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Finding a balance: modulatory effects of positive affect on attentional and cognitive control☆

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Positive affect has been linked to increased flexibility in disparate domains, however, conclusions across these domains are still missing. In this review, we focus on flexibility studied in the context of cognitive control and attention, where striking similarities are observed. Positive affect increases flexibility and broadens attention at the cost of stability or goal maintenance. Importantly, these effects are associated with low levels of approach motivation, whereas when approach motivation is high, goal maintenance and narrowed attention is enhanced. Accordingly, this review suggests that effects of positive affect on cognition could be domain general, but they depend on levels of approach motivation. More research is needed to assess if they could be extrapolated to other aspects of cognition.

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Positive affect and the stability–flexibility–balance

Isen [1] was amongst the first to provide empirical evidence for enhanced flexibility under positive affect, which is defined as the mental ability to smoothly adjust thinking and processing styles to contextual demands. While her findings fueled much research, increased flexibility was found in very different domains, including problem solving [2], verbal fluency [3] or task switching [4]. This list illustrates two problems with the concept *flexibility*: The first one being that it is ill defined and encompasses very different cognitive operations, such as creativity or task switching. Different forms of flexibility may co-exist, such as associative flexibility (e.g. creating new associations in a verbal fluency task), regulative flexibility (e.g. adjusting to changes during task switching) and attentional flexibility (e.g. switching attention between different stimulus features) [5]. The lack of clarity in what flexibility actually is has led to a rather lenient use of this term [6], with sometimes discrepant findings reported for effects of positive affect on it [3].

The second problem is the notion that flexibility *improves* cognition. Although cognitive flexibility enjoys a positive reputation, this is not necessarily the ideal mode of processing [7••]. The *flexibility–stability–balance* of cognitive control [8,9] emphasizes that antagonistic control demands are at play and increased flexibility comes at the cost of reduced stability [7••,10]. While flexibility allows adaptive adjustments, this comes at the cost of increased distractibility [7••]. Stability on the other hand supports goal maintenance at the cost of overly rigid behavior. Therefore, an apparent gain in flexibility is accompanied by a decrease in stability, which depending on the context and task demands, could be either beneficial or detrimental for performance [11••].[7]

In this opinion paper, we focus on effects of positive affect on regulative and attentional flexibility. We discuss this from two perspectives, a cognitive control and an attentional control one. Even though they are strongly intertwined, studies from these two perspectives apply different tasks, which reveal effects that are described in terms of either attention or cognitive control. However, as we argue hereafter, despite these different methodologies and terminologies, common

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[7] Importantly, this framework entails that flexibility and stability operate on the same level of goal hierarchy.

conclusions can be drawn for them, and their results can be reconciled within a common framework. From a standard cognitive control perspective, flexibility is operationalized as improved performance to unexpected or new stimuli. In comparison, studies on attentional control focus on the ability to attend to specific information while resisting distraction. Hence, while the cognitive control perspective allows exploration of the flexibility–stability–balance, the attentional control perspective mostly addresses the impact on distractibility, and therefore reduced stability. In the following sections, we first review the modulatory effects of positive affect and motivation within each of these two research areas separately. Following this, we consider some common principles and suggest that an integrative approach could not only lead to a better conceptualization of the flexibility–stability–balance, but also a better understanding of positive affect on the one hand, and of the common mechanisms underlying attentional and cognitive control on the other hand.

Positive affect and cognitive control

Within the domain of cognitive control, there is ample evidence that positive affect biases the flexibility–stability–balance towards increased flexibility and reduced stability. In a perceptual switching task [7••], participants in positive affect were better in switching towards novel colors (thus increased flexibility), while they were worse in ignoring novel colors (thus decreased stability). These findings were (conceptually) replicated several times by independent researchers, including a recent neuroimaging study showing that the dorsal anterior cingulate cortex, which is an important hub for cognitive control in the brain, was implicated in the flexible selection of new action rules [4]. Similarly, using the AX continuous performance task (AX-CPT), it has been found that positive affect reduced cue maintenance (thus stability) but increased the processing of unexpected rare events (thus flexibility) [12–14].

Importantly, this gain in flexibility has been shown to depend on motivational factors, in particular the intensity of approach motivation, which is defined as 'the impetus to move towards' [15•,16]. Positive affect low in approach motivation improved cognitive flexibility, while positive affect high in approach motivation decreased flexibility and improved stability [17,18]. Interestingly, identical effects were found when reward was used as incentive. When non-contingent rewards were randomly presented, presumably eliciting positive affect low in approach motivation, flexibility was increased [12,19]. However, when rewards were performance-contingent, presumably eliciting positive affect high in approach motivation, flexibility was decreased [12,19]. These and related findings have been discussed in recent reviews [7••,10].

However, an important element, which has not been addressed yet explicitly, is that findings from the AX-CPT are very often discussed within the dual-mechanisms of cognitive control (DCM) framework [20,21]. The DCM framework distinguishes proactive and reactive control modes. In a proactive control mode, goal-relevant information drives perception and actions in an anticipatory manner, that is, before an event occurs. In a reactive control mode, corrective measures are triggered when goals are not met, that is, after an interference is detected. Increased flexibility, as the ability to adjust according to task demands, could therefore result from either decreased proactive control (i.e. action selection is not guided by cue information) or increased reactive control (i.e. new information triggers a larger orienting response). Accordingly, there is no precise mapping between either of these two different control modes and flexibility. Moreover, as these control modes could act more or less independently, the interpretation of these results in terms of the flexibility–stability–balance has to be done with caution (see also Ref. [22]). However, changes in proactive control have been linked to positive affect. For example, positive mood induced by an imagery technique led to decreased proactive control (but increased reactive control) in a standard anti-saccade task, that is, where participants had to inhibit automatic eye movements towards a lateralized target location [23]. Complementary, a computational modelling account [24] showed that task-irrelevant positive affect led to decreased proactive control, while performance contingent reward led to increased proactive control. Similarly, by combining the AX-CPT with task-irrelevant pictures, neurophysiological studies reported that positive affect decreased proactive control [25]. Again, this modulation was affected by motivational factors, as positive affect high in approach motivation (induced by pictures [26,27] or performance contingent reward [28,29]) led to increased proactive control. This suggests that even though there is no clear correspondence between the DCM framework and the flexibility–stability–balance, both are similarly influenced by positive affect and approach motivation, which points to a possible shared underlying mechanism. In summary, positive affect does not unconditionally increase flexibility while reducing stability, as cognitive flexibility under positive affect can be counteracted by high approach motivation and reward prospect.

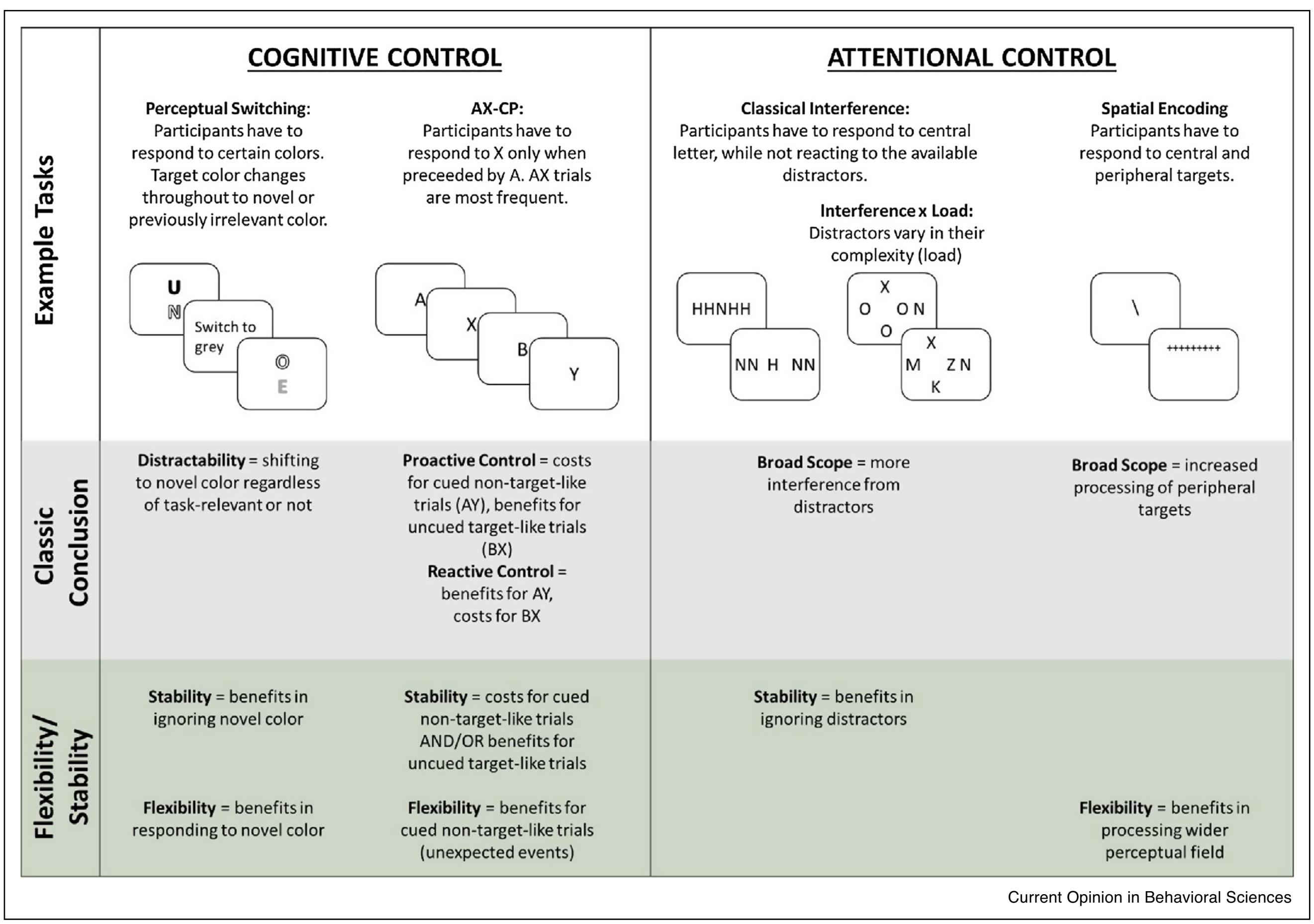
Positive affect and attentional control

Attentional control enables the selection of relevant information and the suppression of irrelevant distractor information. According to the broaden and build theory [30,31•], positive affect can change this information selection through a gain in the attentional scope, that is, *broadened attention*, whereby a larger portion of the visual field is attended [32–36]. Interestingly, there seems to be a trade-off whereby this gain is compensated by increased distractibility. This effect has been studied with varying experimental paradigms.

Initially, the broadening of attention under positive affect has been demonstrated using interference paradigms, where a larger distraction was observed in positive affect [37]. However, studies vastly differed in their methodological approaches and revealed mixed findings [38] (for a review see Ref. [33]). To reconcile these discrepant findings, it has been proposed that the link between positive affect and attentional control is complex, and its strength and direction depend on methodological factors [39]. Accordingly, positive affect does not necessarily trigger attentional broadening, but it could enhance the (currently) dominant scope of attention, possibly through a brain-wide gain in neural communication [40,41]. This variability has also been related to specific motivational effects: while high approach motivation fosters narrowing of attention, low approach motivation fosters broadening instead [15•]. Similar results have been reported when contrasting performance-contingent reward to randomly presented reward [42], where only the first led to less interference (thus narrowing). By contrast, randomly presented rewards can lead to opposite effects in the following trials [41 versus 42], which were explained by local affective changes induced by reward perception: Reward pursuit can increase approach motivation, thereby increasing focus and attentional narrowing. Alternatively, reward attainment can signal a comfortable task performance, increasing exploration and attentional broadening [43–45]. Nevertheless, the temporal dynamics and conditions of how reward pursuit and attainment interact with each other remain open questions.

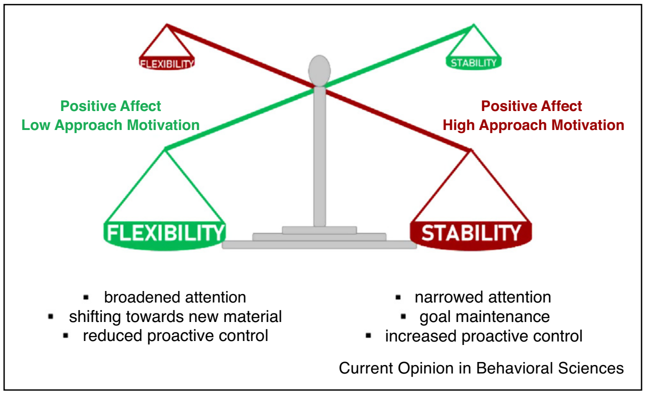
However, these complex interaction effects driven by positive affect and approach motivation from the current to the next trial highlight the fact that these interference tasks likely tap into cognitive control states, besides attentional control. Consequently, the usefulness of these paradigms to study attention has been questioned [33]. To overcome this limitation, attentional control has been explored using the load theory of attention [46], which predicts that the extent to which unattended stimuli are

Figure 1



The studies on positive affect discussed in this paper can roughly be organized according to a division between cognitive control and attentional control. However, this division is rather arbitrary, and mostly stems from different tasks and methodologies used. Interestingly, they can be unified when interpreted within the flexibility–stability–balance.

Figure 2



The influence of positive affect/approach motivation on the flexibility–stability–balance.
Positive affect tips the flexibility–stability–balance depending on motivational intensity: While positive affect low in approach motivation (one side of the balance, green color) leads to more flexibility and consequently less stability, positive affect high in approach motivation (the other side of the balance, red color) fosters stability over flexibility.

suppressed depends on the amount of resources available. Therefore, in subsequent experiments, attentional scope was tested in conditions varying in perceptual (or working memory) load. Using this framework, it has been found that positive affect led to broadened attention: Irrespective of whether these unattended stimuli were task relevant or not, performance and neurophysiological indices showed a decreased filtering as well as reduced differentiation of them [32,47]. All in all, positive affect can broaden attention, but this gain likely reflects a complex and dynamic change in how the incoming information is eventually sampled [48•].

Conclusion and outlook

This short review suggests that effects of positive affect on cognitive control and attention could eventually share some similarities. In the case of cognitive control, positive affect increases the ability to shift to new information at the cost of reduced goal maintenance. When attentional control is considered, positive affect leads to a broader attentional focus at the cost of distractibility. However and importantly, as shown in Figure 2, these effects are found only if approach motivation is low. If approach motivation is high, opposite effects are found with increased stability and narrowed attention. Based on this striking analogy, it is tempting to assume that a similar mechanism is at play for both of them. However, whether or not attentional scope goes hand in hand with the stability–flexibility–balance, still needs to be demonstrated empirically. In this closing section, we suggest three complementing avenues for future research in this area that hold promise to elucidate this important question.

First, future studies should assess effects of positive affect and motivation on cognitive control and attentional control using well-controlled and well-powered within-subjects designs. While some findings presented here above were (conceptually) replicated, the presented studies hardly addressed issues of statistical power. Therefore, conclusions have to be made cautiously, in particular when they are derived from between-subjects or neuroscientific methods. Direct replications as well as well-designed experiments with larger sample sizes are highly desirable to achieve a correct and valid understanding of positive affect, and its role in attention as well as cognitive control. In particular, to establish if a common mechanism could undergird them as we propose here, it appears essential to quantify the amount of variance shared within the same participants. In this context, it would be useful to supplement standard behavioral indices with neurophysiological markers informing about the need for cognitive control [49] or preparations to act [50,51].

Second, different tasks have been used to study cognitive control and attentional control (see Figure 1), which inevitably hinders the possibility to compare them easily. Accordingly, it would be highly beneficial to devise and validate novel experimental paradigms where these two could be measured concurrently.

Last, the approach motivation has almost exclusively been studied using the dichotomy between low and high motivational intensity. Likewise, positive affect is often compared to a non-positive or neutral state. Despite methodological advantages, it appears important to depart from this simple categorization, and to consider more fine-grained variations along both motivation and affect [15•]. When doing so, different manipulations of motivational and affective states should be validated and systematically compared to each other. For example, what exact positive affective state (also in terms of approach motivation) is elicited when reward is made contingent on performance remains currently untested. Likewise, it appears important to better model the influence of arousal as this dimension might also interact with approach motivation (see Ref. [41]). Hence, a richer and more systematic exploration of the variety of possible positive affect states in relation to approach motivation would not only enhance ecological validity, but could also shed some new light on their differential effects on cognition, brain and behavior.

We conclude that it is important to study effects of positive affect on cognition in relation to approach motivation, since they are neither interchangeable nor orthogonal to each other (see Figure 2 and Ref. [16] for a similar discussion). Even though in some situations motivation might outweigh positive affect or *vice versa*, we propose that in many cases, their joint contribution accounts for more variance than their independent effects. As we have proposed here, this framework turns out to be valuable to account for the changes seen across various tasks and contexts in attentional control or cognitive control resulting from positive affect. Their integration into a common framework could (1) help refine and improve the concepts of flexibility and stability in the existing literature and (2) help assess the amount of possible overlap between them in terms of shared cognitive architecture and neural mechanisms.

Conflict of interest statement

Nothing declared.

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References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Isen AM: **Positive affect**. In *Handbook of Cognition and Emotion.* Edited by Dalgleish m, Power MJ. Wiley-Blackwell; 1999:522-539.

2. Shen W, Zhao Y, Hommel B, Yuan Y, Zhang Y, Liu Z, Gu H: **The impact of spontaneous and induced mood states on problem solving and memory**. *Think Skills Creativity* 2019, **32**:66-74.

3. Phillips LH, Bull R, Adams E, Fraser L: **Positive mood and executive function: evidence from Stroop and fluency tasks**. *Emotion* 2002, **2**:12-22.

4. Wang Y, Chen J, Yue Z: **Positive emotion facilitates cognitive flexibility: an fMRI study**. *Front Psychol* 2017, **8**:1-11.

5. Sacharin V: *The Influence of Emotions on Cognitive Flexibility. Doctoral Dissertation*. University of Michigan; 2009.

6. Friedman RS, Förster J: **The influence of approach and avoidance cues on attentional flexibility**. *Motiv Emot* 2005, **29**:69-81.

7. Dreisbach G, Fröber K: **On how to be flexible (or not):**
•• **modulation of the stability-flexibility balance**. *Curr Dir Psychol Sci* 2019, **28**:3-9.
Short review on how positive affect, reward prospect, and task context modulate the stability flexibility balance from a cognitive control perspective.

8. Hommel B: **Between persistence and flexibility: the Yin and Yang of action control**. *Advances in Motivation Science*. Elsevier; 2015:33-67.

9. Goschke T: **Volition in action: intentions, control dilemmas and the dynamic regulation of intentional control**. In *Action Science. Foundations of an Emerging Discipline.* Edited by Prinz W, Beisert M, Herwig A. MIT Press; 2013:409-434.

10. Goschke T, Bolte A: **Emotional modulation of control dilemmas: the role of positive affect, reward, and dopamine in cognitive stability and flexibility**. *Neuropsychologia* 2014, **62**:403-423.

11. Pourtois G, Vanlessen N, Bakic J, Paul K: **Modulatory effects of**
•• **positive mood on cognition: lessons from attention and error monitoring**. *Curr Dir Psychol Sci* 2017, **26**:495-501.
Shows how positive mood increases the processing of external information by discussing neuroscientific work on attention and error monitoring.

12. Fröber K, Dreisbach G: **The differential influences of positive affect, random reward, and performance-contingent reward on cognitive control**. *Cogn Affect Behav Neurosci* 2014, **14**:530-547.

13. van Wouwe NC, Band GPHH, Ridderinkhof KR: **Positive affect modulates flexibility and evaluative control**. *J Cogn Neurosci* 2011, **23**:524-539.

14. Hefer C, Dreisbach G: **The volatile nature of positive affect effects: opposite effects of positive affect and time on task on proactive control**. *Psychol Res* 2020, **84**:774-783.

15. Harmon-Jones E: **On motivational influences, moving beyond**
• **valence, and integrating dimensional and discrete views of emotion**. *Cogn Emot* 2019, **33**:101-108.
Highlights the role of motivational intensity and motivational direction when studying the effects of positive and negative affect on cognition.

16. Gable PA, Dreisbach G: **Approach motivation and positive affect**. *Curr Opin Behav Sci* 2021. in this volume.

17. Liu Y, Wang Z: **Positive affect and cognitive control: approach-motivation intensity influences the balance between cognitive flexibility and stability**. *Psychol Sci* 2014, **25**:1116-1123.

18. Liu L, Xu B: **The effect of low versus high approach-motivated positive affect on the balance between maintenance and flexibility**. *Neurosci Lett* 2016, **622**:55-60.

19. Fröber K, Dreisbach G: **How performance (non-)contingent reward modulates cognitive control**. *Acta Psychol (Amst)* 2016, **168**:65-77.

20. Mäki-Marttunen V, Hagen T, Espeseth T: **Proactive and reactive modes of cognitive control can operate independently and simultaneously**. *Acta Psychol (Amst)* 2019, **199**:102891.

21. Chiew KS, Braver TS: **Context processing and cognitive control: from gating models to dual mechanisms**. In *The Wiley Handbook of Cognitive Control.* Edited by Egner T. Wiley Blackwell; 2017:143-166.

22. Gratton G, Cooper P, Fabiani M, Carter CS, Karayanidis F: **Dynamics of cognitive control: theoretical bases, paradigms, and a view for the future**. *Psychophysiology* 2018, **55**:e13016.

23. Vanlessen N, De Raedt R, Mueller SC, Rossi V, Pourtois G: **Happy and less inhibited? Effects of positive mood on inhibitory control during an antisaccade task revealed using topographic evoked potential mapping**. *Biol Psychol* 2015, **110**:190-200.

24. Grahek I, Musslick S, Shenhav A: **A computational perspective on the roles of affect in cognitive control**. *Int J Psychophysiol* 2020, **151**:25-34.

25. Chaillou A, Giersch A, Hoonakker M, Capa RL, Doignon-Camus N, Pham B, Bonnefond A: **Evidence of impaired proactive control under positive affect**. *Neuropsychologia* 2018, **114**:110-117.

26. Cudo A, Francuz P, Augustynowicz P, Stróżak P: **The effects of arousal and approach motivated positive affect on cognitive control. An ERP study**. *Front Hum Neurosci* 2018, **12**:e320.

27. Li Y, Zhang Q, Liu F, Cui L: **The effect of the high-approach versus low-approach motivational positive affect on the processing stage of cognitive control: an event-related potential study**. *Neuroreport* 2018, **29**:41-47.

28. Chiew KS, Braver TS: **Temporal dynamics of motivation-cognitive control interactions revealed by high-resolution pupillometry**. *Front Psychol* 2013, **4**.

29. Choi JM, Cho YS: **Impaired cognitive control during reward pursuit and punishment avoidance**. *Motiv Emot* 2020, **44**:832-845.

30. Fredrickson BL: **The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions**. *Am Psychol* 2001, **56**:218-226.

31. Fredrickson BL, Joiner T: **Reflections on positive emotions and**
• **upward spirals**. *Perspect Psychol Sci* 2018, **13**:194-199.
Updated perspective on how positive emotions broaden attention and action-repertories and therein build resources to improve health and well-being.

32. Putkinen V, Makkonen T, Eerola T: **Music-induced positive mood broadens the scope of auditory attention**. *Soc Cogn Affect Neurosci* 2017, **12**:1159-1168.

33. Vanlessen N, De Raedt R, Koster EHW, Pourtois G: **Happy heart, smiling eyes: a systematic review of positive mood effects on broadening of visuospatial attention**. *Neurosci Biobehav Rev* 2016, **68**:816-837.

34. Storbeck J, Dayboch J, Wylie J: **Fear and happiness, but not sadness, motivate attentional flexibility: a case for emotion influencing the ability to split foci of attention**. *Emotion* 2019, **19**:655.

35. Jäger DT, Rüsseler J: **Low arousing positive affect broadens visual attention and alters the thought-action repertoire while broadened visual attention does not**. *Front Psychol* 2016, **7**:1-12.

36. Rowe G, Hirsh JB, Anderson AK: **Positive affect increases the breadth of attentional selection**. *Proc Natl Acad Sci U S A* 2007, **104**:383-388.

37. Fredrickson BL, Branigan C: **Positive emotions broaden the scope of attention and thought-action repertoires**. *Cogn Emot* 2005, **19**:313-332.

38. Bruyneel L, van Steenbergen H, Hommel B, Band GPH, De Raedt R, Koster EHW: **Happy but still focused: failures to find evidence for a mood-induced widening of visual attention**. *Psychol Res* 2013, **77**:320-332.

39. Huntsinger JR: **Does emotion directly tune the scope of attention?** *Curr Dir Psychol Sci* 2013, **22**:265-270.

40. Eldar E, Cohen JD, Niv Y: **The effects of neural gain on attention and learning**. *Nat Neurosci* 2013, **16**:1146-1153.

41. Greening SG, Mather M: **How arousal influences neural competition: what dual competition does not explain**. *Behav Brain Sci* 2015, **38**:e77.

42. Yamaguchi M, Nishimura A: **Modulating proactive cognitive control by reward: differential anticipatory effects of performance-contingent and non-contingent rewards**. *Psychol Res* 2019, **83**:258-274.

43. Van Steenbergen H, Band GPH, Hommel B: **Reward counteracts conflict adaptation: evidence for a role of affect in executive control**. *Psychol Sci* 2009, **20**:1473-1477.

44. Braem S, King JA, Korb FM, Krebs RM, Notebaert W, Egner T: **Affective modulation of cognitive control is determined by performance-contingency and mediated by ventromedial prefrontal and cingulate cortex**. *J Neurosci* 2013, **33**:16961-16970.

45. Sadowski S, Fennis BM, van Ittersum K: **Losses tune differently than gains: how gains and losses shape attentional scope and influence goal pursuit**. *Cogn Emot* 2020, **34**:1439-1456.

46. Lavie N: **Distracted and confused?: selective attention under load**. *Trends Cogn Sci* 2005, **9**:75-82.

47. Vanlessen N, Rossi V, De Raedt R, Pourtois G: **Feeling happy enhances early spatial encoding of peripheral information automatically: electrophysiological time-course and neural sources**. *Cogn Affect Behav Neurosci* 2014, **14**:951-969.

48. • Gottlieb J, Oudeyer PY: **Towards a neuroscience of active sampling and curiosity**. *Nat Rev Neurosci* 2018, **19**:758-770.
An integrative approach of neuroscientific literature that examines different motives that drive attention and curiosity and their relationship with decision-making, in particular in the learning and exploration–exploitation literature.

49. Cavanagh JF, Zambrano-Vazquez L, Allen JJB: **Theta lingua franca: a common mid-frontal substrate for action monitoring processes**. *Psychophysiology* 2012, **49**:220-238.

50. Threadgill AH, Gable PA: **Intertrial variability in emotive reactions to approach-motivated positive pictures predicts attentional narrowing: the role of individual differences**. *Biol Psychol* 2019, **142**:19-28.

51. Bickel S, Dias EC, Epstein ML, Javitt DC: **Expectancy-related modulations of neural oscillations in continuous performance tasks**. *Neuroimage* 2012, **62**:1867-1876.