the findings that goal in/congruence leads to negative/positive affect given that it does not postulate the existence of goals (as valued representations) per se. Expectations and

[7] Prediction errors can also produce negative affect insofar as they constitute a stimulus that is discrepant with the goal to be good at predicting things.

goals are non-overlapping constructs: People can want something they don't expect, and they can expect something they don't want. Many people want world peace but don't expect it to happen any time soon. Still, every tiding of war and suffering is a blow to their happiness. Conversely, people can expect trouble without wanting it. One way out for this theory would be to argue that goals and expectations are not orthogonal, but rather oblique (i.e. they still correlate). This would mean that studies that manipulate goal-in/congruence unwittingly also manipulate un/expectedness. Another way out is to argue that what other theories call 'goals' are in fact 'stable expectations', in the sense of being (a) high-precision (i.e. robust to negating evidence), and (b) high-level (i.e. spanning a larger temporal range [36•,37]). This move helps to preserve the functional features of goals: the higher the value of the goal (in the goal-directed theory), or the more stable an expectation (in the predictive processing theory), the more resistance to accommodation. It also helps to elucidate cases in which people want things they don't expect. They may not expect world peace to happen overnight, but they may have a stable expectation that it will one day.

Conclusion

Parsimonious accounts of affect, offered by the goal-directed theory and the predictive processing theory seem, at first sight, unable to explain certain findings, thus requiring more complex accounts, as proposed by the appraisal theory. We hope to have illustrated, however, that there are ways in which these findings can nevertheless be accommodated in single-determinant accounts of affect. A major challenge for these parsimonious theories is to put the suggested alternative explanations to the test. Disambiguation between theories focusing on goals and theories focusing on expectations may be more difficult, as some of the disagreement seems to be semantic.

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Nothing declared.

CRediT authorship contribution statement

Agnes Moors: Conceptualization, Writing - original draft, Writing - review & editing. **Sander Van de Cruys:** Conceptualization, Writing - review & editing. **Gilles Pourtois:** Writing - review & editing.

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