



Development in uncertain contexts: An ecologically informed approach to understanding decision-making during adolescence

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Abstract

Adolescence is a period of development in which youth have new opportunities for decision-making, often in situations where they may have little information or experience to guide their choices. Thus, learning to make decisions under uncertainty is a key challenge during adolescence. To date, researchers have applied economics formalisms to understand the processes that support adolescents in making decisions under two distinct forms of uncertainty: economic risk and economic ambiguity. Economic risk is when the probabilities of outcomes are known. Economic ambiguity is when the probabilities of outcomes are unknown or unknowable. This research has led to foundational knowledge about the basic processes involved in adolescent decision-making, but many experimental paradigms that dissociate economic risk and ambiguity rely on monetary or point-based choices. Given that adolescence is a period of development characterized by a changing social environment, it remains unclear whether the processes that adolescents engage during decision-making on monetary or point-based experimental tasks generalize to their day-to-day experiences in the real world. In this brief piece, we explore how developmental research applying economics formalisms can be bolstered by research on youth's social environments to advance our understanding of decision-making in adolescence. First, we review developmental research by using economic uncertainty paradigms. Next, we highlight research on adolescents' social environments to provide examples of the day-to-day choices that adolescents face among their peers and in their broader communities. Finally, we propose directions for future research integrating these separate approaches to create a more nuanced, ecologically informed understanding of adolescent decision-making.

Keywords Uncertainty · Risk · Ambiguity · Experiment · Social environment · Adolescence

Adolescence, the developmental period from ages 10 to 24 years (Sawyer et al., 2018), is a time of widespread uncertainty. During this period, youth experience significant cognitive, emotional, and biological development. At the same time, youth experience substantial changes in their social environments, including increased time away from caregivers and a heightened focus on peers and the broader social environment (Andrews et al., 2021). These changes in the social environment present adolescents with increased opportunities for independent decision-making, often in circumstances where they may have little information or past experience to guide their choices (Ciranka & van den Bos, 2021). Thus, adolescents are tasked with increased responsibility and culpability for their choices (Blakemore, 2019)

during a period of life when uncertainty is especially high. In recent years, researchers have focused increasingly on identifying the neurocognitive processes that support adolescents in decision-making under uncertainty.

One approach that has been useful for identifying the cognitive and neural processes involved in decision-making borrows economics formalisms to subdivide uncertainty into two distinct components: economic risk and economic ambiguity. Economic risk is when the outcome probabilities are known, and economic ambiguity is when the outcome probabilities are unknown or unknowable (Levy, 2017). On the whole, people are averse to economic risk and economic ambiguity. Moreover, economic risk and economic ambiguity preferences are dissociable (FeldmanHall et al., 2016; Huettel et al., 2006; Tymula et al., 2013) and are thought to play independent roles in guiding decision-making and influencing real-world behavior (Konova et al., 2020). Among adolescents, blunted aversion to economic ambiguity is thought to be one mechanism that supports adolescent-specific exploration tendencies (Hartley

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& Somerville, 2015; Tymula et al., 2012). However, while extant experimental research elegantly disentangles differences in economic risk and economic ambiguity preferences, experimental decision-making tasks based on monetary/point-based choices often fail to capture the types of decisions adolescents face in their real-world social environments.

In this brief piece, we explore how developmental research applying economics formalisms can be integrated with research on youth's social environments to enhance our understanding of decision-making in adolescence. First, we review the current developmental research on adolescent decision-making under different forms of economic uncertainty. Next, we look to a separate area of developmental research on adolescents' social environments to examine examples of decisions adolescents encounter under uncertainty in the real world. More specifically, we highlight research on peer and community factors that contribute to adolescents' experiences with uncertainty in their broader social environments. Finally, we argue that bridging the gap between these different areas of research may be useful for developing a more complete understanding of the mechanisms that support adolescents in navigating uncertainty outside of the laboratory in their broader social environments.

How is economic uncertainty manipulated in experimental settings?

Using economics formalisms, researchers often use task paradigms involving a series of monetary or point-based choices to dissociate decision-making under conditions of uncertainty with known outcome probabilities, labelled economic *risk*, and unknown outcome probabilities, labelled economic *ambiguity*¹ (Levy, 2017). Some of the most commonly used paradigms include wheel of fortune or bar-choice tasks, in which participants make a series of choices between two options with certain or uncertain outcomes (Blankenstein et al., 2021; Tymula et al., 2012). For example, on economic risk trials, participants are given a choice between a certain outcome (e.g., \$5) and a gambling outcome with an explicit probability of a higher or lower outcome (e.g., 80% chance of \$10 or 20% chance of \$3). On economic ambiguity trials, participants are given a choice between a certain outcome (e.g., \$5) and a gambling outcome where the probability of higher or lower outcomes is partially or fully unknown (e.g., 25% chance of \$10 or 25% chance of \$3 with 50% of the probability information occluded).

¹ Although there are other experimental tasks that measure decision-making about money/point-based choices with unknown outcome probabilities (e.g., Iowa Gambling Task, Balloon Analog Risk Task, the Stoplight task), these tasks are thought to engage other potentially confounding learning processes that cannot be dissociated and are not considered “pure” measures of economic ambiguity (Blankenstein et al., 2021; Schonberg et al., 2011).

In general, studies using these economics uncertainty paradigms suggest that adolescents show heightened economic risk aversion (Tymula et al., 2012, 2013) and blunted economic ambiguity aversion (Blankenstein et al., 2016; Tymula et al., 2012, 2013; van den Bos & Hertwig, 2017) relative to adults (c.f. Blankenstein et al., 2021). The distinction between these different forms of uncertainty—economic risk and economic ambiguity—also has begun to shed light on developmental trends in real-world behavior (Levy, 2017). In particular, researchers have proposed that blunted economic ambiguity aversion may support adolescent-specific exploration tendencies (Hartley & Somerville, 2015; Tymula et al., 2012), which may promote adaptive or positive forms of real-world risk-taking² (e.g., standing up for one's beliefs) (Duell & Steinberg, 2021) or expose adolescents to potential health- and legal-hazards. Studies show that reduced sensitivity to economic ambiguity, but not economic risk, information in adolescence is associated with adolescent self-reported engagement in speeding, potentially unsafe sex, and other forms of rebellious and rule-breaking behavior (Blankenstein et al., 2016; Tymula et al., 2012; van den Bos & Hertwig, 2017; see Buckholtz et al. (2017) for a similar effect in emerging adults and adults). Thus, by adopting economics formalisms to decompose uncertainty on experimental tasks, it has been possible to begin to pinpoint the components of uncertainty processing that may be most relevant for real-world outcomes among adolescents.

Yet, it is reasonable to wonder, do these experimental tasks reflect the real-world scenarios in which adolescents encounter uncertainty? On the one hand, in the real world, uncertainty often takes the form of ambiguity since adolescents rarely are confronted with decisions about choices where the probabilities of outcomes are fully known (e.g., the outcome probabilities are never fully known when youth make choices about whether they should approach a crush at a party or whether they will be safe walking in a neighborhood with high levels of crime). It also stands to reason that ambiguity may be especially high during adolescence when youth undergo numerous social, emotional, cognitive, and biological changes that may limit their knowledge about the probabilities of real-world outcomes (Ciranka & van den Bos, 2019; Romer et al., 2017). In this way, decision-making under conditions of economic ambiguity, which seems to relate to patterns of adolescent behavior in the real world, certainly resembles the component of uncertainty that adolescents face in the real world. On the other hand, the majority of experimental tasks that explicitly dissociate economic

² To be consistent with developmental research on adolescent risk-taking, references to “risk-taking” or “risk” without the “economic” qualifier denote the colloquial use of “risk” as any form of behavior that may carry potential for harm.

risk and economic ambiguity involve monetary or point-based choices (see Blankenstein et al., 2021 for review), whereas adolescents often encounter choices about other forms of information in the real world. Therefore, while extant research on decision-making has clear strengths, it is important to recognize the limitations of the inferences that we can draw from tasks that rely on money/points and strive to adapt these tasks to better resemble the real-world scenarios in which adolescents are confronted with decisions about uncertain, specifically ambiguous, information.

What is the nature of uncertainty in adolescents' real-world social environments?

Outside of the laboratory, adolescents must learn to make decisions under uncertainty in their broader social environments where information about outcome probabilities is seldom known (Blankenstein et al., 2021). Adolescent uncertainty preferences, specifically blunted economic ambiguity aversion, are thought to promote exploration (Hartley & Somerville, 2015; Tymula et al., 2012) during this developmental period when youth's social environments undergo considerable changes (Blakemore, 2018; Branje et al., 2021) and ambiguity may be especially high (Ciranka & van den Bos, 2021). However, little experimental research has examined how adolescents process and respond to choices about the different forms of ambiguous information that they encounter in their real-world social environments. Therefore, it remains unknown whether the basic processes identified using laboratory-based uncertainty tasks with money/points actually reflect the processes that adolescents engage when making decisions under ambiguity in the real world. Here, we review developmental research on adolescents' social environments with a focus on peer and community factors to highlight key elements of the day-to-day choices adolescents face under ambiguity in the real world.

The importance of peers is a hallmark of adolescence. Relative to children and adults, adolescents place more value in peer norms and peer acceptance (Brown & Larson, 2009). For example, a recent study found that adolescents reported higher concerns than adults about engaging in social risk behavior such as wearing clothes, listening to music, or defending opinions that are "unpopular" or different from their friends (Andrews, Foulkes, et al., 2020a). Furthermore, it has been proposed that adolescents may engage in health risk behaviors to avoid social risks, such as choosing to use substances to avoid peer rejection (Blakemore, 2018). When adolescents make choices about clothes, music, taking a stance, or using substances, the likelihood of peer acceptance or rejection is never fully known. In other words, information about peers represents a salient form of

ambiguous content that appears to impact adolescents' day-to-day decisions.

Peers also play an important role as a context that can influence decision-making among adolescents (Albert et al., 2013; Smith et al., 2014). Studies show that adolescents are more likely to experiment with drugs, alcohol, and tobacco with peers than alone (Chassin et al., 2009). In addition, researchers document a positive association between engagement with delinquent peers and adolescent delinquency (McGloin & Thomas, 2019), and, unlike adults, adolescents are more likely to commit crime in the presence of peers than when alone (Zimring, 1998). These peer influence effects are not limited to potentially problematic substance use or delinquent behaviors. Observational and experimental studies demonstrate that peer presence can influence increases in prosocial goal pursuit and behavior (e.g., cooperation, altruistic donating, and volunteering) (Sullivan et al., 2022; Telzer et al., 2018) and affiliation with prosocial peers can exert positive influence on school grades and healthy habits (e.g., physical activity) (Laursen & Veenstra, 2021). Thus, in the real world, adolescents make many decisions under ambiguity with their peers in mind, in the company of their peers, or both.

Another well-researched source of ambiguity in adolescents' lives is disadvantage-based uncertainty, which has been defined as unpredictable insecurities in essential resources and safety within the social environment (Tomas et al., 2022). By some estimates, nearly 40% of youth under the age of 18 years live under 200% of the federal poverty line (Koball & Jiang, 2018) and 60% of youth will experience threats to safety (e.g., witnessing or being victimized by violence) in their neighborhoods (Finkelhor et al., 2015). Adolescents who experience disadvantage-based uncertainty constantly must make choices about how to keep themselves safe from harm without knowing the probabilities of outcomes that all too often carry life-altering consequences. For example, one study found that adolescents facing food insecurity reported making day-to-day decisions about skipping meals or engaging in criminal activity to be able help feed their families (Fram et al., 2011). Further, this study showed that while adults experience food insecurity as ambiguity about their monetary/economic context, adolescents experience food insecurity as ambiguity specifically about their food context (e.g., how much food is in the household) and their social context more broadly (e.g., concern about parental stress and how they will interact with family members, neighbors, teachers, or peers). There also is evidence that many day-to-day decisions that adolescents face such as choosing to walk on one route to school or another, or choosing to walk alone or with a group of friends for protection, or even choosing whether to go outside or not, may carry severe consequences, such as witnessing or being the victim of crime or violence for youth who experience

ambiguity about safety in their neighborhoods (Cobbina et al., 2008; Dong et al., 2020; Zuberi, 2018). In short, many of the decisions adolescents face under disadvantage-based uncertainty involve choices that carry multiple outcomes with unknown or unknowable probabilities within broader contexts of ambiguity.

Experimental research suggests that there are associations between experiencing disadvantage-based uncertainty during adolescence and decision-making on monetary/point-based task paradigms. Specifically, experiencing disadvantage-based uncertainty during adolescence has been associated with greater difficulty discriminating between reward values during decision-making under economic risk (Guyer et al., 2006). Another study found that, relative to controls, adolescents who experienced disadvantage-based uncertainty incorporated less information about known rewards into choices during probabilistic learning, which also contributed to real-world disruptive behavioral problems (Hanson et al., 2017). Further, disadvantage-based uncertainty has been linked to adolescent engagement in health-risk behaviors (i.e., substance use) via increased neural sensitivity to economic risks and heightened delay discounting (i.e., the tendency to choose smaller more immediate rewards over larger rewards that require waiting a delay period) (Kim-Spoon et al., 2019). Overall, these studies demonstrate that disadvantage-based uncertainty may influence how adolescents process information about choices. However, little research directly has evaluated how adolescents process information and navigate decision-making about the various ambiguous choices they are confronted with in the context of disadvantage-based uncertainty.

Altogether, peers and disadvantage-based uncertainty represent two well-established influences on adolescent decision-making. This research highlights that adolescents are faced with ambiguity in the content of their choices (e.g., peer acceptance/rejection; basic resources) and ambiguity in the contexts that they make choices (e.g., around peers; in resource-scarce or unsafe environments). Yet, our knowledge of the processes that support adolescent decision-making in the real world remain limited due to a methodological gap between experimental decision-making research and research on youth's social environments.

Bridging the gap: An ecologically informed approach to understanding adolescent decision-making under ambiguity

Two separate lines of developmental research, one that measures uncertainty using experimental tasks based on money/points and the other that focuses on adolescents' broader social environments, have led to foundational knowledge about how adolescents process and experience

uncertainty. However, research has been limited in merging these different approaches to understand how uncertainty, specifically ambiguity, acts as an influence on adolescent decision-making in the real world. We propose several next steps for integrating these largely separate areas of developmental research to develop a more holistic understanding of the processes involved in adolescent decision-making under ambiguity.

First, research may benefit from adapting experimental decision-making tasks to include a wider range of *content* that reflects the day-to-day choices adolescents face under ambiguity in the real world. As noted above, adolescent decision-making may be especially motivated by gaining peer approval and avoiding peer rejection (Tomova et al., 2021). One study found that adolescents expected to engage in health- and legal-risk behaviors that they anticipated would lead to social benefits (Andrews, Mills, et al., 2020b). There also is evidence that adolescents may increase or decrease prosocial behavior depending on the behavior that is "liked" by peers (van Hoorn, van Dijk, Güroğlu, & Crone, 2016a; van Hoorn, van Dijk, Meuwese, et al., 2016b). Therefore, future studies that include explicit choices about peer approval and rejection on experimental tasks that manipulate ambiguity may enhance our understanding of relationships between adolescent uncertainty preferences and real-world behavior. For example, participants can be asked to choose between options about social media followers or "likes" (e.g., choose between a certain outcome of gaining 5 new followers/5 likes and an uncertain outcome of greater or fewer followers/likes). Future studies also are needed to evaluate the boundaries of adolescent uncertainty preferences across choices about other (non-monetary) content, especially when choices involve multiple integrated outcomes. What would decision-making preferences among adolescents look like if they had to choose between a certain outcome of gaining peer approval and taking a health risk and an uncertain outcome of more or less peer approval without taking a health risk?

Second, future work will benefit from evaluating how the *contexts* in which adolescents experience ambiguity in their broader social environments may impact decision-making computations. Considerable research already has examined peers as a contextual influence on decision-making on economic uncertainty tasks. Specifically, studies have focused on decision-making under conditions of experimental ambiguity when peers are present (either experimental "observation" or when accompanied by peers) or by providing information about peer choices. Some research suggests that these peer manipulations do not impact decision-making under ambiguity (Blankenstein et al., 2016; Tymula, 2019), but other research suggests adolescents seem to be especially sensitive to information about peer choices promoting economic

risk- and economic ambiguity-avoidant behavior on monetary choice tasks (Ciranka & van den Bos, 2019), particularly between ages 15–18 years (Braams et al., 2019). One possible explanation for these discrepancies could be variability in the peer manipulations (i.e., peer observation vs. information about peer choices; peers who promote economic risk-taking vs. economic risk-avoidant behavior). Nonetheless, many real-world peer influence effects have been related to adolescent decision-making about substance use (Chassin et al., 2009), delinquency (McGloin & Thomas, 2019), and prosocial (Telzer et al., 2018) and health-promoting behaviors (Laursen & Veenstra, 2021). These different contexts of peer influence have limited representation on experimental tasks that explicitly dissociate economic risk and economic ambiguity preferences. Thus, it will be important to apply peer context manipulations to decision-making paradigms that include choices about health and legal information.

Furthermore, future work will benefit from developing experimental paradigms that explicitly manipulate other (i.e., non-peer) contexts in which adolescents experience ambiguity in their broader social environments. For example, building on research showing that disadvantage-based uncertainty (i.e., resource scarcity) can influence attentional biases and perceptions of value (Shah et al., 2012, 2018), Chang et al. (2022) examined associations between neighborhood disadvantage and decision-making on patch-foraging tasks. While this study was conducted in adults, we highlight it because it provides an example of how to implement ecologically relevant choices and contexts into experimental designs in a sample of participants with diverse backgrounds across race, sex, and experiences of neighborhood disadvantage. In this experiment, participants were presented with low and high disadvantage task-contexts that were represented with aerial views of land with apple trees. In both contexts, participants were instructed to harvest as many apples as possible but were never provided explicit information about harvest probabilities (i.e., each task-context was ambiguous). Overall, regardless of their real-world experiences of neighborhood disadvantage, all participants made decisions that violated social norms (e.g., trespassing and taking from a neighbor) under conditions of experimental disadvantage, suggesting violating social norms is not endemic to people living in disadvantage but is a reflection of the conditions of the environment (in this case the experimental environment). Therefore, by manipulating ambiguity in the overall task-contexts, the researchers were able to identify environmental disadvantage as an influence on decision-making about resource acquisition. It is theorized that it is adaptive for individuals to be sensitive to the potential returns of real-world risk-taking in contexts with elevated levels of unpredictable outcome variability (e.g., resource ambiguity) (Frankenhuis & Del Giudice, 2012). Thus, this manipulation provides one starting point for future studies to examine how other ambiguous

contexts related to disadvantage- (e.g., neighborhood violence, income/residential instability) and social environment-based uncertainty (e.g., fragmented parenting) may influence adolescent decision-making about other forms of real-world risk-taking. These future studies will benefit from recruiting samples of youth from a range of backgrounds to develop a more robust and generalizable understanding (Hruschka et al., 2018) of how youth's real-world experiences interact with experimental manipulations of social environment-based uncertainty to influence decision-making.

Finally, we should strive to evaluate the processes involved in complex decision-making by examining interactions between ambiguous choices and ambiguous contexts. Researchers propose that adolescent decision-making is influenced by the overall ecology of choices in the broader social environment (Defoe et al., 2019), not only by individual choices or individual contexts. For example, adolescents with limited access to alcohol will be presented with fewer choices about drinking relative to adolescents with greater access to alcohol, and the choice to drink may carry different social and legal consequences (i.e., outcomes) depending on whether an adolescent is with a group of close peers, acquaintances, or family members and at home or in the community. In each of these scenarios, the level of ambiguity about outcomes associated with choices about alcohol will vary depending on adolescents' broader social environments (e.g., adolescents with limited access to alcohol may experience greater ambiguity about outcomes due to inexperience relative to adolescence with greater access to alcohol; drinking with peers may carry greater ambiguity about legal consequences for adolescents than drinking with family members in states that permit underage drinking with parental consent). Modifying experimental tasks to represent this complexity is an important step for moving closer to the goal of more fully understanding the processes involved in adolescent decision-making in the real world where decisions often involve choices with multiple outcomes (not just a binary option; e.g., peer approval but legal consequences, peer rejection and legal consequences, etc.) within multiple contexts (e.g., peers, family, alone).

Conclusions

In this brief piece, we summarized developmental research on how adolescents process and experience different forms of uncertainty. Developmental scientists have leveraged economics formalisms to dissociate the basic cognitive and neural processes involved in adolescent decision-making under economic risk and economic ambiguity (Blankenstein et al., 2016; Blankenstein & van Duijvenvoorde, 2019; Tymula et al., 2012, 2013; van den Bos & Hertwig, 2017). A necessary next step is to evaluate the generalizability of these basic decision-making processes across a wider range

of experimental paradigms that better resemble the day-to-day scenarios in which adolescents face choices under uncertainty in their broader social environments. Ultimately, research on adolescents' social environments provides a blueprint for refining our experimental uncertainty paradigms and developing a more complete, ecologically informed understanding of adolescent decision-making.

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