Adolescent risk-taking

OVERVIEW

This document provides an overview of the scientific community's current understanding of why adolescents are more likely than children or adults to engage in risk-taking behavior, how this behavior is measured in experimental contexts, and how this knowledge can be applied to support evidence-based practice.

What emotional and cognitive operations develop during adolescence?

Adolescence is marked by heightened risk-taking, reward-seeking, and impulsive behaviors. Some of these behaviors serve a functional purpose as adolescents begin to establish independence from their parents and take on adult roles and responsibilities[1], but they can also result in negative consequences, such as increased rates of mortality and addiction.

Researchers have identified a number of emotional and cognitive processes that develop during adolescence that are related to the behavioral changes observed during this time. Processes involved in **cognitive control** (such as the abilities to selectively choose an action or thought based on rules or plans, inhibit impulsive behaviors, and hold information in working memory) improve in a gradual linear fashion from childhood through adolescence and into adulthood. People also get better with age at resisting immediate temptation in order to receive a larger reward at a later time (a process known as "temporal discounting of reward" or "delay of gratification")[2]. These processes are part of an overarching construct of **self-control**. The development of these processes has been linked to the maturation of the **prefrontal cortex (PFC)**.

In contrast, there is evidence that other processes are at their peak in adolescence, rather than changing in a linear way from childhood to adulthood. Two such processes that have been of great interest to researchers attempting to understand the prevalence of risk-taking behavior in adolescence are **sensation seeking** and **reward sensitivity**. Adolescents tend to seek out new and exciting situations more than children or adults do, and this tendency is related to an increase in risk-taking behavior. Intuitively, this makes sense and is adaptive. Adolescence is a time for physical growth and making a path for independence from one's nuclear family. However, what is adaptive in some situations can be maladaptive in others, especially if adolescents are experiencing trauma, stress, neighborhood violence, etc. For example, adolescents who report enjoying "exploring new places" and doing "frightening things" are more likely to engage in risky behavior, such as using drugs[3].

Adolescents are also more likely than children or adults to value rewards as pleasurable. Therefore, they may be more likely to engage in risky behavior in response to an increase in the value of rewarding events and items[4]. Adolescents' behavior is also more affected by emotional information. Adolescents are less able than children or adults to **inhibit** impulsive behaviors in response to emotional information, like happy faces[5], and they engage in

Adolescence
a period of transition between the onset of puberty (~age 10-12 years) and adulthood (~age 18-21 years)

Cognitive control
often referred to with the term 'executive functions,' a family of skills needed when you have to choose an action or thought based on rules or plans, when you have to concentrate and pay attention in the presence of distraction, and when going on automatic or relying on instinct or intuition would not be adaptive

Self-control
the ability to suppress inappropriate or competing thoughts, desires, emotions, and actions in favor of appropriate ones

Prefrontal cortex (PFC)
cortical brain structure involved in cognitive control

Sensation seeking
the inclination to pursue new or exciting experiences and the willingness to take risks for the sake of such experiences

Reward sensitivity
level of responsiveness or susceptibility to changes in the value of a rewarding stimulus

Inhibition
voluntary or automatic constraint or suppression of a process or behavior

more risk-taking in the presence of peers in comparison to when they are alone[6]. This heightened sensitivity to social context can lead to positive outcomes as well. For example, adolescents increase their prosocial behavior, or behavior intended to benefit others, in response to prosocial feedback from peers[7].

Many of the developmental changes in emotional and cognitive operations discussed above are consistent with results from studies of animal species, including rats and non-human primates. Across many species, adolescence is a time of increased novelty-seeking, peer interactions, and independence from caregivers. Although risk-taking in adolescence is often viewed negatively, this persistence across species points to the ways in which some risky behavior is adaptive for survival. Adolescence is an important time for exploring peer relationships outside of one's nuclear family and preparing to "leave the nest" to build a life of one's own independent of caregivers. Thus, this drive towards risk-taking may be positive in many ways, unless co-opted by opportunities that are truly dangerous, like excessive alcohol or drug use. In addition, individual variation among adolescents makes some more likely than others to engage in sensation-seeking and/or risk-taking behavior.

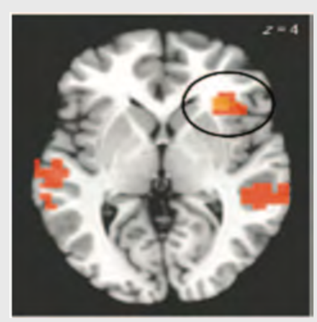
How do we know this?

Much of what we know about emotional and cognitive development comes from experimental or task-based approaches. Researchers develop experimental tasks with the intention of eliciting observable and measurable behaviors that are related to underlying mental constructs (e.g., motivation). Tasks are carefully designed to isolate specific mental processes that are difficult (or impossible) to measure through observable behavior outside of an experimental setting.

METHOD SPOTLIGHT

functional magnetic resonance imaging (fMRI)

Functional magnetic resonance imaging, or fMRI, is a neuroimaging technique for measuring brain activity. Neurons, the cells that send electrical and chemical messages throughout the brain and the rest of the nervous system, require energy to transmit signals. This energy is delivered through increased blood flow to regions that are relatively more active at a given moment. By measuring changes in blood flow, fMRI detects which brain regions are more or less active when a person engages in a certain task. This method provides a powerful tool for investigating which brain regions (and networks of brain regions) are involved in cognitive processes such as reward-seeking, risk assessment, and inhibition of impulsivity. However, conducting fMRI research is expensive and logistically difficult, making it impractical for many research environments. It should also be noted that fMRI images may suggest relations between certain brain regions and cognitive processes, but causation is nearly impossible to establish due to the complex nature of these processes.



Areas highlighted in color on visualizations of fMRI results reflect brain regions that are relatively more (or less) active during one activity as compared to another

While directly observable behaviors, like reaction times when pressing a button in response to emotional stimuli, can provide insight into internal mental processes, new brain imaging technologies have supplied researchers with an additional tool for investigating the relationship between brain and behavior. One such technique that is commonly used in the study of emotional and cognitive processes across development is functional magnetic resonance imaging (fMRI, see the Method Spotlight box for more information).

What experimental tasks are used to study adolescent development?

A number of tasks have been used to study the development of risk-taking, reward-seeking, and cognitive control in adolescence. One task that is often used to test cognitive control is the **go/no-go task**, in which participants are instructed to press a button ("go") in response to target stimuli that appear frequently and refrain from pushing the button ("no-go") in response to non-target stimuli that appear infrequently. In the traditional go/no-go task, the target and non-target stimuli are non-emotional (e.g., letters). In general, the ability to exercise self-control by not pushing the button when non-targets appear (while still responding quickly to targets) improves from childhood to adolescence into adulthood. In one study, researchers investigated whether this ability to control one's behavior is influenced by emotional information[5]. Children, adolescents, and adults completed an emotional version of the go/no-go task with happy face targets and neutral face non-targets (Figure 1) while in an fMRI scanner. The ability to inhibit button presses to neutral face no-go stimuli improved with age, whereas adolescents were worse than both children

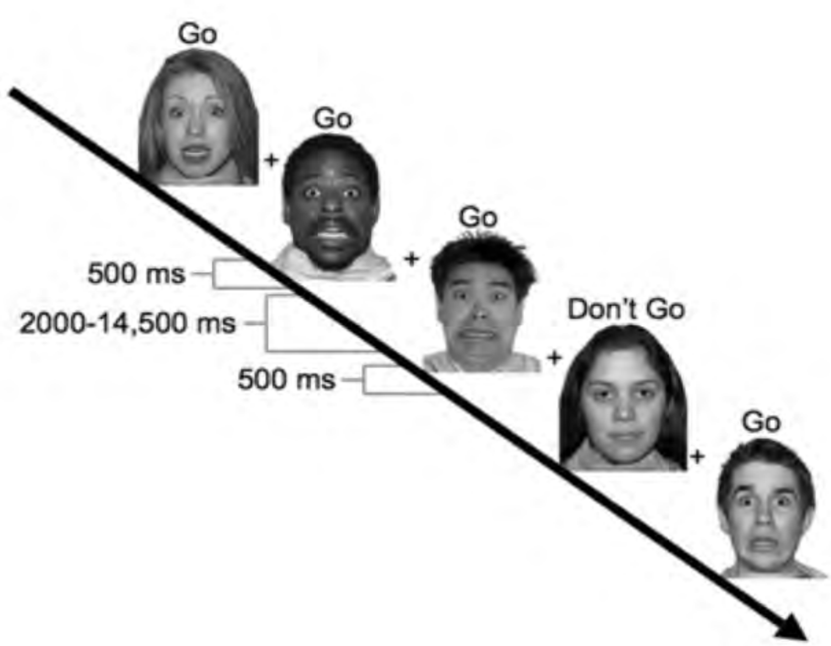


Figure 1. Emotional go/no-go task (Somerville, Hare, & Casey, 2011).

Striatum
subcortical brain structure involved in reward-seeking behavior

and adults at inhibiting presses to happy face no-go stimuli, suggesting that they were more affected by, and less able to inhibit, a response to the emotionally rewarding positive faces. This behavioral result was mirrored in a measure of brain activity using fMRI. Relative to children and adults, adolescents had enhanced activity in response to happy faces in a brain region called the **striatum**. The striatum is a subcortical (below the cortex) brain region that has been implicated in reward-seeking behavior, and thus, this result is consistent with a model of peak reward-seeking during adolescence.

Another task that is widely used in the study of cognitive control is the **Stroop task** (Figure 2), in which participants see the name of a color (e.g., "blue") printed in a colored font, and they are then asked to report the font color. On congruent trials, the color word and the color of the font match (e.g., "blue" displayed in blue font), but on incongruent trials, the word and font color do not match (e.g., "blue" displayed in red font). Successful responses on incongruent trials require acting according to a rule, i.e., attending only to the font color and ignoring the meaning of the word. The difference in response time between congruent and incongruent trials is used as a measure of cognitive control.

This task was used in a study of the relationship between cognitive control and risk-taking in adolescence[8]. In addition to the classic "cognitive" Stroop task described above, 13- to 17-year-old adolescents also completed an emotional version of the task in which an adjective (e.g., "joyful") was displayed over a face displaying an emotional expression. The facial expression was either congruent (e.g., "joyful" displayed over a happy face) or incongruent (e.g., "joyful" displayed over an angry face) with the meaning of the word. Participants were asked to report the emotion category of the word, regardless of the expression on the face. Finally, participants also played a driving simulation game called the **Stoplight task** (Figure 3) in which they tried to complete a course as quickly as possible. At each intersection, participants had

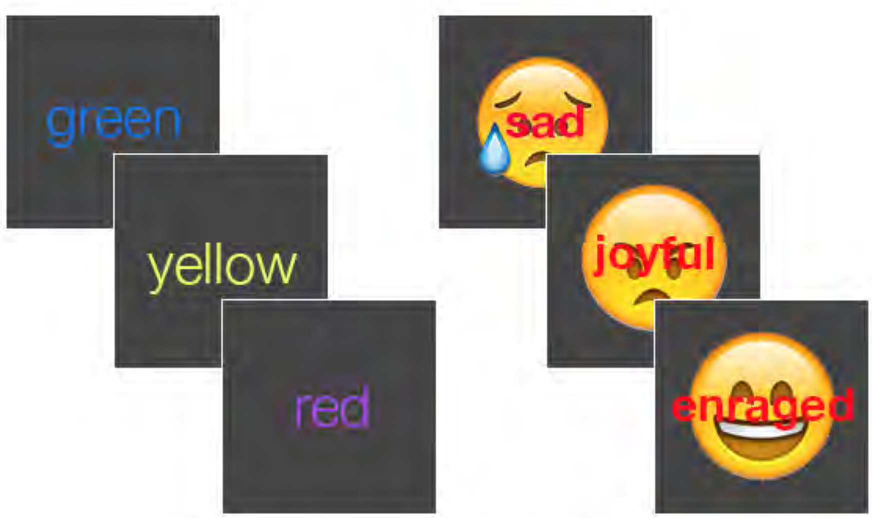
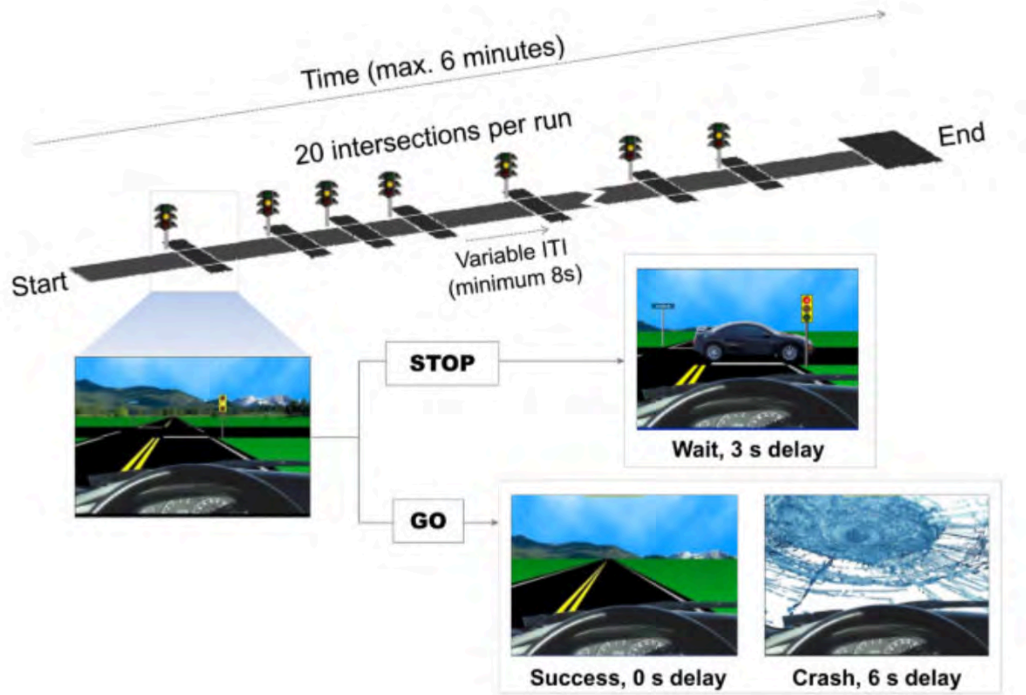


Figure 2. Classic (left) and emotional (right) Stroop task.



to choose between stopping at a stoplight for a small delay, or risking a longer "crash" delay by running the light. Adolescents' risk-taking behavior on the driving task (i.e., running lights) was predicted by their performance on the emotional Stroop task but not the cognitive Stroop task. In other words, adolescents who chose to run through more stoplights were less able to ignore the facial expression in the emotional Stroop task, but they were just as good at the color Stroop task as adolescents who took fewer risks. These results suggest that cognitive control predicts risk-taking, but only when it is assessed in an emotionally arousing context. In another study using the same Stoplight driving task and fMRI, adolescents took more risks when they were being observed by peers than when they were alone[9].

The **Iowa Gambling Task** is a task used to assess decision-making when outcomes are uncertain. Participants are presented with four decks of cards that have rewards or punishments on them. Two of the decks have more rewards than punishments (and are thus deemed "advantageous" decks), and the other two have more punishments than rewards ("disadvantageous" decks). The participant continuously draws cards from a deck, with the option to switch decks at any time. If the participant draws more cards from the advantageous decks over time, this is seen as evidence that he or she is sensitive to the probability of receiving a reward from those decks. One study of people between the ages of 10 and 30 found that adolescents were faster than adults or children to switch their picks to the advantageous decks, suggesting that they were more sensitive to the overall reward value of each deck[4].

Nucleus accumbens
subcortical brain structure involved in reward processing

Orbito frontal cortex
cortical brain region involved in associative learning and cognitive control

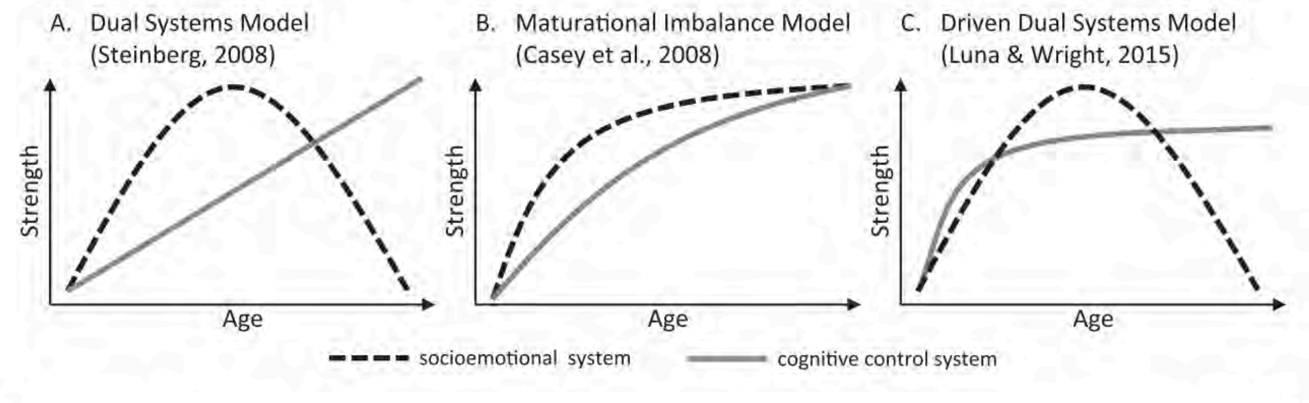
One notable neuroimaging study investigated adolescents' sensitivity to reward value by using a simple **cuing task**[10]. While in an fMRI scanner, participants were shown cues (images of pirates) followed by images depicting varying reward values (images of coins), and then asked to press a button corresponding to the side of the screen on which the cue had appeared. Each cue image was always associated with a specific reward value (small, medium, or large). Both adolescents and adults were faster to respond on trials with larger rewards than smaller rewards, showing that both age groups learned the associations between cues and reward values. Although behavior was similar for adolescents and adults, patterns of brain activation differed with age. In the **nucleus accumbens**, a subcortical area of the brain associated with reward processing, adolescents had more activation to large rewards than children or adults. In the **orbital frontal cortex**, an area involved in associative learning and cognitive control, adolescents showed a pattern of activity that was more similar to that of children than adults. These results highlight that adolescence is a period of transition in which reward networks mature earlier than control networks.

The **temporal discounting of reward task** is a task used to assess cognitive control and decision-making when presented with possible rewards. Participants were given a choice of receiving an amount of money immediately or a larger amount of money after a set period of time, ranging from a week to a year later. Studies have found that people tend to perceive the value of a reward as lower if it is not received immediately, but rather after a length of time[11]. One study found that adolescents discounted the monetary rewards at a significantly higher rate in comparison to adults, suggesting that adolescents are more likely than adults to be drawn to immediate reward and less likely to resist temptation[12].

Self-report measures can be used to assess a person's perception of their own desires or behavior. For example, one study measured adolescents' sensation seeking using the Brief Sensation Seeking Scale (BSSS)[13]. The BSSS evaluates four dimensions: thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility. Respondents rated their agreement on a four-point agree/disagree scale for statements like the following: (1) I like to explore strange places; (2) I like to do frightening things; (3) I like new and exciting experiences, even if I have to break the rules, and (4) I prefer friends who are exciting and unpredictable. Scores on this scale have been demonstrated to be correlated with longer measures of sensation seeking as well as adolescent drug use[14].

Theoretical models of adolescent reward-seeking and risk-taking

A number of theoretical models have been proposed to explain the peak of risky, impulsive, and reward-seeking behavior in adolescence. Models based on early neurobiological studies of brain development focused on the development



of the prefrontal cortex (PFC), a brain area that has been found to be very important for self-regulation and impulse inhibition. These models, however, could not account for why risk-taking behaviors increased from childhood to adolescence. Two current leading models, the dual systems model and the imbalance model, consider the ways in which both motivational and control capacities develop and interact to produce behavior.

According to the **dual systems model**[15] (Figure 4A), the profile of behavior often seen in adolescence results from an early-developing socioemotional system that increases motivation to seek rewards paired with a relatively slow-developing cognitive control system that inhibits impulses. According to this model, the socioemotional system peaks in terms of arousability/reactivity in middle adolescence (ages 14-17), while the cognitive control system continues to mature through late adolescence and into adulthood. Adolescence, therefore, is characterized by a highly reactive socioemotional system that is not yet fully counteracted by a mature system of cognitive control. The authors of this model note that although the biological propensity for risk-taking is highest in middle adolescence, higher rates of risk taking in late adolescence (ages 18-21) relative to middle adolescence are likely due to a general increase in the opportunity for risk-taking with age (e.g., less adult supervision, more financial resources, easier access to alcohol, cars, etc.).

While similar to the dual systems model in many ways, the **imbalance model** (Figure 4B) does not conceive of different systems for motivation and control, but rather "attempts to account for adolescent behavior from an integrated, circuit-based perspective"[16]. According to this model, the emotional and control components of these neural systems are parts of an integrated network and therefore must be considered in terms of the connections within and between these circuits. According to this model, local circuits in subcortical areas (areas that are known to be very involved in reward-seeking and other motivated action) must be formed and strengthened before connections between these subcortical areas and cortical areas (which allow for control) can be built.

Neurotransmitter
chemical messenger that carries messages from neuron to neuron

Dopamine (DA)
neurotransmitter that is important for incentive-driven (motivated) behavior

Imbalances in this brain circuitry can therefore account for the impulsive behavior seen in adolescence as compared to childhood or adulthood.

As discussed above, the striatum is a brain region that has been found to be very involved in incentive-driven behavior in a number of contexts. According to the **integrative component model** of cognitive control (a model that shares many principles with the imbalance model described above), one explanation for this is the striatum's place in the dopaminergic reward circuit[17].

Dopamine (DA) is a **neurotransmitter** that has been shown to increase incentive-driven behavior by activating favored behaviors and inhibiting less desired/competing behaviors, and it is associated with reward and the feeling of pleasure. There is evidence that DA levels peak during adolescence in both humans and animal models, and the authors of the integrative component model nicely summarize the effect of this on adolescent behavior: "The PFC and striatum support incentive driven behaviors through their unique interconnectivity, which is modulated in part by the function of DA. DA availability and signaling is heightened during the adolescent period and may promote novelty seeking in an adaptive fashion in order to gain skills that support adult survival. However, exaggerated DA levels in both striatum and PFC in adolescence may result in an increased sensitivity to rewards coupled with poor executive regulation of impulse driven behaviors, thereby increasing vulnerability for risk-taking behaviors"[18].

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