





















- negative situations in both cooperative and non-cooperative contexts. *Frontiers in Human Neuroscience*, *11*, 275.
- Rudebeck, P. H., Walton, M. E., Smyth, A. N., Bannerman, D. M., & Rushworth, M. F. S. (2006). Separate neural pathways process different decision costs. *Nature Neuroscience*, *9*(9), 1161–1168.
- Sandra, D. A., & Otto, A. R. (2018). Cognitive capacity limitations and need for cognition differentially predict reward-induced cognitive effort expenditure. *Cognition*, *172*, 101–106.
- Seaman, K. L., Brooks, N., Karrer, T. M., Castellon, J. J., Perkins, S. F., Dang, L. C., Hsu, M., Zald, D. H., & Samanez-Larkin, G. R. (2018). Subjective value representations during effort, probability and time discounting across adulthood. *Social Cognitive and Affective Neuroscience*, *13*(5), 449–459.
- Shenhav, A., Botvinick, M. M., & Cohen, J. D. (2013). The expected value of control: An integrative theory of anterior cingulate cortex function. *Neuron*, *79*(2), 217–240.
- Shenhav, A., Musslick, S., Lieder, F., Kool, W., Griffiths, T. L., Cohen, J. D., & Botvinick, M. M. (2017). Toward a rational and mechanistic account of mental effort. *Annual Review of Neuroscience*, *40*, 99–124.
- Shenhav, A., Prater Fahey, M., & Grahek, I. (2021). Decomposing the motivation to exert mental effort. *Current Directions in Psychological Science*, *30*(4), 307–314.
- Sidarus, N., Palminteri, S., & Chabon, V. (2019). Cost-benefit trade-offs in decision-making and learning. *PLoS Computational Biology*, *15*(9), e1007326.
- Sullivan-Toole, H., DePasque, S., Holt-Gosselin, B., & Galván, A. (2019). Worth working for: The influence of effort costs on teens' choices during a novel decision making game. *Developmental Cognitive Neuroscience*, *37*, 100652.
- Tran, T., Hagen, A. E. F., Hollenstein, T., & Bowie, C. R. (2020). Physical- and cognitive-effort-based decision-making in depression: Relationships to symptoms and functioning. *Clinical Psychological Science*, *9*(1), 53–67.
- Tusche, A., Böckler, A., Kanske, P., Trautwein, F. M., & Singer, T. (2016). Decoding the charitable brain: Empathy, perspective taking, and attention shifts differentially predict altruistic giving. *Journal of Neuroscience*, *36*(17), 4719–4732.
- Vekaria, K. M., Brethel-Haurwitz, K. M., Cardinale, E. M., Stoycos, S. A., & Marsh, A. A. (2017). Social discounting and distance perceptions in costly altruism. *Nature Human Behaviour*, *1*(5), 112474.
- Verguts, T., Vassena, E., & Silvetti, M. (2015). Adaptive effort investment in cognitive and physical tasks: A neurocomputational model. *Frontiers in Behavioral Neuroscience*, *9*, 57.
- Vogel, T. A., Savelson, Z. M., Otto, A. R., & Roy, M. (2020). Forced choices reveal a trade-off between cognitive effort and physical pain. *ELife*, *9*, e59410.
- Volz, L. J., Welborn, B. L., Gobel, M. S., Gazzaniga, M. S., & Grafton, S. T. (2017). Harm to self outweighs benefit to others in moral decision making. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(30), 7963–7968.
- Westbrook, A., & Frank, M. (2018). Dopamine and proximity in motivation and cognitive control. *Current Opinion in Behavioral Sciences*, *22*, 28–34.
- Westbrook, A., Frank, M. J., & Cools, R. (2021). A mosaic of cost-benefit control over cortico-striatal circuitry. *Trends in Cognitive Sciences*, *25*(8), 710–721.
- Westbrook, A., Lamichhane, B., & Braver, T. (2019). The subjective value of cognitive effort is encoded by a domain-general valuation network. *Journal of Neuroscience*, *39*(20), 3934–3947.
- Westbrook, A., van den Bosch, R., Määttä, J. I., Hofmans, L., Papadopetraki, D., Cools, R., & Frank, M. J. (2020). Dopamine promotes cognitive effort by biasing the benefits versus costs of cognitive work. *Science*, *367*(6484), 1362–1366.
- Will, G. J., Rutledge, R. B., Moutoussis, M., & Dolan, R. J. (2017). Neural and computational processes underlying dynamic changes in self-esteem. *ELife*, *6*, e28098.
- Williams, L., & Gill, D. L. (1995). The role of perceived competence in the motivation of physical activity. *Journal of Sport and Exercise Psychology*, *17*(4), 363–378.
- Wittmann, M. K., Kolling, N., Faber, N. S., Scholl, J., Nelissen, N., & Rushworth, M. F. S. (2016). Self-Other mergence in the frontal cortex during cooperation and competition. *Neuron*, *91*(2), 482–493.
- Yee, D. M., & Braver, T. S. (2018). Interactions of motivation and cognitive control. *Current Opinion in Behavioral Sciences*, *19*, 83–90.
- Yee, D. M., Crawford, J. L., Lamichhane, B., & Braver, T. S. (2021). Dorsal anterior cingulate cortex encodes the integrated incentive motivational value of cognitive task performance. *Journal of Neuroscience*, *41*(16), 3707–3720.
- Zaki, J., Wager, T. D., Singer, T., Keyesers, C., & Gazzola, V. (2016). The anatomy of suffering: Understanding the relationship between nociceptive and empathic pain. *Trends in Cognitive Sciences*, *20*(4), 249–259.
- Zénon, A., Devesse, S., & Olivier, E. (2016). Dopamine manipulation affects response vigor independently of opportunity cost. *Journal of Neuroscience*, *36*(37), 9516–9525.

## Value Analysis determines when and how to strive

CAO Si-Qi<sup>1,2</sup>, TANG Chen-Chen<sup>3</sup>, WU Hai-Yan<sup>4</sup>, LIU Xun<sup>1,2</sup>

(<sup>1</sup> CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China)

(<sup>2</sup> Department of Psychology, University of Chinese Academy of Sciences, Beijing 100049, China)

(<sup>3</sup> Department of Psychology, Beijing Sport University 100084, China)

(<sup>4</sup> Center for Cognition and Brain Sciences, Department of Psychology, University of Macau, Macau 999078, China)

**Abstract:** The optimization of effort investment, which minimizes the cost of effort and maximizes benefits, is a core issue in every field. This study aims to review previous theoretical and empirical studies on analysis of effort value. Based on the Paradox of Effort theory, this study expounds on the two sides of effort: inherent cost and potential value. By extending the Expected Value of Control theory, we discussed the non-social and social factors that influence effort. Studies on the mechanisms of effort provide essential insights into understanding the adaptive effort in social life and provide references for treating motivational disorders, shaping learned industriousness and prosocial behavior.

**Key words:** effort, Expected Value of Control theory, cost-benefit trade-off