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The Development of Self and Identity in Adolescence: Neural Evidence and Implications for a Value-Based Choice Perspective on Motivated Behavior

Jennifer H. Pfeifer Elliot T. Berkman

University of Oregon

Abstract

Following a key developmental task of childhood—building a foundation of self-knowledge in the form of domain-specific self-concepts—adolescents begin to explore their emerging identities in ways that foster autonomy and connectedness. Neuroimaging studies of self-related processes demonstrate enhanced engagement of the ventromedial prefrontal cortex in adolescence, which may facilitate and reflect the development of identity by integrating the value of potential actions and choices. Drawing from neuroeconomic and social cognitive accounts, we propose that motivated behavior during adolescence can be modeled by a general value-based decision-making process centered around value accumulation in the ventromedial prefrontal cortex. This approach advances models of adolescent neurodevelopment that focus on reward sensitivity and cognitive control by considering more diverse value inputs, including contributions of developing self- and identity-related processes. It also considers adolescent decision making and behavior from adolescents' point of view rather than adults' perspectives on what adolescents should value or how they should behave.

Keywords

adolescence; value-based decision making; self-development

Adolescents are physically, cognitively, and socioemotionally more advanced than children but prone to behave in ways that are inconsistent with adult values and norms. Adolescents are frequently caricatured as excessive risk takers, overly self-focused, and highly susceptible to social pressure. Despite agreement that such a portrayal is an oversimplification, the field is still searching for a framework to explain why these tendencies are more common in adolescents than in children or adults. One influential approach, the dual-systems model (1), conceptualizes behavior in terms of a competition or conflict between developing neural circuits implicated in reward sensitivity and cognitive control, and describes how the functioning of these networks may relate to adolescents' risk taking. Another prominent approach considers contributions of networks that process social information to understand adolescents' social reorientation, in which social influences expand beyond the family to emphasize peers (2). However, these models do not account for

the contributions of identity- and self-related processes, such as core personal values and self-verification, to motivated adolescent behavior. This gap is disconcerting because the self represents a key intersection among social, cognitive, affective, motivational, and regulatory processes (3).

To address this gap, we propose a neurobiologically grounded model of value-based decision making that more flexibly accommodates more diverse inputs to behavior, such as considerations related to self and identity that are relevant in adolescence and can promote or prevent risky behavior depending on context. We first review adolescents' development of self and identity, linking the behavioral and neural levels. We then outline the general value-based decision-making approach and describe the predictions of this model in the context of adolescent development. Our goal is to produce a more flexible, comprehensive account of adolescent behavior – one that might improve adolescent outcomes, as well as enhance our understanding of positive and prosocial development in adolescence.

The Development of Self and Identity in Adolescence

Adolescence is crucial for many aspects of developing self and identity, including commitments, personal goals, motivations, and psychosocial well-being (4–7). During adolescence, youth seek autonomy, particularly from parents, along with increased commitments to social aspects of identity and greater needs for connection with peers (8). Relatedly, self-evaluations become increasingly differentiated and complex across roles and relationships (9). Adolescents also frequently report greater self-consciousness, and are more concerned with and interested in others' perceptions of self (10).

Given the theoretical and empirical prominence of changes in aspects of self and identity during adolescence, researchers have begun to examine how they are expressed at a neural level. Most of this work has examined self-evaluation, typically by asking youth to judge whether various (often overtly positive or negative) traits and attributes describe them. Like adults, children and early adolescents use cortical and subcortical midline structures, in particular the ventromedial prefrontal cortex (vmPFC) and adjacent rostral/perigenual anterior cingulate cortex (ACC), more when evaluating themselves than when evaluating others (10–12; although this pattern can be attenuated with close others like adolescents' best friends; 13, 14). Even in clinical populations of children and adolescents, the vmPFC is usually more active during self-evaluations than most control conditions. Typically developing youth also seem to use the vmPFC more during self-evaluations than do youth with autism spectrum disorder (3) and, at times, youth experiencing depression (15, 16).

We are just beginning to learn more about how neural responses elicited by self-evaluation develop *across* adolescence, rather than between childhood or adolescence and adulthood. In two studies on the self-reference effect in memory (wherein information evaluated in relation to the self is remembered more accurately than other information), activity in the rostral/perigenual ACC increased from ages 7 to 13 during encoding for self versus mother (17), and from ages 13 to 19 during encoding for self versus distant other (18).

Furthermore, in a longitudinal fMRI study, responses to self-evaluations in the rostral/perigenual ACC (and ventral striatum, VS) self-evaluations were stable from age 10 to 13 (19). Activity also increased in the vmPFC over time during evaluations of self (relative to other), especially for self-evaluations in the social (versus academic) domain, and in adolescents with more advanced pubertal development during social self-evaluations. This suggests the interrelated biological and social changes associated with puberty may affect self-referential processes and the value derived from them.

Although these studies of self-evaluative processes emphasized the vmPFC and adjacent rostral/perigenual ACC, several other regions were also important. As mentioned earlier, VS responses have been observed not only during direct self-evaluations (19), but also in indirect (reflected) social self-evaluations, specifically when an adolescent thinks about what a best friend thinks of his or her social abilities (14). The involvement of VS during self-evaluation is consistent with studies of adults, which highlight the overlap between self-reference and reward (20) through assigning value (21). Additionally, the dorsal medial PFC (dmPFC) and the temporal-parietal junction (TPJ) are sometimes more active in children's and adolescents self-evaluations (10, 11, 18); in adults, these regions are typically attuned to mentalizing, social perspective taking, and evaluating others. Furthermore, functional connectivity between the TPJ and the vmPFC relates positively to generosity in adults (22), suggesting that the TPJ might affect social value by modulating the vmPFC during choices involving the self and others.

In summary, in research using functional neuroimaging, explicit self-evaluation as well as more indirect forms of social self-evaluation implicated in relational identity robustly engage the vmPFC and the rostral/perigenual ACC (as part of a broader network including the VS, TPJ, and dmPFC) in children and adolescents, often more so than in adults. Activity in the vmPFC and rostral/perigenual ACC seems to increase from late childhood through middle adolescence, when it either plateaus or continues to increase. These findings are consistent with empirical evidence and theoretical proposals that adolescence is critical for developing identity (4–7).

Despite the behavioral and neural evidence of the elevated importance of self- and identity-related processes during adolescence, what role these processes may play in neurodevelopmental models of adolescent behavior is unclear. Dual-systems models in particular focus on a mismatch between mature reward-related circuitry and immature cognitive control circuitry (1). However, self/identity does not fit clearly in either category because it can contribute alternately or concurrently to reward-seeking and regulatory behavior. For example, a teenager with an emerging academic identity is likely to prioritize studying over other activities, though it is unclear whether the effect of such an identity operates through rewarding or regulatory processes (or both, or if this distinction is not meaningful theoretically for self/identity). In the next section, we present a model that prioritizes self- and identity-related processes in determining behavior and explains a prominent functional role of the vmPFC during this period.

Value-Based Decision Making as a Mechanism of Motivated Behaviors in Adolescence

Choosing to attend a party where there may be alcohol as well as an attractive classmate against parental wishes and despite math tutoring in the morning sounds like a failure of self-control—to parents, at least. But from an adolescent's point of view, this decision might be driven by the high subjective value of partying and associated opportunities relative to some alternative, like studying algebra. This should not be surprising; researchers noted decades ago that adolescents routinely chose to behave in ways that are of optimal utility for their social microenvironments (23), and utility-maximizing functions can account for decisions like this one made by people at any age (24, 25). However, researchers have recently characterized the computational and neural processes involved in value-based decision making, defined as either-or choices between two or more options with varied attributes (26). In a value-based decision-making approach, diverse gains and costs are integrated in a dynamic and noisy way to yield choices (see Figure 1; relevant inputs are specific to a given choice and not necessarily confined to one—e.g., parental incentives for good grades are both *tangible* and *social* rewards). As we describe next, this flexibility is a key feature of the model. The gains and costs (represented throughout the brain) act as inputs to the process, and are integrated in the vmPFC after being weighted and transformed into a common neural value currency (27).

From this perspective, one cause of what adults consider to be problematic adolescent behavior may be a normative developmental process that increases the subjective value of self- and identity-relevant inputs relative to childhood. The increased activity observed in the vmPFC during self-evaluation and relational identity processes in adolescence overlaps spatially with the representation of *value* in the brain (see Figure 2), and thus could reflect greater subjective value afforded to the self and its varied traits, roles, and aspirations. This suggests that identity and other associated self-related processes may increase as a source of value to shape decision-making and motivated behavior across adolescence.

Value-based choice describes decision making as the output of a unified value-accumulation process centered in the vmPFC. The valuation process integrates signals from regions that represent relevant attributes of choice (e.g., self-related value in the mPFC, social values in the TPJ, abstract goals such as health in the lateral PFC). We note two aspects of this process of value integration: First, we do not presume it to be deliberative; in other words, inputs are integrated computationally without relying on explicit reasoning. The model allows for rational decision making independent of formal reasoning, unlike fuzzy-trace theory's distinction between decisions based on explicit reasoning and those based on intuition or gist (28). Second, a value-based decision-making approach accounts explicitly for the diversity of inputs, and recognizes that these inputs may not fall neatly into consistent clusters. For example, *hot* processes such as reward and *cold* processes such as regulation do not necessarily map on to risky and safe behaviors, respectively, and do not necessarily oppose one another. As such, observed activations in two or more regions during choice might reflect simultaneous contributions to value integration rather than competition or inhibition (see 29 for a similar point and a more integrative account).

Dissolving the one-to-one mapping between process (e.g., hot versus cold or reward versus regulation) and outcome (e.g., risky and safe) averts the issue that can arise when these inputs are funneled through two systems that battle for control over behavior (e.g., 1, 30). The most important distinction in a value-based decision-making model is in fact not between types of processes, but between factors that contribute to the value of one behavior or another. For example, what matters in this model is which behavior is promoted by social influence, regardless of whether it is hot or cold. By refocusing on the many diverse reasons for potential behaviors, the model also suggests new experimental paradigms that manipulate the motivating reasons behind a behavior, as well as new pathways for intervention from the variety of value inputs to choice, rather than just two processes (reward and control) whose functioning is mainly determined by neurodevelopment.

The Identity-Value Model (31) expands on this general value-based decision-making approach by emphasizing the special role of identity in self-regulation and motivated behavior broadly. The central hypothesis of the Identity-Value Model is that goal-directed behaviors are valued more when they are relevant to the identity. Consider the previously mentioned example: If the adolescent had a strong academic identity commitment, the identity might boost the chance of skipping the party by increasing the value of studying. If, instead, the adolescent wished to fit in with a peer group that valued late-night socializing, that aspect of identity would increase the value of going to the party.

The model considers identity as multifaceted, so different aspects of identity (e.g., academic, social/relational, familial, ethnic/cultural, interest-based) can influence the value of self-regulatory behaviors to the extent that such aspects are salient and perceived as relevant to the decision (see also 32). Key features of identity thought to facilitate its effectiveness in adulthood include stability, positivity, and accessibility. Given that identity development is considered a core task of adolescence (33), and evidence suggests significant exploration of and commitments to key identities during this period (4, 5, 7), we expect identity-relevant inputs to increase in value across adolescence, affecting self-regulation and other motivated behaviors. Additionally, identities and behaviors might be reinforced mutually: aspects of identity that favor consistently chosen actions might be more valued, and aspects of identity that favor actions that are consistently not chosen might be less valued (e.g., through dissonance or reward-devaluation processes; 34).

Additional Developmental Considerations for Value-Based Decision Making

One important consideration is the extent of developmental change in the decision-making processes implicated in this model. Even young children apparently understand expected value, and by late childhood use it to decide in a manner similar to adults, which includes sensitivity to probability and magnitude of outcome (35, 36). These abilities apparently mature by middle adolescence, particularly for decision-making contexts that are relatively less affective (37). However, adolescents may also be more sensitive behaviorally and neurally than adults to increasing expected value (38), and may be more tolerant of ambiguity (39). The range of simple value inputs in much of the relevant research cited previously was limited; researchers should therefore expand the set of stimulus types used in experiments to include more complex, identity-relevant targets and ecologically valid

decision-making contexts. Additionally, despite this support for the general value-based choice model in adolescence, researchers have not manipulated the self-relevance of response options to directly test the contribution of identity-based values to adolescent decision-making processes.

Other components of the value-based decision-making model (detailed in 27) may also be affected by development, such as delay discounting in which participants choose between smaller-sooner and larger-later rewards. For example, delay discounting decreases rapidly from early to middle adolescence, a finding that represents an additional important constraint that shapes the value-based decision-making process in adolescence differently than in adulthood (40, 41).

Finally, in addition to the possibility that identity-based and other self-related values become increasingly important to adolescent decision making, particular social motivations like social status and peer or romantic relationships are expected to surge in relevance as well (2, 42, 43). One set of social-cognitive weights on the decision-making process undoubtedly includes perceptions of what others—especially peers (e.g., friends, romantic partners, members of social ingroups, members of high-status social groups)—value; in this context, others also include respected individuals (e.g., family members, teachers). The interaction between this concept and identity development processes is also an interesting consideration. Specifically, these social perceptions provide information about the self (10, 14) and help shape adolescents' personal values and identity, which subsequently or concurrently are perceived as increasingly significant in decision making.

Conclusion

Although adolescent behavior is influenced by normative developmental changes in sensitivity to rewards and social context, the self also evolves to become an important source of value and intrinsic motivation. With increasing development and exploration of identity commitments and autonomy, the self can be harnessed for self-regulation and other motivated behavior. This creates a space for intervening to improve outcomes in maladaptive cases of adolescent decision making that does not exist within current models, in which such behaviors are portrayed to result from expected maturational trajectories of frontostriatal circuitry. In particular, identity-based and other self-related values may be much more modifiable targets, either in terms of the content of identity in various contexts or the relative salience of different aspects of identity that might promote different behaviors (e.g., athletic versus academic). For example, the juvenile justice system is considering ways to foster positive and prosocial identities as a way to keep adolescents from engaging in antisocial behavior (44).

On a broader level, a neurodevelopmentally informed, value-based decision-making approach may provide not only a more comprehensive theory but also an opportunity to reframe our thinking about adolescents' choices and actions. If a value-based decision-making account is correct, choices that adults perceive as bad can be considered instead as rational from the adolescent point of view, at least inasmuch as they represent choices with the highest subjective value. The adolescent decision-making system is not broken;

adolescents (individually and as a group) may simply consider different value attributes and weight those attributes differently than do adults. By taking the normative adult perspective, we may be artificially constraining the sources of value we consider relevant to adolescent decision making, thereby restricting what we can learn about how and why adolescents' priorities differ from those of adults, and limiting our ability to develop ways to encourage positive outcomes. Given that developing positive personal and social identities (4–7, 9), as well as balancing autonomy and connectedness, are core tasks of adolescence (8, 33), these self-related and social sources of value are worth prioritizing in investigations and translational efforts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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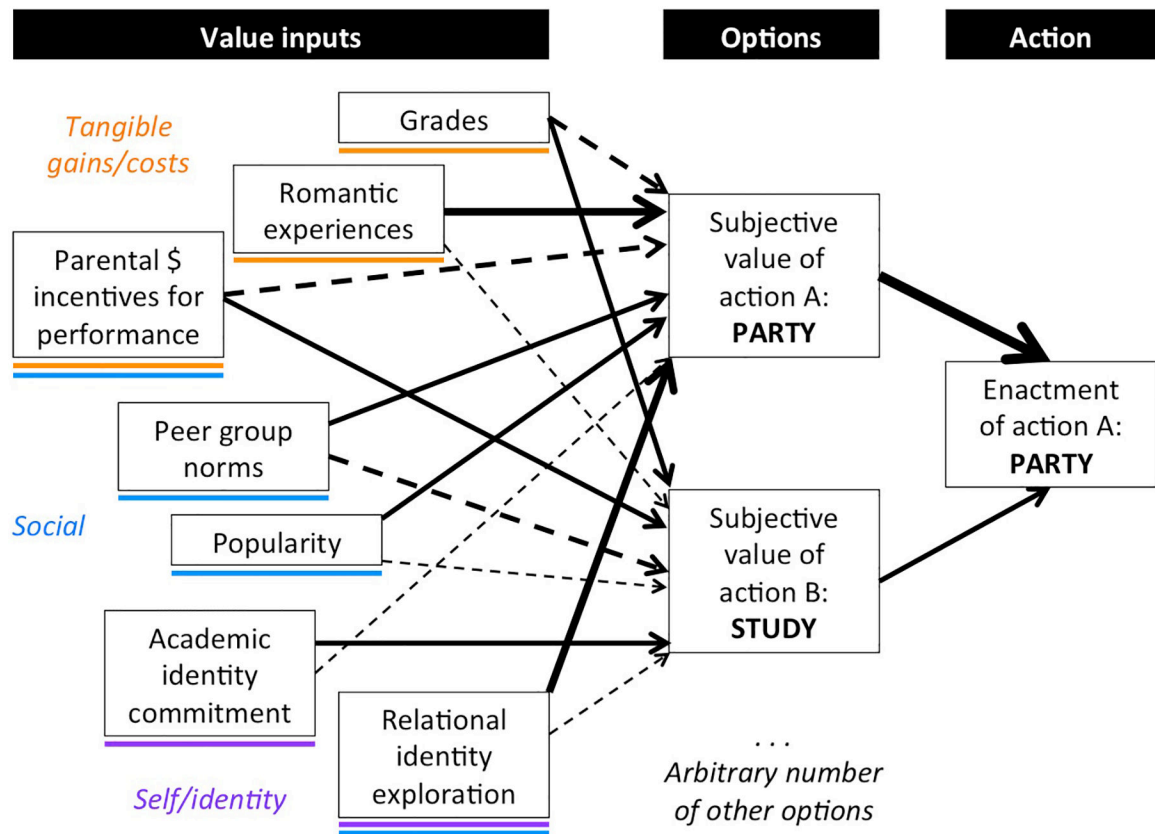


Figure 1. Value-based decision-making in adolescence

Note. Solid arrows from value inputs represent positive value, dashed arrows represent negative value, and line thickness indicates relative weight. Sample tangible inputs (primary or secondary gains and costs) are tagged in orange, sample social inputs are tagged in blue, and sample self/identity related inputs are tagged in purple. Value inputs can be cross-tagged. Adapted from (27).

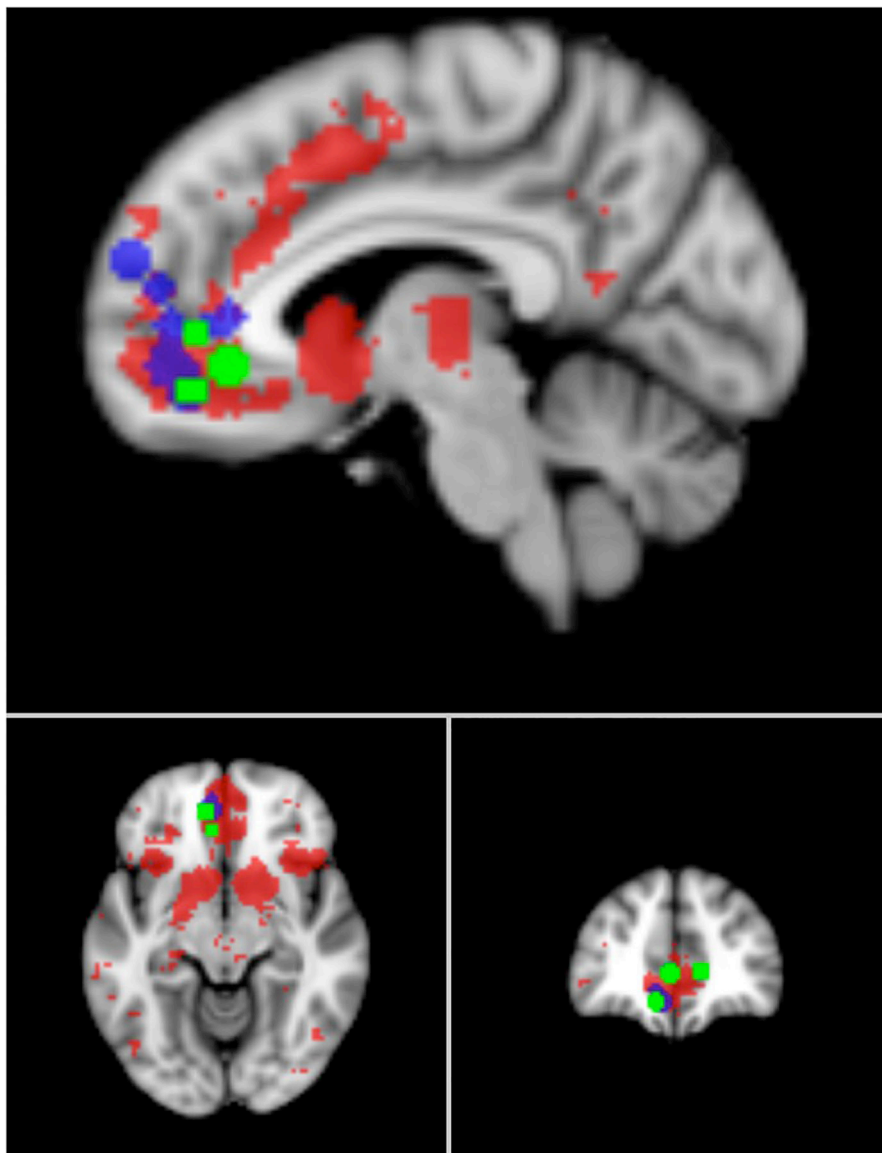


Figure 2. Developmental self-evaluation studies and value

Note. Regions in red are likely to appear in studies using the term *value*, calculated by Neurosynth's automated meta-analysis tool. Peaks from studies of self-evaluation using typically developing adolescents are overlaid. Blue represents peaks from the self > other contrast in child or adolescent samples, and green represents peaks that show increases during self-evaluation with age. Slices are displayed at $x = -6$, $y = 44$, and $z = -10$. To be included here, studies had to report activations in medial prefrontal cortex from the contrast of self > other from a developmental sample or changes in that contrast with age. A full list of studies and coordinates can be found at: <http://osf.io/64qh5>.