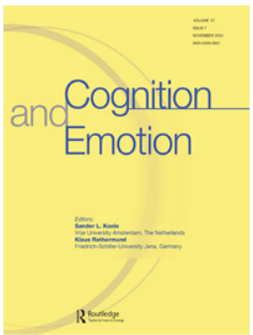

Routledge
Taylor & Francis Group

Cognition and Emotion

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/pcem20

Perceptual control or action-selection? Comment on: a perceptual control theory of emotional action

Bob Bramson & Karin Roelofs

To cite this article: Bob Bramson & Karin Roelofs (2023) Perceptual control or action-selection? Comment on: a perceptual control theory of emotional action, Cognition and Emotion, 37:7, 1193-1198, DOI: 10.1080/02699931.2023.2269830

To link to this article: https://doi.org/10.1080/02699931.2023.2269830

COGNITION AND EMOTION
2023, VOL. 37, NO. 7, 1193–1198
https://doi.org/10.1080/02699931.2023.2269830

Routledge
Taylor & Francis Group

ARTICLE COMMENTARY

Perceptual control or action-selection? Comment on: a perceptual control theory of emotional action

Bob Bramson [a,b] and Karin Roelofs[a,b]

[a]Donders Institute for Brain, Cognition and Behavior, Centre for Cognitive Neuroimaging, Radboud University Nijmegen, Nijmegen, The Netherlands; [b]Behavioral Science Institute (BSI), Radboud University Nijmegen, Nijmegen, The Netherlands

ABSTRACT

The *Perceptual Control Theory of Emotional Action* provides a compelling view of the synergy between action and perception in the context of emotion. In this invited response, we outline three suggestions to further clarify and concretesise the theory in the hope that it can provide a solid basis for the theoretical, empirical, and clinical fields of emotion and emotion regulation. First, we emphasise the importance of concretesising these ideas in a way that is biologically plausible and testable in terms of its neuronal implementation, which has not been addressed in the main manuscript. Secondly, we highlight the challenges for this account to effectively describe core symptoms in emotional disorders, an essential step if the theory aims to foster the development of better-tuned neurocognitively grounded interventions. Finally, we take a leap on what action-oriented accounts of emotion can mean for the field of emotion regulation.

ARTICLE HISTORY
Received 21 July 2023
Accepted 3 September 2023

KEYWORDS
Action-selection; emotion; emotion-control; emotion-regulation; emotional-action

In the article *A Perceptual Control Theory of Emotional Action* (this issue), Andreas Eder puts forward a valuable perspective on emotional action. As the title suggests, this theory casts emotional action into cybernetic perceptual control theory that describes how action is employed to control perception. In the case of emotion, actions are performed to alter emotional percepts, which are reflections of the value of the current or anticipated state of the world relevant to the organism and its internal milieu. Those perceptions (in this account often referred to as raw feelings) consist of interoceptive signals that reflect deviations from internal set-points dictated by homeo- or allostatic controllers, relevant to inform the need to change behaviour and benefit the organism. We welcome an emotion theory that takes action so seriously again, not merely ascribing emotion and its regulation to verbal or cognitive constructs. We also greatly appreciate the emphasis on raw feelings as a form of perception, and the role of physiological processes in the emotional action control cascade. There are several emotion theories that are based on cybernetic control theory (e.g. Seth, 2013; Seth & Friston, 2016; Barrett, 2017), of which this account may be among the most explicit when it comes to the fundamental role of action in control emotional percepts.

However, we do see three non-trivial challenges that remain underarticulated in this account and in the field of emotion control as a whole. Resolving those issues would increase the ability of current action accounts of emotion to provide a practically useful and research-guiding framework. First, in its current state, the theory remains abstract in terms of its predictions on biologically plausible neural and behavioural processes that allow- and implement control over perception. Second, it remains unarticulated how controlling perception relates to the core emotion-related problems we face in psychopathological conditions and clinical practice. Finally, although the proposed view on how emotional percepts are controlled flows naturally from the cybernetic

CONTACT Bob Bramson bob.bramson@donders.ru.nl

perceptual control framework, the current formulation might also be prone to create misunderstanding. For instance, when it comes to improving *emotion regulation*, agents may be poorly equipped to improve perceptual control and instead are best equipped to optimise action selection. Those actions are almost never aimed at resolving deviations from a single set-point (or raw-feeling) but are often compromises to satisfy the needs of several controllers. For clinical translation purposes but also to provide a clearer embedding in larger theoretic frameworks of cognitive control, it might be more intuitive and efficient to emphasise the action-selection aspects of the theory. None of these three points should be read as critique. They are merely meant to inspire sharpened discussion of the account and its boundary conditions as well as to aid its ability to become widely implemented. Below we discuss these three considerations in more depth.

The relevance of concrete hypotheses on biologically plausible neural implementations

The first and major challenge of the current framework is to provide biologically plausible and testable hypotheses with respect to its neural implementations. Although theoretically elegant, the account remains a rather abstract and high-level description. It is a non-trivial but necessary exercise to constrain a theory by concretising different conceptual levels to a form in which we are able to distil concrete and biologically plausible implementations that we can test. Eder also emphasises this need: "*Understanding action control hence means knowing what perceptions are being controlled, how they are being controlled, and why*". This challenge of constraining theory to biological plausibility is not unique to the current perceptual control framework but is a broader issue in cognitive science. The main issue with a lack of concrete and testable predictions is that theorising can remain frivolous and unchecked, which may lead to the maintenance of concepts that have no clear biological reality in the brain. This point has been made extensively over the last few years, for instance with respect to attention research (Hommel et al., 2019), but also in research on emotional processing (Pessoa et al., 2022). So how can this be achieved? There are examples where survival-relevant behaviours and processes have been concretised successfully. For instance, computational modelling of rodent and human behaviour based on concrete hypotheses has shown that behavioural inhibition linked to anxiety can result from neural optimisation algorhitms rather than often assumed automatic or preprogrammed reactions (Bach, 2015). This concretisation has had important consequences for our thinking about how emotional behaviour is the endproduct of many competing neural controllers that all aim to maintain or control properties that they are sensitive to (Bach & Dayan, 2017). In another example, we have tried to formulate a model that can separate how parameters of the current threat-elicited physiological state of an organism can potentially feedback on action-selection via multiple neural controllers depending on the challenges of emotionally charged situations (Livermore et al., 2021). This latter model is currently being tested, and the first results have shown that threat-induced freezing is linked to enhanced action preparation and value integration of approach-avoidance action decisions (Klaassen et al., 2021). There is a plethora of other examples (e.g. (Letkiewicz et al., 2023; Yamamori & Robinson, 2023)) and the mathematical tools for separating different hypothesised operations are available. The main challenge that remains is that we need to extract concrete hypotheses and questions from the abstract cybernetic framework that is presented here, without regressing into unformalised psychological concepts (Cisek, 2019; Pessoa et al., 2022).

In its present form, the theory put forth by Eder remains unarticulated about what is being controlled exactly and how one would arbitrate between different simultaneously relevant control demands. In contrast, such concretisations have been made in other instances where cybernetic, phylogenetically plausible, and neurobiologically well-defined solutions have been proposed for the problem of action-control (e.g. Cisek, 2019, 2022). For this reason, we recently translated those action control accounts to the context of emotion control (Bramson et al., 2023). In case of multiple demands, which controller is given influence over the limited output channel (actions) at one time? The main suggestion provided in the current theory is lateral inhibition of neural ensembles encoding competing action plans based on the dominance of one neural controller. Although this is plausible, for example in acute approach-avoidance decisions where multiple action plans similar in their movement parameters compete for execution (e.g. Bramson et al., 2018),

lateral inhibition seems unlikely to be able to arbitrate between goals with differing levels of abstraction. We do not see how the goal of achieving success in your career leading you to focus on writing a paper, and the acute desire for ice cream can easily be resolved by lateral inhibition of action plans. Instead, we suggest to incorporate hierarchical feedback control which allows easier conceptualisation of drivers across hierarchical levels through the prediction of action consequences (Pezzulo & Cisek, 2016). Let's illustrate the need for those specifications using an example: A typical and powerful illustration of an emotionally charged context is the example of encountering a situation with acute homeostatic relevance, such as the detection of a threat. Depending on the imminence of the threat rapid neural controllers in areas such as the midbrain periaqueductal grey shortcut decisions to fight and flight, depending on the availability of available escape routes (Mobbs et al., 2020), or, when more time is available multiple potential action strategies are computed on the fly in (pre-)motor and parietal systems, based on available affordances (Frijda, 1986; Feinberg & Mallatt, 2016; Badre & Nee, 2018; Cisek, 2022). In our action-control theory of emotion regulation (Bramson et al., 2023) we suggest that concrete hypotheses can be generated on how strategies are employed and neurally implemented to restore homeostasis, or in fact proactively control behaviour through allostatic processes. These strategies compete for execution based on their predicted outcomes whilst continuous feedback loops provide updated predictions during the unfolding of the selected action strategy to maintain the behaviour until the trigger state has dissipated or until counterfactual strategies become more beneficial (Pezzulo & Cisek, 2016; Koch et al., 2018).

There is another issue that cannot be avoided in light of this section about the need for more refined and biologically plausible mechanisms. The emphasis that Eder puts on dopamine and serotonin is valid, given their importance in the regulation of motivational behaviour, but glosses over the contributions of other neurotransmitters such as norepinephrine and acetylcholine that are vital for controlling the sympathetic and parasympathetic branches of the autonomic nervous system, systems that are crucial for the concept of raw feelings but also for action inhibition, perception and optimising coping strategies during emotionally charged situations (Roelofs & Dayan, 2022).

Challenges for translation to psychopathological states and their treatment

A second challenge is that the current framework remains unspecific with respect to how we can use it concretely to benefit research on psychopathology. An important advantage of a good emotion theory is that it helps to refine at what levels processes go awry, in order to advance insight into psychopathological conditions. It would be a nice step if the theory could explain how we can determine at which level in the control hierarchy processes fail and how that could explain core symptoms of emotional disorders. For example, does it matter for perceptual control theory (PCT) whether the avoidance of social situations in a patient suffering from social anxiety is due to excessive threat assessment, because of lack of control over avoidance tendencies, or both? At what level would the percepts be affected in distinct psychopathological states and how would that drive different types of action selection? A related question would be, how would PCT inform on the selection of a treatment, and can we assess whether symptoms relate to aberrant internal set points or does the problem stem from the selection of actions that are employed to solve deviations in raw feeling.

Some instances might be relatively straightforward, such as the therapeutic effects of behavioural activation in depression, which might be formulated as a treatment targetting the action component, rather than directly focusing on changing an internal set point. In this example, shifts in internal set points could be framed as a consequence of the behavioural activation. Other treatments utilise mental action simulation to treat emotional disorders. Take for instance the example of imaginary exposure in patients who developed post-traumatic stress disorder after an assault during which they were unable to move. This therapy invites patients to imagine an alternative action strategy, for example, to stand up and stop their assailant. Those techniques have been found to be effective not only for PTSD but also for other conditions characterised by intrusive cognitions (Holmes et al., 2021), for example, spider phobia. Before treatment, the imagination of approaching a spider without actual sensory input associated with coming closer to an actual spider led to significant increases in subjective fear, skin conductance, and activity in neural fear circuits, including amygdala and ACC. A ten-minute session of imaginary

exposure therapy significantly reduced those fear-related processes (Hoppe et al., 2021). Crucially, those types of action simulations rely on the same circuitry that is also involved in acute action selection and behavioural control (Barsalou, 2009). A nice challence for PCT would be to define concretely how the emphasis on perception-control can help explain psychopathology and its intervention. For instance, how can PCT help the tuning of interventions in the above-mentioned example of action-imagination. More broadly, an important and non-trivial step in the maturation of the perception-control account of emotion is to provide examples of how the emphasis on perceptual controllers can help our understanding of emotional disorders and their interventions, beyond the notion that our bodies are full of perceptual-controlers that aim for homeostasis. This brings us to the third point: Would it be more useful to think about emotion control in terms of perception control or instead in terms of action selection?

Emotion control: perception control or action selection?

Although Eder's emotion theory is not explicit about emotion regulation per se, a theory of emotion can provide valuable starting points for thinking about emotion regulation. We share the positions that raw feelings can inform about current or anticipated deviations from internal set-points, and that emotions are for action. Both these ideas have consequences for the way we think about emotion regulation. If emotions are elicited to promote behaviour that benefits the organism and to bias behaviour away from dangerous situations, in other words, when they provide an estimate of the goodness or badness of the current behavioural strategy (Bach & Dayan, 2017) and thereby act as the basis for action selection, we could go one step further and view emotion regulation as a subsidiary to action selection (Bramson et al., 2023). To summarise our own view, we think emotion regulation is an extension of action-outcome prediction, where discrepancies between current/anticipated states and desired states (set-points) are resolved by taking actions (Seth, 2015; Pezzulo & Cisek, 2016; Barrett, 2017). In acute emotion-eliciting situations, this prediction process is an instance of forward modelling, employing innate or learned action-outcome relationships (Etkin et al., 2015). These can select between Pavlovian action-tendencies such as freeze-fight-flight reactions, as well as between instrumental actions, such as to approach or to avoid in order to achieve a certain goal, for example resolving the (anticipated) deviation from an internal set-point. Given that there are often multiple controllers vying for control, and generally only one (or at most very few) behavioural output is possible at any one time, determining which raw feeling to regulate is always an action-selection problem (Frijda et al., 2014). Crucially, this action-selection conceptualisation of emotion regulation based on action-outcome prediction can also account for more abstract instances of emotion regulation such as cognitive reappraisal, which can be reformulated as counterfactual modelling of alternative actions and potential outcomes. Formulated this way, reappraisal can be described as a form of supervised forward modelling, implemented through hierarchically nested control loops initially developed for action selection in pre-motor systems (Pezzulo & Cisek, 2016; Fine & Hayden, 2022). Those instances of supervised forward modelling can change action selection by modifying goals and motivations; can elicit changes in visceral and physiological responses and, subsequently, can modulate affective components such as feelings through prediction and corollary discharge (Barsalou, 2008; Buzsáki et al., 2014; Winkielman et al., 2018). Formulating emotion regulation as such can bring new and concrete neural hypotheses, for instance on the role of a circuit around the lateral frontopolar cortex in arbitrating among multiple emotional control strategies when there is uncertainty about the efficiency of the current emotional control strategy (Roelofs et al., 2023). In sum, although Eders' theory is one of emotion and does not deal explicitly with emotion control, we feel that the current framework might benefit from specifying what implications the core elements of the theory have for emotion control. Our views on emotion regulation briefly sketched above (Bramson et al., 2023) might be compatible with the perceptual control theory of emotional action and may help to concretise the theory further.

To conclude, the perceptual control theory by Eder is important, appealing, and valuable in many respects. It provides a robust framework for conceptualising emotional action and potentially its control. It elegantly describes raw feelings as a form of perception and rightfully emphasises the role of physiological processes in the emotional action control cascade. Framing emotion control an issue of perceptual control may follow naturally from the cybernetic

perceptual control theory. However, we hope to have inspired a discussion on the use and validity of this framing when it comes to emotion control. An important step to take for this and several other theories in the field is to specify the concrete neural, computational, and behavioural hypotheses as that exercise may put important constraints to limit theory and would help the formulation of testable hypotheses.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by consolidator grant DARE2APPROACH from the European Research Council: (ERC_CoG_772337).

ORCID

Bob Bramson http://orcid.org/0000-0002-0752-0805

References

Bach, D. R. (2015). Anxiety-like behavioural inhibition is normative under environmental threat-reward correlations. *PLoS Computational Biology*, *11*(12), e1004646.

Bach, D. R., & Dayan, P. (2017). Algorithms for survival: A comparative perspective on emotions. *Nature Reviews Neuroscience*, *18*(5), 311–319. https://doi.org/10.1038/nrn.2017.35

Badre, D., & Nee, D. E. (2018). Frontal cortex and the hierarchical control of behavior. *Trends in Cognitive Sciences*, *22*(2), 170–188. https://doi.org/10.1016/j.tics.2017.11.005

Barrett, L. F. (2017). The theory of constructed emotion: An active inference account of interoception and categorization. *Social Cognitive and Affective Neuroscience*, *12*, 1–23.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*(1), 617–645. https://doi.org/10.1146/annurev.psych.59.103006.093639

Barsalou, L. W. (2009). Simulation, situated conceptualization, and prediction. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1521), 1281–1289. https://doi.org/10.1098/rstb.2008.0319

Bramson, B., Jensen, O., Toni, I., & Roelofs, K. (2018). Cortical oscillatory mechanisms supporting the control of human social–emotional actions. *Journal of Neuroscience*, *38*(25), 5739–5749.

Bramson, B., Toni, I., & Roelofs, K. (2023). Emotion regulation from an action-control perspective. *Neuroscience & Biobehavioral Reviews*, 105397.

Buzsáki, G., Peyrache, A., & Kubie, J. (2014). Emergence of cognition from action. *Cold Spring Harbor Symposia on Quantitative Biology*, *79*, 41–50. https://doi.org/10.1101/sqb.2014.79.024679

Cisek, P. (2019). Resynthesizing behavior through phylogenetic refinement. *Attention, Perception, and Psychophysics*, *81*, 2265–2287.

Cisek, P. (2022). Evolution of behavioural control from chordates to primates. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *377*(1844), 20200522. https://doi.org/10.1098/rstb.2020.0522

Etkin, A., Büchel, C., & Gross, J. J. (2015). The neural bases of emotion regulation. *Nature Reviews Neuroscience*, *16*(11), 693-700.

Feinberg, T. E., & Mallatt, J. M. (2016). *The ancient origins of consciousness: How the brain created experience*. MIT Press.

Fine, J. M., & Hayden, B. Y. (2022). The whole prefrontal cortex is premotor cortex. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *377*(1844), 20200524. https://doi.org/10.1098/rstb.2020.0524

Frijda, N. H. (1986). *The emotions*. Cambridge University Press.

Frijda, N. H., Ridderinkhof, K. R., & Rietveld, E. (2014). Impulsive action: Emotional impulses and their control. *Frontiers in Psychology*, *5*, 518. https://doi.org/10.3389/fpsyg.2014.00518

Holmes, E. A., Espinosa, L., Visser, R. M., Bonsall, M. B., & Singh, L. (2021). Psychological interventions as they relate to intrusive thinking: Intrusive, emotional mental imagery after traumatic and negative events. Strüngmann Forum Reports MIT Press 2020.

Hommel, B., Chapman, C. S., Cisek, P., Neyedli, H. F., Song, J. H., & Welsh, T. N. (2019). No one knows what attention is. *Attention, Perception, & Psychophysics*, *81*, 2288–2303.

Hoppe, J. M., Holmes, E. A., & Agren, T. (2021). Exploring the neural basis of fear produced by mental imagery: imaginal exposure in individuals fearful of spiders. *Philosophical Transactions of the Royal Society B*, *376*(1817), 20190690. https://doi.org/10.1098/rstb.2019.0690

Klaassen, F. H., Held, L., Figner, B., O'Reilly, J. X., Klumpers, F., de Voogd, L. D., & Roelofs, K. (2021). Defensive freezing and its relation to approach–avoidance decision-making under threat. *Scientific Reports*, *11*(1), 12030.

Koch, S. B. J., Mars, R. B., Toni, I., & Roelofs, K. (2018). Emotional control, reappraised. *Neuroscience & Biobehavioral Reviews*, *95*, 528–534. https://doi.org/10.1016/j.neubiorev.2018.11.003

Letkiewicz, A. M., Kottler, H. C., Shankman, S. A., & Cochran, A. L. (2023). Quantifying aberrant approach-avoidance conflict in psychopathology: A review of computational approaches. *Neuroscience & Biobehavioral Reviews*, *147*, 105103. https://doi.org/10.1016/j.neubiorev.2023.105103

Livermore, J. J. A., Klaassen, F. H., Bramson, B., Hulsman, A. M., Meijer, S. W., Held, L., Klumpers, F., de Voogd, L. D., & Roelofs, K. (2021). Approach-avoidance decisions under threat: The role of autonomic psychophysiological states. *Frontiers in Neuroscience*, *15*, 1–12.

Mobbs, D., Headley, D. B., Ding, W., & Dayan, P. (2020). Space, time, and fear: Survival computations along defensive circuits. *Trends in Cognitive Sciences*, *24*(3), 228–241. https://doi.org/10.1016/j.tics.2019.12.016

Pessoa, L., Medina, L., & Desfilis, E. (2022). Refocusing neuroscience: Moving away from mental categories and towards complex behaviours. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *377*(1844), 20200534. https://doi.org/10.1098/rstb.2020.0534

Pezzulo, G., & Cisek, P. (2016). Navigating the affordance landscape: Feedback control as a process model of behavior

and cognition. *Trends in Cognitive Sciences*, *20*(6), 414–424. https://doi.org/10.1016/j.tics.2016.03.013

Roelofs, K., & Dayan, P. (2022). Freezing revisited: coordinated autonomic and central optimization of threat coping. *Nature Reviews Neuroscience*, *23*(9), 568–580.

Roelofs, K., Bramson, B., & Toni, I. (2023). A neurocognitive theory of flexible emotion control: The role of the lateral frontal pole in emotion regulation. *Annals of the New York Academy of Sciences*, *1525*(1), 28–40.

Seth, A. K., & Friston, K. J. (2016). Active interoceptive inference and the emotional brain. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1708), 20160007.

Seth, A. K. (2015). The cybernetic Bayesian brain. *Open MIND*, *35*, 1–24.

Seth, A. K., & Friston, K. J. (2016). Active interoceptive inference and the emotional brain. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*.

Winkielman, P., Coulson, S., & Niedenthal, P. (2018). Dynamic grounding of emotion concepts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1752), 20170127. https://doi.org/10.1098/rstb.2017.0127

Yamamori, Y., & Robinson, O. J. (2023). Computational perspectives on human fear and anxiety. *Neuroscience & Biobehavioral Reviews*, *144*, 104959. https://doi.org/10.1016/j.neubiorev.2022.104959