Title

Deciding What to Do: Developments in Children’s Spontaneous Monitoring of Cognitive Demands

Journal

Child Development Perspectives, 14(4)

ISSN

1750-8592

Authors

Niebaum, Jesse
Munakata, Yuko

Publication Date

2020-12-01

DOI

10.1111/cdep.12383

Peer reviewed

CHILD DEVELOPMENT PERSPECTIVES

Deciding What to Do: Developments in Children's Spontaneous Monitoring of Cognitive Demands

Jesse Niebaum, and Yuko Munakata

University of California, Davis

ABSTRACT—***How do children decide which tasks to take on? Understanding whether and when children begin to monitor cognitive demands to guide task selection is important as children gain increasing independence from adults in deciding which tasks to attempt themselves. In this article, we review evidence suggesting a developmental transition in children's consideration of cognitive demands when making choices about tasks: Although younger children are capable of monitoring cognitive demands to guide task selection, spontaneous monitoring of cognitive demands begins to emerge around 5–7 years. We describe frameworks for understanding when and why children begin to monitor cognitive demands, and propose additional factors that likely influence children's decisions to pursue or avoid cognitively demanding tasks.***

KEYWORDS—*cognitive development; decision-making; metacognition*

Jesse Niebaum and Yuko Munakata, Department of Psychology and Center for Mind and Brain, University of California.

The work reported in this article was supported by grants from the Eunice Kennedy Shriver National Institute of Child Health & Human Development (R01 HD086184) and the National Science Foundation Graduate Research Fellowship Program (Grant No. 1650042). We thank Vladimir Sloutsky, Ryan Guild, and Nicolas Chevalier, as well the members of the Cognitive Development Center at the University of Colorado Boulder and the Cognition in Context Lab at the University of California, Davis, for many helpful discussions on these topics. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Correspondence concerning this article should be addressed to Jesse C. Niebaum, Department of Psychology, University of California, Davis, Center for Mind and Brain, 267 Cousteau Place, Davis, CA 95618. e-mail: jcniebaum@ucdavis.edu.

DOI: 10.1111/cdep.12383

Cognitive tasks that are more difficult typically require thinking harder than cognitive tasks that are less difficult. Adults are sensitive to these cognitive demands, reporting that more demanding tasks require more cognitive effort and that exerting cognitive effort *feels* effortful (Kurzban, Duckworth, Kable, & Myers, 2013; Saunders, Milyavskaya, & Inzlicht, 2015). Adults are usually miserly with their cognitive effort, avoiding exerting unnecessary effort by choosing less demanding tasks over more demanding tasks (for reviews, see Shenhav et al., 2017; Westbrook & Braver, 2015). Sensitivity to cognitive demands helps adults conserve effort and efficiently expend effort only on worthwhile tasks.

Are children as sensitive to cognitive demands as adults? Do children use cognitive demands to guide their selection of tasks? Answering these questions is fundamental for theoretical frameworks across education and cognitive development. For example, in achievement motivation theory, children's perceptions of effort and demands related to tasks are essential components driving their developing understanding of competence, which strongly predicts academic achievement (Nicholls, 1978; Rosenzweig, Wigfield, & Eccles, 2019). However, despite extensive research into children's motivation to achieve, perceptions of cognitive effort (framed as costs) have been largely unexplored, especially in children (Jiang, Rosenzweig, & Gaspard, 2018). Recent theoretical frameworks for the development of cognitive control have emphasized children's growing repertoire of cognitive control strategies (Munakata, Snyder, & Chatham, 2012), suggesting that age-related improvements in cognitive control are driven partially by better coordination of control strategies and effort in response to the demands of tasks (Chevalier, 2015).

Responding to cognitive demands relies on two components of procedural metacognition: *monitoring* to assess mental states while performing a cognitive task and *control* to coordinate behavior according to monitoring signals (Nelson & Narens, 1990; Shenhav et al., 2017). Investigations into the development of metacognition have focused primarily on declarative knowledge and perceptual decisions; in these, monitoring involves subjective confidence in learning, and control leads to adapting behavior to improve learning (Ghetti, Hembacher, & Coughlin, 2013). In this article, we extend this framework to consider monitoring of the cognitive demands of tasks, and subjective effort and control in the form of coordinating task selection according to these demand signals. We outline an emerging literature suggesting that although young children can monitor and control behavior according to cognitive task demands, spontaneous cognitive monitoring of effort and task selection based on cognitive demands only begins to emerge at about 5–7 years. We then discuss factors that influence children's attention to cognitive demands in task selection, highlighting areas requiring additional research to understand more completely the complexity of children's decisions to pursue or avoid tasks.

DEVELOPMENTS IN SPONTANEOUS COGNITIVE DEMAND MONITORING AND EFFORT-BASED TASK SELECTION

Cross-sectional studies have indicated a potential developmental transition in spontaneously monitoring cognitive task demands, showing that children generally begin to monitor and coordinate behavior according to cognitive demands at about 5–7 years. Many of these studies have used demand selection tasks, in which participants are presented with two task options that differ in cognitive demands but are otherwise similar (e.g., Kool, McGuire, Rosen, & Botvinick, 2010). Participants typically gain familiarity with each option before deciding on their own which option to select across a series of trials.

For example, in a demand selection task contrasting cognitive control demands by manipulating the frequency of rule switches (e.g., sorting stimuli based on color versus shape; Monsell, 2003), the less demanding option switched task rules on only 10% of trials, whereas the more demanding option switched rules on 90% of trials. During familiarization with the different options, adults, 11-year olds, and 6-year olds all exhibited signals of demand, responding less accurately and more slowly on rule-switching than on rule-repeating trials (Niebaum, Chevalier, Guild, & Munakata, 2019). However, only adults and 11-year olds preferentially selected the less demanding option, whereas 6-year olds selected options at chance levels. Adults and 11-year olds also reported the less demanding option as easier and preferred, but 6-year olds did not, suggesting that only the older children and adults spontaneously monitored cognitive demands and avoided effort by selecting the less demanding option.

Young children also do not monitor differences between tasks that vary according to when cognitive control should be engaged. In another demand selection task, one option encouraged proactive engagement of control by showing a sorting rule prior to a stimulus to sort and removing the rule at the onset of the stimulus, whereas the other option showed the sorting rule and stimulus simultaneously, requiring participants to engage control reactively (Niebaum, Chevalier, Guild, & Munakata, in press). Participants of all ages responded more quickly on the proactive option, but 5-year olds were also more accurate on the reactive option. Adults selected the proactive option, reflecting their temporal control tendencies (Braver, 2012), and reported the temporal differences between task options. Ten-year olds did not select either option more than chance but did monitor demands, with most reporting differences between options. Overall, 5-year olds did not preferentially select either option or reliably report differences between task options. However, about half of 5-year olds did report task differences; this subset preferentially selected the reactive option, suggesting that the 5-year olds who spontaneously monitored task differences selected the option that enabled their preferred control mode and higher accuracy (Chevalier, Martis, Curran, & Munakata, 2015). This finding aligns well with research in adults indicating that awareness of demand differences is required for avoiding cognitive demands (Desender, Buc Calderon, Van Opstal, & Van den Bussche, 2017).

Another cross-sectional study used a demand selection task that taxed the approximate number system, requiring participants to decide which of two dot arrays had more dots. The easier option presented dot arrays at a 2:1 ratio (e.g., 10 versus 5 dots), whereas the difficult option presented arrays at ratios of 9:10–13:14 (O'Leary & Sloutsky, 2017, 2019). Adults could identify the easier option and preferentially selected it. However, even given similar differences in accuracy between the easy and hard tasks, 5-year olds selected options at chance and commonly reported no differences in difficulty (O'Leary & Sloutsky, 2017). Seven-year olds appeared to be in a transitional period, selecting at chance and reporting no differences in difficulty in some studies but selecting the easier option more often than chance in others, although only 30% rated their performance as higher on the easier option compared with the harder option (O'Leary & Sloutsky, 2019).

Children older than 7 years have consistently spontaneously monitored cognitive demands to select tasks. Children may increasingly view cognitive effort as costly like adults, preferring to avoid unnecessary cognitive demands and conserve their cognitive effort unless presented with enough incentives. For example, 8- to 12-year olds chose to complete easier tasks that involved updating working memory for less reward over more difficult working memory updating tasks for more reward, similar to adults (Chevalier, 2018). Greater relative differences between the difficult and easy tasks in children's pupil dilation, a common index of cognitive effort, positively predicted the incentive needed to complete the harder task, suggesting that children who put forth more cognitive effort required greater incentive to complete the difficult tasks (Chevalier, 2018). When given the option to complete a trial for rewards or skip to a different trial, 9-year olds tended to skip high-effort trials if offered a low reward but tended to accept low-effort tasks at all reward levels, indicating that these children considered effort as costly and integrated cognitive effort and reward when making decisions about the tasks (Gatzke-Kopp, Ram, Lydon-Staley, & DuPuis, 2018). Older children also report that more difficult academic tasks *feel* more effortful, like adults. For example, 10- to 13-year olds rated more difficult arithmetic as requiring more effort and feeling more difficult (Efklides, Kourkoulou, Mitsiou, & Ziliaskopoulou, 2006), and in adolescents, a composite survey measure of costs associated with math, including perceptions of cognitive effort, strongly predicted self-reported avoidance of math schoolwork (Jiang et al., 2018).

The age when children begin to spontaneously monitor cognitive demands likely varies based on the complexity, length, and cognitive domain of the tasks involved. However, these results collectively indicate that spontaneously monitoring cognitive demands typically begins to emerge in children at about 5–7 years. Older children use demand signals more reliably to select tasks, adaptively controlling their behavior to avoid unnecessary cognitive effort.

YOUNG CHILDREN CAN MONITOR COGNITIVE DEMANDS

Although younger children do not spontaneously monitor relative cognitive task demands, they can select tasks based on demands when instructed to do so. For example, 5- and 7-year olds can select an easier dot discrimination task when instructed to select the easier game before each trial, demonstrating that children can monitor and select tasks based on subjective signals of the tasks' difficulty, at least when relative differences in difficulty are high (~30% difference between options; O'Leary & Sloutsky, 2019). When provided only feedback on accuracy, 5- and 7-year olds did not preferentially play the easier option, despite more accurately estimating their relative performance on each task compared to a condition without feedback. Thus, children at this age do not reliably avoid demand when not provided a goal to do so, despite differences in monitoring performance between task options.

Young children can also use unambiguous visual cues of task difficulty to select tasks. For example, 5- to 12-year olds reported that puzzles with more pieces were more difficult, and children younger than 7 chose to complete easier puzzles, potentially to match their perceptions of competence (Nicholls & Miller, 1983). When choosing between toys that required different combinations of buttons to activate, 5- to 7-year olds reliably chose to play with toys that had fewer buttons, inferring that toys with more buttons were more difficult to play (Bridgers, Jara-Ettinger, & Gweon, 2020). When choosing between sitting at one of two tables that varied in sticker rewards and the wait time needed to earn the stickers, 5-year olds integrated described delay costs and rewards when deciding, choosing the table with longer wait times only if the number of stickers was sufficiently higher than at the other table (Liu, Gonzalez, & Warneken, 2019).

WHY DO CHILDREN BEGIN TO INCORPORATE COGNITIVE EFFORT INTO TASK SELECTIONS?

Increasing Attention to Cues and Signals of Cognitive Demand

Shifts in what children pay attention to while completing cognitive tasks could change how they select tasks. For example, in task-switching paradigms, young children gazed preferentially at the target object before examining the sorting rule or even ignored the rule cue entirely, whereas older children and adults were more likely to examine the cue prior to looking at the target (Chevalier, Dauvier, & Blaye, 2018). Children's greater neglect of task cues could impede associations between effort and task options in demand selection tasks. For example, instead of associating difficult dot discrimination judgments with a specific option, children may only learn that arrays with more proximal ratios are more difficult.

Children also use feedback differently as they age, which could result in stronger associations between tasks and demands. For example, 8- to 9-years olds performed less optimally after negative feedback than adults, whereas adults used negative feedback to subsequently correct their behavior (Van Duijvenvoorde, Zanolie, Rombouts, Raijmakers, & Crone, 2008). In the demand selection task requiring dot array discriminations, 5-year olds overestimated their performance with and without feedback about performance (O'Leary & Sloutsky, 2019). If children do not use negative feedback to adapt behavior and overestimate their own performance, then they may have less motivation to select less demanding cognitive tasks, unless the differences in feedback between task options are especially high.

Adults use many cues about anticipated effort to select tasks, including past experiences of difficulty (Desender, Van Opstal, & Van den Bussche, 2017), even when objective signals of demand are equivalent across task options. In a demand selection task in which rotated words were read either horizontally or diagonally, adults preferred to read the words horizontally and rated horizontal reading as less demanding, even though the options had similar completion times, rates of error commission, and eyeblink rates, another proxy of cognitive demand (Dunn, Lutes, & Risko, 2016). If young children lack sufficient experience in the cognitive domain assessed, they will not be able to make inferences about anticipated cognitive demands when selecting tasks. Young children do select physical tasks based on anticipated difficulty, potentially because prior experience enables inferences about their success or failure on a task. For example, 4- to 5-year olds assigned harder or easier ball- and ring-toss tasks to themselves or other children according to age, giving older children more difficult tasks than themselves and younger children easier tasks (Magid, DePascale, & Schulz, 2018).

Increasing Capacity to Maintain Task Performance and Monitor Demands

Strategies to monitor task demands and coordinate behavior away from demands may not benefit overall performance on the task. For example, after memorization strategies in learning paradigms, young children did not benefit as much as older children from using good strategies, referred to as a *utilization deficiency* (Clerc, Miller, & Cosnefroy, 2014). Young children often struggle to translate these strategies into new but similar tasks, either failing to use a strategy or performing less optimally despite using a good strategy. Young children may have limited attentional capacity or working memory to monitor task demands while both executing the learned strategy and performing the task (Clerc et al., 2014). In tasks assessing monitoring and adaptation of cognitive demand, young children may be unable to perform the local task, like selecting a majority dot array, while spontaneously monitoring demands and selecting easier tasks. Young children may also fail to establish associations between task options and relative cognitive demands because their attention is usually directed toward local task goals through task instructions rather than toward maintaining a broader goal to avoid cognitive demands.

Decreasing Interest in the Task

Interest in a task attenuates perceptions of cognitive effort and reduces avoidance of cognitive demand in adolescents and adults. Interest in math predicted the proportion of time university and high school students spent on mental arithmetic tasks instead of watching videos or playing a video game, and individuals with higher interest in math reported being less fatigued after the task, despite spending more time on the seemingly more effortful activity (Milyavskaya, Galla, Inzlicht, & Duckworth, 2018). Adults reported less fatigue from manipulating four-digit numbers than from watching number strings passively, suggesting that cognitive effort may be less tiring than boredom (Milyavskaya, Inzlicht, Johnson, & Larson, 2019). Adolescents with greater interest in math also reported that math was less effortful and that they were less likely to avoid difficult math schoolwork (Jiang et al., 2018; Song, Kim, & Bong, 2019).

Young children may be more interested in simple cognitive tasks than older children and adults, and interest in a task could influence how cognitive demands are used to select tasks with age. After an experimenter demonstrated three tasks varying in cognitive demands, 4- to 10-year olds could select tasks based on difficulty when instructed to choose a task that was not too easy or too hard but “just right” (Danner & Lonky, 1981). Children’s choices matched not only their ability but also their self-reported interests in the tasks: Younger children rated the easier tasks as more interesting and played them more often, whereas older children rated the harder tasks as more interesting and played them more often. Simple cognitive tasks may cause greater boredom for older children, which may be used as a cost signal for selecting tasks, with boredom indicating that a task is not worth the effort (Westgate, 2020).

Emerging Associations Between Effort and Incentives

Although cognitive effort is typically rewarded, young children may not have developed the association between effort and reward. Higher rewards after greater effort can result in continued effort even in the absence of rewards, such as with learned industriousness, in which effortful tasks that were rewarded previously become rewarding in their own right because of prior associations with reward. Adults also change their perceptions of reward based on the effort expended (for a review, see Inzlicht, Shenhav, & Olivola, 2018). However, effort and subsequent reward may be functionally separate for children younger than 6 years. For example, 4- and 6-year olds completed high- or low-effort tasks until they obtained 10 attractive or unattractive stickers as rewards (Benozio & Diesendruck, 2015). Then, they completed a game in which they could distribute 10 attractive or unattractive stickers to another child or keep the stickers for themselves. Six-year olds kept more stickers for themselves after the high- than the low-effort tasks, regardless of the attractiveness of the stickers, suggesting that 6-year olds felt more deserving of the sticker rewards after effort. However, 4-year olds kept similar amounts of attractive stickers for themselves regardless of effort, indicating consistent valuation of attractive rewards independent of effort. When distributing unattractive stickers, 4-year olds gave away *more* stickers after effortful tasks, suggesting that the value of unattractive rewards did not increase following effort. Without a history of rewarded effort, younger children may be less likely to avoid unnecessary cognitive effort, whereas older children—who have had experience getting rewards—calibrate effort with anticipated rewards.

Children older than 7 years also choose to do more difficult tasks when they understand that completing these tasks carries a higher incentive value for external evaluation. For example, when asked to choose from puzzles labeled with different levels of difficulty, children ages 7 years and older preferentially selected the more difficult puzzles (Nicholls, 1978). These older children also reported that success on the more difficult puzzles would most please a teacher just before deciding on a puzzle. In contrast, children younger than 7 years did not reliably report that succeeding on more difficult puzzles would most please a teacher, indicating an immature understanding of this incentive of succeeding on difficult tasks.

CONCLUSIONS AND OUTSTANDING QUESTIONS

Children do not spontaneously monitor cognitive demands to select tasks reliably until after around 7 years, even though they can do so when instructed or when cognitive demands are made salient through other goals. Several developmental changes may lead to the emergence of spontaneous monitoring of cognitive effort in childhood. Children’s increased prioritization of task cues and use of feedback likely help build associations between specific tasks and cognitive demands. Children's increasing cognitive capacities, especially working memory, could help them maintain meta-level strategies like avoiding more demanding tasks while still performing well. Interest in tasks likely changes with development, leading to differences in children's perceptions of effort and decisions about what to pursue. Lastly, children may increasingly establish an association between cognitive effort and reward and increasingly consider cognitive effort as costly.

Several outstanding questions remain. Sensitivity to and avoidance of cognitive demand are considered adaptive in adults, enabling the efficient use of cognitive resources (e.g., Kurzban et al., 2013; Shenhav et al., 2017). But whether the same holds true for children is less clear. Avoiding cognitive demands might preclude children from critical learning opportunities, but sensitivity to cognitive demands might foster learning opportunities that are developmentally appropriate. Assessments of cognitive demands in children have typically used self-reports or explicit choice measures; whether young children show discrepancies between physiological indices of demand, such as pupil dilation, and self-report or behavioral performance should be examined further. Individuals also differ in spontaneous demand monitoring and choices to avoid or seek demand, likely due to many factors that warrant additional investigation, including cognitive skills and traits (e.g., working memory, susceptibility to boredom). How demands are integrated into the broader contextual factors that influence task selections likely also changes with age. Decisions to tackle cognitively demanding tasks do not occur in isolation; in school and the broader community, other people and an individual's values and beliefs play a role (Doebel, 2020); perceptions of cognitive effort could reciprocally influence children's peers and the development of children's values and beliefs, including about how to invest cognitive effort and decisions about the value of education. Exploring how social and other contextual factors influence the monitoring of cognitive effort and task selection, and vice versa, will be important for a more complete understanding of developmental changes in decisions about what to do.

REFERENCES

Benozio, A., & Diesendruck, G. (2015). From effort to value: Preschool children's alternative to effort justification. *Psychological Science*, *26*, 1423–1429. https://doi.org/10.1177/0956797615589585

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences*, *16*, 106–113. https://doi.org/10.1016/j.tics.2011.12.010

Bridgers, S., Jara-Ettinger, J., & Gweon, H. (2020). Young children consider the expected utility of others' learning to decide what to teach. *Nature Human Behaviour*, *4*, 144–152. https://doi.org/10.1038/s41562-019-0748-6

Chevalier, N. (2015). The development of executive function: Toward more optimal coordination of control with age. *Child Development Perspectives*, *9*, 239–244. https://doi.org/10.1111/cdep.12138

Chevalier, N. (2018). Willing to think hard? The subjective value of cognitive effort in children. *Child Development*, *89*, 1283–1295. https://doi.org/10.1111/cdev.12805

Chevalier, N., Dauvier, B., & Blaye, A. (2018). From prioritizing objects to prioritizing cues: a developmental shift for cognitive control. *Developmental Science*, *21*, e12534. https://doi.org/10.1111/desc.12534

Chevalier, N., Martis, S. B., Curran, T., & Munakata, Y. (2015). Metacognitive processes in executive control development: The case of reactive and proactive control. *Journal of Cognitive Neuroscience*, *27*, 1125–1136. https://doi.org/10.1162/jocn_a_00782

Clerc, J., Miller, P. H., & Cosnefroy, L. (2014). Young children's transfer of strategies: Utilization deficiencies, executive function, and metacognition. *Developmental Review*, *34*, 378–393. https://doi.org/10.1016/j.dr.2014.10.002

Danner, F. W., & Lonky, E. (1981). A cognitive-developmental approach to the effects of rewards on intrinsic motivation. *Child Development*, *43*, 1043–1052. https://doi.org/10.2307/1129110

Desender, K., Buc Calderon, C., Van Opstal, F., & Van den Bussche, E. (2017). Avoiding the conflict: Metacognitive awareness drives the selection of low-demand contexts. *Journal of Experimental Psychology: Human Perception and Performance*, *43*, 1397–1410. https://doi.org/10.1037/xhp0000391

Desender, K., Van Opstal, F., & Van den Bussche, E. (2017). Subjective experience of difficulty depends on multiple cues. *Scientific Reports*, *7*, 44222. https://doi.org/10.1038/srep44222

Doebel, S. (2020). Rethinking executive function and its development. *Perspectives on Psychological Science*, *15*, 942–956. https://doi.org/10.1177/1745691620904771

Dunn, T. L., Lutes, D. J., & Risko, E. F. (2016). Metacognitive evaluation in the avoidance of demand. *Journal of Experimental Psychology: Human Perception and Performance*, *42*, 1372–1387. https://doi.org/10.1037/xhp0000236

Efklides, A., Kourkoulou, A., Mitsiou, F., & Ziliaskopoulou, D. (2006). Metacognitive knowledge of effort, personality factors, and mood state: Their relationships with effort-related metacognitive experiences. *Metacognition and Learning*, *1*, 33–49. https://doi.org/10.1007/s11409-006-6581-0

Gatzke-Kopp, L. M., Ram, N., Lydon-Staley, D. M., & DuPuis, D. (2018). Children's sensitivity to cost and reward in decision making across distinct domains of probability, effort, and delay. *Journal of Behavioral Decision Making*, *31*, 12–24. https://doi.org/10.1002/bdm.2038

Ghetti, S., Hembacher, E., & Coughlin, C. A. (2013). Feeling uncertain and acting on it during the preschool years: A metacognitive approach. *Child Development Perspectives*, *7*, 160–165. https://doi.org/10.1111/cdep.12035

Inzlicht, M., Shenhav, A., & Olivola, C. Y. (2018). The effort paradox: Effort is both costly and valued. *Trends in Cognitive Sciences*, *22*, 337–349. https://doi.org/10.1016/j.tics.2018.01.007

Jiang, Y., Rosenzweig, E. Q., & Gaspard, H. (2018). An expectancy-value-cost approach in predicting adolescent students' academic motivation and achievement. *Contemporary Educational Psychology*, *54*, 139–152. https://doi.org/10.1016/j.cedpsych.2018.06.005

Kool, W., McGuire, J. T., Rosen, Z. B., & Botvinick, M. M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology: General*, *139*, 665–682. https://doi.org/10.1037/a0020198

Kurzban, R., Duckworth, A., Kable, J. W., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance.

Behavioral and Brain Sciences, *36*, 661–679. https://doi.org/10.1017/S0140525X12003196

Liu, S., Gonzalez, G., & Warneken, F. (2019). Worth the wait: Children trade off delay and reward in self-and other-benefiting decisions. *Developmental Science*, *22*, e12702. https://doi.org/10.1111/desc.12702

Magid, R. W., DePascale, M., & Schulz, L. E. (2018). Four-and 5-year-olds infer differences in relative ability and appropriately allocate roles to achieve cooperative, competitive, and prosocial goals. *Open Mind*, *2*, 72–85. https://doi.org/10.1162/opmi_a_00019

Milyavskaya, M., Galla, B., Inzlicht, M., & Duckworth, A. (2018). More effort, less fatigue: How interest increases effort and reduces mental fatigue. Unpublished manuscript.

Milyavskaya, M., Inzlicht, M., Johnson, T., & Larson, M. (2019). Reward sensitivity following boredom and depletion: A high-powered neurophysiological investigation. *Neuropsychologia*, *123*, 159–168. https://doi.org/10.1016/j.neuropsychologia.2018.03.033

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*, 134–140. https://doi.org/10.1016/S1364-6613(03)00028-7

Munakata, Y., Snyder, H. R., & Chatham, C. H. (2012). Developing cognitive control: Three key transitions. *Current Directions in Psychological Science*, *21*, 71–77. https://doi.org/10.1177/0963721412436807

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory*, Vol. *26* (pp. 125–173). New York, NY: Academic Press.

Nicholls, J. G. (1978). The development of the concepts of effort and ability, perception of academic attainment, and the understanding that difficult tasks require more ability. *Child Development*, *49*, 800–814. https://doi.org/10.2307/1128250

Nicholls, J. G., & Miller, A. T. (1983). The differentiation of the concepts of difficulty and ability. *Child Development*, *54*, 951–959. https://doi.org/10.2307/1129899

Niebaum, J. C., Chevalier, N., Guild, R. M., & Munakata, Y. (2019). Adaptive control and the avoidance of cognitive control demands across development. *Neuropsychologia*, *123*, 152–158. https://doi.org/10.1016/j.neuropsychologia.2018.04.029

Niebaum, J. C., Chevalier, N., Guild, R. M., & Munakata, Y. (in press). Developing adaptive control: Age-related differences in task choices and awareness of proactive and reactive control demands. *Cognitive, Affective, and Behavioral Neuroscience*, https://doi.org/10.31234/osf.io/tgdbu

O'Leary, A. P., & Sloutsky, V. M. (2017). Carving metacognition at its joints: Protracted development of component processes. *Child Development*, *88*, 1015–1032. https://doi.org/10.1111/cdev.12644

O'Leary, A. P., & Sloutsky, V. M. (2019). Components of metacognition can function independently across development. *Developmental Psychology*, *55*, 315–328. https://doi.org/10.1037/dev0000645

Rosenzweig, E. Q., Wigfield, A., & Eccles, J. S. (2019). Expectancy-value theory and Its relevance for student motivation and learning. In K. A. Renninger & S. E. Hidi (Eds.), *The Cambridge handbook of motivation and learning* (pp. 617–644). Cambridge, UK: Cambridge University Press.

Saunders, B., Milyavskaya, M., & Inzlicht, M. (2015). What does cognitive control feel like? Effective and ineffective cognitive control is associated with divergent phenomenology. *Psychophysiology*, *52*, 1205–1217. https://doi.org/10.1111/psyp.12454

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. https://doi.org/10.1146/annurev-neuro-072116-031526

Song, J., Kim, S. I., & Bong, M. (2019). The more interest, the less effort cost perception and effort avoidance. *Frontiers in Psychology*, *10*, 2146. https://doi.org/10.3389/fpsyg.2019.02146

Van Duijvenvoorde, A. C., Zanolie, K., Rombouts, S. A., Raijmakers, M. E., & Crone, E. A. (2008). Evaluating the negative or valuing the positive? Neural mechanisms supporting feedback-based learning across development. *Journal of Neuroscience*, *28*, 9495–9503. https://doi.org/10.1523/JNEUROSCI.1485-08.2008

Westbrook, A., & Braver, T. S. (2015). Cognitive effort: A neuroeconomic approach. *Cognitive, Affective, & Behavioral Neuroscience*, *15*, 395–415. https://doi.org/10.3758/s13415-015-0334-y

Westgate, E. C. (2020). Why boredom is interesting. *Current Directions in Psychological Science*, *29*, 33–40. https://doi.org/10.1177/0963721419884309