Robustness of Decision-Making Competence:

Evidence from two measures and an 11-year longitudinal study

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Abstract

Decision-making competence is the ability to follow normative principles when making decisions. In a longitudinal analysis, we examine the robustness of decision-making competence over time, as measured by two batteries of paper-and-pencil tasks. Participants completed the youth version (Y-DMC) at age 19 and/or the adult version (A-DMC) eleven years later at age 30, as part of a larger longitudinal study. Both measures are comprised of tasks adapted from ones used in experimental studies of decision-making skills. Results supported the robustness of these measures and the usefulness of the construct. Response patterns for Y-DMC were similar to those observed with a smaller initial sample drawn from the same population. Response patterns for A-DMC were similar to those observed with an earlier community sample. Y-DMC and A-DMC were significantly correlated, for participants who completed both measures, 11 years apart, even after controlling for measures of cognitive ability. Nomological validity was observed in correlations of scores on both tests with measures of cognitive ability, cognitive style, and environmental factors with predicted relationships to decision-making competence, including household SES, neighborhood disadvantage, and paternal substance abuse. Higher Y-DMC and A-DMC scores were also associated with lower rates of potentially risky and antisocial behaviors, including adolescent delinquency, cannabis use, and early sexual behavior. Thus, the Y-DMC and A-DMC measures appear to capture a relatively stable, measurable construct that increases with supportive environmental factors and is associated with constructive behaviors.

Key words: Decision-making competence, adolescents, life span, individual differences

Robustness of Decision-Making Competence: Evidence from two measures and an 11-year longitudinal study

Day-to-day, we make decisions that range from the relatively trivial to ones with major effects on our lives. Traditionally, normative theories of decision making have posited how people should make decisions that maximize the expected utility of their outcomes (e.g., Bernoulli, 1954; von Neumann & Morgenstern, 1953; Simon, 1978). Descriptive research in behavioral decision making has long focused on identifying when and why individuals systematically deviate from the principles posited by traditional normative theories, and on the efficiency of the heuristic strategies that sometimes replace them (e.g., Einhorn & Hogarth, 1981; Hastie & Dawes, 2010; Kahneman, Slovic, & Tversky, 1982). For example, people may violate the normative 'sunk cost' principle by continuing to invest in unprofitable options, especially when they have made large unrecoverable investments (Arkes & Blumer, 1985). People may also violate the traditional normative principle of 'description invariance,' as when they rate a team as more successful when described in terms of its 60% success rate rather than its 40% failure rate (Dunegan, 1993), perhaps reflecting conversational norms that prescribe using success rates to describe successful teams and failure rates to describe failing ones (Sher & McKenzie, 2006).

As a result of its focus on understanding how individual violations occur, the field long left open the question of whether there are stable individual differences in the ability to avoid such violations, across time and contexts. Such decision-making competence (DMC) would be similar to, but distinct from, other cognitive abilities such as IQ or executive cognitive function (e.g., Stanovich & West, 1998, 2008; West, Toplak, & Stanovich, 2008).

Suggestively, studies that used multiple items to measure adherence to a given normative principle have found relative internal consistency for participants' ability to resist violations of the sunk cost principle (Stanovich, 1999), resist framing effects that violate description invariance (Levin, Gaeth, Schreiber, & Lauriola, 2002), apply decision rules consistently (Bröder, 2000), and express appropriate confidence in their knowledge (Bornstein & Zickafoose, 1999; Klayman, Soll, González-Vallejo, & Barlas, 1999; Stankov & Crawford, 1996, 1997; West & Stanovich, 1997; Wolfe & Grosch, 1990). As with most experimental research, these studies report little else about participants' traits, behaviors, and life circumstances. The one exception is that several studies that have also measured cognitive ability, typically finding it to be positively correlated with performance on decision-making tasks, such as ones testing resistance to sunk costs (Larrick, Nisbett, & Morgan, 1993), resistance to framing (Smith & Levin, 1996), and under/overconfidence (Stanovich & West, 2000; Wolfe & Grosch, 1990).

Twenty years ago, we received an unusual opportunity to examine the validity of tasks used in behavioral decision research. We administered a battery of seven such tasks to 110 males, at the age-19 assessment of a longitudinal study conducted by the Center for Education and Drug Abuse Research (CEDAR; Tarter & Vanyukov, 2001). As described below, CEDAR provided a wealth of other measures, including ones with predicted relationships with decision-making competence. Results from our initial study suggested individual differences in performance that are correlated across behavioral decision-making tasks, as reflected in the primary factor of an exploratory factor analysis across task scores (Parker & Fischhoff, 2005). These scores (called Y-DMC, for Youth Decision-Making Competence) were related to other theoretically postulated measures, such as maladaptive risk-taking behavior and supportive home environment, even after controlling for two measures of cognitive ability (Parker & Fischhoff, 2005).

In order to expand that initial study, we developed an adult version of Y-DMC, called A-DMC, with items suited to a general adult population, and improving some elements of Y-DMC (Bruine de Bruin, Parker, & Fischhoff, 2007; Parker, Bruine de Bruin, & Fischhoff, 2015). Administration of A-DMC to a diverse community sample of adults revealed patterns similar to those in the initial Y-DMC study. Performance on the tasks was positively correlated, yielding a common factor in an exploratory factor analysis (Bruine de Bruin et al., 2007). Moreover, the overall A-DMC score predicted life experiences, as reported on a Decision Outcome Inventory (DOI) developed in the study, even after controlling for measures of cognitive ability (Bruine de Bruin et al., 2007). Thus, Y-DMC and A-DMC are measures of decision-making competence that appear to demonstrate three key aspects of construct validity (Cronbach & Meehl, 1955; Messick, 1989; Nunnally & Bernstein, 1994). Namely, the tasks (a) span a theoretical domain, focusing on skills identified in behavioral decision research as ones that would indicate decision quality; (b) have structural validity, revealed in the correlations between performance on the constituent tasks; and (c) reveal convergent, discriminant, and predictive validity.

In the ensuing period, CEDAR continued to administer Y-DMC to participants, as part of its age-19 assessment, adding 416 individuals to our original sample of 110. It also administered A-DMC to 214 individuals completing their final CEDAR assessment at age 30, including 146 who had completed Y-DMC eleven years earlier. The next section summarizes the original Y-DMC and A-DMC studies, followed by the new data and analyses.

Original studies

The Center for Education and Drug Abuse Research (CEDAR; Tarter & Vanyukov, 2001) enrolled high-risk youth (defined as having fathers who met clinical diagnostic criteria for substance use disorder) and low-risk youth (defined as having fathers with no diagnosed substance use disorder), at age 9-13, with the aim of following them until age 30. The initial CEDAR sample recruited only males, adding females in subsequent years. Participants underwent periodic intensive assessments. At the age-19 assessment, 110 of the initial male CEDAR sample completed a battery of seven tasks adapted from the behavioral decision research literature, chosen to capture key decision-making skills, and formulated to reduce shared method variance (Table 1).[1]

As reported more fully in Parker & Fischhoff (2005), performance was correlated across tasks, revealed a strong first factor in an exploratory factor analysis, and showed good test-retest reliability on a subsample of participants who completed the materials twice. Scores on the common factor, called Y-DMC, were positively correlated with measures of both fluid and crystallized intelligence (Cattell, 1987; Horn, 1985). They were also correlated with other measures relevant to the decision-making competence construct, even after controlling for cognitive ability, suggesting a distinct construct. More specifically, semi-partial correlations that controlled for the two measures of cognitive ability found that individuals with higher Y-DMC scores also reported less polarized thinking, more constructive behavioral coping strategies (Epstein & Meier, 1989; Katz & Epstein, 1991), and greater self-monitoring (suggesting greater cognitive flexibility; Graziano et al., 1987; Snyder, 1974; Snyder & Cantor, 1980). Semi-partial correlations with the same controls found that individuals with higher Y-DMC scores reported fewer risky and antisocial behaviors[2] suggestive of poor decision making, such as externalizing and delinquent behavior, cannabis use, and early sexual activity. Finally, semi-partial correlations found that individuals with higher Y-DMC scores had better family and social environments, in ways that should promote the development of decision-making skills.

As reported more fully in Bruine de Bruin, Parker, and Fischhoff (2007), the Adult Decision-Making Competence (A-DMC) measure adapted the Y-DMC tasks to be more suitable for adults and their life experiences. As with Y-DMC, A-DMC task scores were significantly correlated with one another, and their composite score was positively correlated with a measure of fluid intelligence. Holding age, SES, and cognitive ability constant, individuals with higher A-DMC scores reported fewer negative life outcomes (e.g., foreclosure, getting kicked out of an apartment) on the Decision Outcome Inventory (see also Parker et al., 2015).

Subsequent research has found further support for the validity of the Y-DMC and A-DMC measures. Higher Y-DMC scores have been associated with greater ability to make choices consistent with maximizing expected value (Parker & Weller, 2015) and with fewer emotional, behavioral, and peer-related difficulties, reported two years after assessment (Weller, Moholy, Bossard, & Levin, 2014). Studies have also found better performance on A-DMC tasks to be associated with higher scores on tests of cognitive abilities (e.g., Del Missier et al., 2013, 2015; Frederick, 2005) and self-reports of theoretically productive decision-making styles (e.g., Carnevale, Inbar & Lerner, 2012; Dewberry, Juanchich & Narendran, 2013; Parker, Bruine de Bruin & Fischhoff, 2007). One study found that individuals with higher A-DMC scores reported seeing less expected value in various risk behaviors and engaging in fewer of them (Weller, Ceschi, & Randolph, 2015). A-DMC has been used to assess the decision-making competence of US policy leaders (Carnevale et al., 2012), Swedish adults with ADHD (Mäntylä, Still, Gullberg & DelMissier, 2012), US psychiatric patients at risk for suicide (Szanto et al., 2015), Slovak students (Bavolar, 2013), and US students in high school history classes with and without a focus on decision making (Jacobson et al., 2012).

The current study

The new CEDAR data allow further analyses of the psychometric properties of the Y-DMC and A-DMC measures used in the original studies, and of the decision-making competence construct that they assess (Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005). These new data also provide a first examination of how stable the construct is over time, for participants who completed the closely related measures at the age-19 and age-30 assessments. Several studies have used cross-sectional designs to assess decision-making competence in individuals at various life stages (e.g., Bruine de Bruine, Parker, & Fischhoff, 2012; Finucane & Gullion, 2010; Weller, Levin, Rose, & Bossard, 2012). However, such designs confound age groups and cohorts. CEDAR's longitudinal design allowed us to follow individuals as they aged through a formative developmental period.

Thus, we had three main research aims:

Aim 1: Assess the internal validity of Y-DMC and A-DMC, as revealed in the relationships among scores on their component tasks.

Aim 2: Assess the nomological validity of Y-DMC and A-DMC, in terms of whether they correlate in expected ways with constructs reflecting participants' (a) general cognitive abilities, (b) social environments, (c) cognitive styles, and (d) risk behaviors.

Aim 3: Assess the stability of decision-making competence over time and across assessment tools, in terms of the relationship between age-19 Y-DMC and age-30 A-DMC, controlling for cognitive ability.

Aims 1 and 2 expand results from prior work (Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005) to new samples, providing context for our novel longitudinal analyses. Aim 3 examines the stability of relationships across an 11-year age span, and across two related instruments.

Method

Longitudinal data collection

The Center for Education and Drug Abuse Research (CEDAR) conducted a longitudinal study examining the etiology of substance abuse (Tarter & Vanyukov, 2001). Beginning in 1989, it recruited 9-13 year-olds (M = 11.4, SD = 0.9) at high or low risk for developing substance-use disorders, defined by whether a participant's father had a history of substance-use disorders. High-risk youth were identified through clinical settings, advertising, and a marketing firm; low-risk youth were drawn through random-digit dialing and advertising. The initial baseline assessment included the child and the child's parents, and covered domains such as health behavior, psychopathology, cognitive functioning, and family and social environment. Subsequent assessments were conducted every 2-3 years through age 30.[3] In 1998, CEDAR added Y-DMC to the age-19 assessment; in 2007, CEDAR added A-DMC to the age-30 assessment. The National Institute of Drug Abuse discontinued funding CEDAR in 2015. As a result, although most CEDAR participants completed Y-DMC, not all completed (or will ever complete) A-DMC.

Y-DMC and A-DMC samples

Our study involved the three CEDAR samples (Table 2): First, the Y-DMC initial sample (N=108)[4] included male youth who completed Y-DMC at age 19, as reported in Parker and Fischhoff (2005). Second, the Y-DMC expansion sample (N=416) included male and female youth who completed the age-19 Y-DMC assessment at later times, whose data have not been published previously. Third, the A-DMC sample (N=214) included participants who completed A-DMC at age 30; among them, 146 (73.4%) had also completed Y-DMC at age 19 (the others had completed the age-19 assessment before the initial Y-DMC data collection began). Lngitudinal analyses reported here involve those 146 participants. A-DMC scores were similar for participants with and without Y-DMC scores, t(212)=.91, ns.; Y-DMC scores were similar for participants with and without A-DMC score, t(522)=-1.51, ns.

The Y-DMC expansion sample included female participants (44%), who had not been recruited in CEDAR's early stages. The Y-DMC expansion sample was somewhat less Caucasian (71.1%) than the Y-DMC initial sample (86.1%), $\chi^2(1)=7.75$, $p<.05$, r=.12, slightly older at the age-19 assessment (mean 18.9 vs. 18.6 years), t(513)=7.13, $p<.001$, d=.77, more likely to have graduated high school or received a GED by the age-19 assessment (81.6% vs. 56.1%, partly reflecting the older mean age), $\chi^2(1)=30.4$, $p<.001$, r=.24, but no more likely to have graduated high school or received a GED by the age-30 assessment (96.6% vs. 95.8%), $\chi^2(1)=.07$, ns., r=.01. There were no differences between the two samples in their age at the age-30 assessment, likelihood of having a bachelor's degree by age 30, or membership in the low-risk vs. high-risk group for developing substance use disorders ($p>.05$).

In the analyses that follow, we focus on the new data, in the Y-DMC expansion sample and the age-30 sample, considering the Y-DMC initial and combined samples (including both initial and expansion samples) for context when helpful.

Both Y-DMC and A-DMC included six tasks assessing the ability to follow normative principles of decision making (Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005). They are publicly available for download from the Society for Judgment and Decision Making (http://www.sjdm.org/dmidi/Youth_-_Decision_Making_Competence.html; http://www.sjdm.org/dmidi/Adult_-_Decision_Making_Competence.html). Below, we briefly describe each task and its scoring. Further detail can be found in the original papers (Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005) and online supplementary material.

Resistance to Framing measured whether participants valued options similarly despite normatively irrelevant variations in their descriptions. As such, items were paired, with each representing an equivalent choice presented differently. Participants received both items in each pair, separated by other tasks. Y-DMC included five pairs of binary-choice items, with the overall Resistance to Framing score reflecting the number of consistent choices (0-5). Two of the five item pairs represent valence-framing problems, where the same outcomes or attributes are framed positively or negatively (Levin, Schneider, & Gaeth, 1998). The other three represent non-valence frames. Cronbach's alpha is low in the Y-DMC expansion sample (α=.19), as it was in the Y-DMC initial sample (α=.30; Parker & Fischhoff, 2005).

Suspecting that the diverse forms of framing in the Y-DMC set were sampling more than one domain, we designed A-DMC to use only valence framing problems.[5] We also increased the number of pairs from five (Y-DMC) to fourteen (A-DMC) and changed from a discrete choice response mode to a six-point rating scale, hoping to discriminate better among preferences. That scale was anchored at 1=definitely would choose A and 6=definitely would choose B. The Resistance to Framing score was one minus the mean absolute difference in ratings on the fourteen question pairs. Cronbach's alpha for A-DMC was much higher (α=.70) than for Y-DMC, presumably reflecting these changes and similar to results with the A-DMC community sample (α=.62; Bruine de Bruin et al., 2007).

Resistance to Sunk Cost measured how well participants follow the normative prescription to ignore unrecoverable past expenditures when making decisions (Arkes & Blumer, 1985). Y-DMC was scored as the number of choices, across two items, that resisted sunk cost. Cronbach's alpha was very low in the Y-DMC expansion sample (α=.13), as it had been in the Y-DMC initial sample (α=.03; Parker & Fischhoff, 2005). A-DMC expanded this scale, using ten items instead of two. Additionally, the latter scale implemented a 6-point rating scale to assess how likely respondents were to choose the sunk-cost (versus normatively correct) option. Presumably reflecting those changes, Cronbach's alpha improved but remained lower than typically sought for scales (α=.55), replicating previous findings (α=.54 in the A-DMC community sample; Bruine de Bruin et al., 2007).

Applying Decision Rules asked participants to indicate which option to select from a choice set, using decision rules from Payne, Bettman, and Johnson (1993). For example, one A-DMC item states that, "Lisa wants the Blu-ray player with the highest average rating across features," and provides ratings of each option on features such as picture quality, sound quality, and programming options. A-DMC differed from Y-DMC by having more items (ten vs. seven), more options per item (five vs. three), an updated cover story (Blu-ray players vs. Walkmen), and numeric rather than graphical rating displays. The overall score reflected the percent of items for which the choice followed the decision rule. Cronbach's alpha was .58 for the Y-DMC expansion sample (α=.68 for the Y-DMC initial sample; Parker & Fischhoff, 2005) and .67 for the A-DMC sample (α=.73 for the A-DMC community sample; Bruine de Bruin et al., 2007).

Under/overconfidence assessed how well participants assess the extent of their own knowledge. For each of 42 statements for Y-DMC and 34 for A-DMC, participants indicated whether it was true or false, and then assessed their confidence in their answer, on a scale anchored at 50% (just guessing) and 100% (absolutely sure). Y-DMC items covered topics relevant to adolescents, including (a) general knowledge (e.g., history, geography), (b) the effects of alcohol and drugs, and (c) potential consequences of risky sexual behavior and HIV/AIDS transmission. A-DMC items included topics taken from advice books targeting adults' life decisions (e.g., finances, health). The overall Under/overconfidence score equaled one minus the absolute difference between mean confidence and percentage correct, so that higher scores reflected better performance. Cronbach's alpha was .76 for the Y-DMC expansion sample (α=.79 for the Y-DMC initial sample; Parker & Fischhoff, 2005) and .80 for the A-DMC sample (α=.77 for the A-DMC community sample; Bruine de Bruin et al., 2007).

Consistency in Risk Perception measured participants' ability to follow the normative rules of probability theory when assessing risks. Each item asked participants to judge the probability of an event occurring on a linear scale ranging from 0% (=no chance) to 100% (=certainty). Item pairs included nested subset and superset events, complementary events, conjunctions of two events, and disjunctions of two events. A-DMC had more items than Y-DMC (twenty vs. five). Scores reflected the percentage of item pairs assigned consistent probabilities. Cronbach's alpha was.45 for the Y-DMC expansion sample (α=.50 for the Y-DMC initial sample; Parker & Fischhoff, 2005) and .65 for the A-DMC sample (α=.72 for the A-DMC community sample; Bruine de Bruin et al., 2007).

Recognizing Social Norms measured how well participants assess peer social norms, following previous measures (Jacobs, Greenwald, & Osgood, 1995; Loeber, 1989), and is the same for Y-DMC and A-DMC. Participants indicated how many "out of 100 people your age" would agree that "it is sometimes OK" to engage in each of 16 undesirable behaviors (e.g., to steal under certain circumstances). After completing other tasks, participants indicated whether they thought that “it is sometimes OK” to engage in each behavior. The score for each participant was the rank-order correlation (from -1 to 1) between the estimated and actual percentage of endorsers in the sample, as computed across the 16 behaviors. Cronbach’s alpha was .68 for the Y-DMC expansion sample (α=.40 for the Y-DMC initial sample; not previously reported) and .57 for the A-DMC sample (α=.64 for the A-DMC community sample; Bruine de Bruin et al., 2007).

Overall score. For both Y-DMC and A-DMC, the overall score reflected the mean of the six task scores, after standardizing each with z transformations. This algorithm was used by Bruine de Bruin et al. (2007), but differed from Parker & Fischhoff (2005), who extracted a factor score from a principal components analysis (i.e., creating a weighted average). Y-DMC scores were largely unaffected by this change in computation, with the two calculations correlated at r = .93 (p<.001) in the Y-DMC combined sample. We used the procedure proposed by Nunnally and Berstein (1994, pp. 266-274) to estimate the internal consistency of composite scores, which recognizes that linear combinations of loosely-correlated measures can have greater reliability than the original measures (much as a summative scale is more reliable with more items). This estimate was computed as an average of the task alphas weighted by factor scores from a principal components analysis. For the DMC composite measure, this estimate of alpha was .77 for the Y-DMC expansion sample (vs. α=.76 in the Y-DMC initial sample; Parker & Fischhoff, 2005), with a mean inter-item correlation of .13, and .81 for the A-DMC sample (vs. α=.83 in the A-DMC community sample; Bruine de Bruin et al., 2007), with a mean inter-item correlation of .15.

Covariates

We drew on the large CEDAR database to establish the nomological validity of the Y-DMC and A-DMC assessments. We report all covariates reported in Parker and Fischhoff (2005), along with several substitutions chosen to improve comparisons, as noted below. The ages at which each covariate was assessed appear as footnotes to Table 4.

Cognitive ability. Following Parker & Fischhoff (2005), we used the vocabulary assessment of Wechsler Intelligence Scale for Children - Revised (WISC-R; Wechsler, 1972) as a measure of crystallized cognitive ability. Fluid cognitive ability was represented by executive cognitive functioning (ECF), assessed by combining the block design test from the WISC-R with other measures of inhibition and executive functioning, including the Porteus maze, vigilance, motor restraint, and forbidden toy tasks (see Giancola and Parker, 2001, for details).

Social and family influences. We used five measures related to conditions that should foster the development of decision-making abilities (Parrill-Burnstein, 1978; Baron & Hershey, 1988; Jones et al., 1997): (a) whether the participant's father had a history of substance use disorders; (b) household socio-economic status (Hollingshead, 1975); (c) neighborhood disadvantage, defined by Census estimates of the percentage of households below the poverty level, the percentage of households headed by females, the percentage of adults over age 24 without college degrees, and the percentage of households not occupied by owner (following Ridenour et al., 2009); (d) social support, as assessed by the Interpersonal Support Evaluation List (ISEL) (Cohen & Hoberman, 1983); (e) peer environment, including peers' problem behavior (e.g., drug or alcohol use) and constructive behavior (e.g., participation in school clubs and athletics; Tarter, 1991).

Cognitive style. As in Parker & Fischhoff (2005), we considered four measures of self-reported cognitive style. Two are from the Constructive Thinking Inventory (Epstein & Meier, 1989; Katz & Epstein, 1991): Polarized Thinking, which assesses difficulty with seeing nuances in situations (e.g., "I tend to classify people as either for me or against me"), and Behavioral Coping, which captures behavioral strategies for coping with adversity (e.g., "I am the kind of person who takes action rather than just thinks or complains about a situation"). Both assessed the kind of open-minded, flexible thinking that should accompany decision-making competence (Baron, 1988; Stanovich & West, 1998, 2000). The other two were the Self-consciousness Scale, which assesses introspection and concern for how others view one, hence should reflect attention to social norms (e.g., "I care a lot about how I present myself to others," Fenigstein et al., 1975), and the Self-monitoring Scale, which asked about the tendency to monitor and critique one's own behavior in social situations (e.g., "There are many things I would only tell to a few of my friends," Graziano et al., 1987; Snyder, 1974; Snyder & Cantor, 1980).

Risk behavior. We focused on measures of risk and antisocial behavior that can incur significant physical, emotional, and societal costs. Psychiatric diagnoses that reflect disruptive and antisocial behaviors included Oppositional Defiant Disorder and Conduct Disorder up through age 16 (using a diagnostic instrument derived from Endicott & Spitzer, 1978; Spitzer, Williams, & Gibbon, 1987). Because respondents who miss a visit could return for future visits and the psychiatric interviews retrospectively covered the intervening time, we included all available data. Externalizing behavior (e.g., fighting, teasing) and delinquency (e.g., stealing, running away) were reported by the participant's mother at age 14, using the Child Behavior Checklist (Achenbach & Edelbrock, 1983). The number of times the respondent had had sexual intercourse and number of sexual partners were self-reported for the year prior to the age-16 assessment (using the natural logarithm of overall scores +1, to account for positive skewness). For self-reported alcohol and drug use, we followed CEDAR's convention of using estimates derived from the Drug Use Screening Inventory (Kirisci, Tarter, & Tse-Chi, 1994; Tarter, 1990). At the age-16, age-19, and age-22 assessments, respondents reported their alcohol and drug use in a typical month, with the response options of 0, 1-2, 3-9, 10-20, and more than 20 times.

Analytic approach

Our analyses followed our three research aims. First, we used confirmatory factor analysis on the new CEDAR data for the Y-DMC expansion sample and A-DMC, to examine whether we could replicate sufficiency of fit for the single-factor model identified in exploratory factor analyses on previous data (Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005). Second, we examined the nomological validity of overall Y-DMC and A-DMC scores in terms of their correlations with the posited covariates, presenting results separately for the Y-DMC initial and expansion samples. Third, we compared Y-DMC and A-DMC scores for the 146 participants who completed both tests, assessing the stability of decision-making competence over time, using zero-order and semi-partial correlations controlling for cognitive ability.

Attrition analysis. The logistical challenges of longitudinal data collection led to varying amounts of missing data across variables. We used all available data, with the resulting sample sizes for nomological validity analyses (i.e., correlations) ranging from 89-108 for the Y-DMC initial sample, 334-416 for the Y-DMC expansion sample, 427-516 for the Y-DMC combined sample, and 176-214 for the A-DMC sample.[6] Overall, 29.7% of CEDAR participants had at least one missing score. These individuals had slightly lower mean scores for Y-DMC ($M=-.08$, $SD=.54$ vs. $M=.03$, $SD=.52$, $t(522)=2.30$, $p < .05$) and A-DMC ($M=-.07$, $SD=.61$ vs. $M=.03$, $SD=.51$, $t(144)=1.28$, ns.).

The online supplementary material include additional task details, descriptive statistics, and correlations among the tasks.

Results

Aim 1: Assess the internal validity of Y-DMC and A-DMC, as revealed in the relationships among scores on their component tasks

Y-DMC (Age 19). Table 3 presents a confirmatory factor analysis on the Y-DMC expansion sample, which revealed a good fit for a single overall factor. All Y-DMC tasks loaded significantly ($p < .01$), except for Resistance to Sunk Cost (which also had low internal consistency). The overall fit was similar when Resistance to Sunk Cost was removed from the model (CFI=.95, RMSEA=.05, SRMR, .04, $\chi^2(10)=19.3$, $p<.05$). In order to maintain comparability to past studies, we kept Resistance to Sunk Cost in the composite measure.

A-DMC (age 30). The confirmatory factor analysis for A-DMC also showed a good fit and yielded results similar to those with Y-DMC. The main exception is that Resistance to Sunk Cost loaded positively and significantly, which may reflect its improved measurement.

Aim 2: Assess the nomological validity of Y-DMC and A-DMC, in terms of whether they correlate in expected ways with other constructs

Y-DMC (Age 19). Table 4 shows significant zero-order Pearson correlations between overall Y-DMC score and both measures of cognitive ability, for the Y-DMC initial sample (as reported in Parker & Fischhoff, 2005), the Y-DMC expansion sample, and the combined sample. Table 4 shows that participants with higher Y-DMC scores also had more favorable social and family environments, as measured by the absence of paternal substance abuse, higher household socio-economic status, less neighborhood disadvantage, greater social support, and more positive peer environment.[7] Higher Y-DMC scores were also correlated with self-report measures of cognitive style plausibly related to better decision making. Participants with higher Y-DMC scores showed less of several problematic behavior tendencies, as measured by CEDAR staff (childhood antisocial disorders) and reported by the youth's mother (externalizing behavior, delinquency). They self-reported more cannabis use, more sex, and more sexual partners. Y-DMC scores showed little relationship to self-reported alcohol use. Generally speaking, these relationships were similar in the two samples. Controlling for the two measures of cognitive ability reduced these correlations, but many of the associations remain significant – most notably neighborhood disadvantage, self-monitoring, and several risk behaviors.

A-DMC (age 30). The fifth column of Table 4 shows correlations between A-DMC and the CEDAR covariates. Overall, they were very similar to those for Y-DMC, assessed eleven years earlier, with covariates from earlier CEDAR assessments. Perhaps the most notable difference was the weaker correlation with childhood antisocial disorders, assessed at age 16. A-DMC was more strongly correlated with cannabis use self-reports collected closer in time to its assessment. Controlling for the two measures of cognitive ability had a similar effect with A-DMC as with Y-DMC, leaving the signs unchanged, but taking most below the threshold of statistical significance.

Aim 3: Assess the stability of decision-making competence over time and across assessment tools

Overall Y-DMC scores at age 19 were strongly correlated with A-DMC scores at age 30 ($r=.50$, $p<.001$), despite the 11-year time difference and the modest differences in the measures (with A-DMC drawing on Y-DMC results to improve its design). Controlling for cognitive ability reduces this correlation somewhat, but it remains strongly significant ($r=.33$, $p<.001$). There were also positive correlations for scores on corresponding versions of most of the six individual tasks: Resistance to Framing ($r=.17$, $p<.05$), Resistance to Sunk Cost ($r=.18$, $p<.05$), Applying Decision Rules (r=.55, p<.001), Under/Overconfidence (r=-.03, ns.),[8] Consistency in Risk Perception (r=.07, ns.), and Recognizing Social Norms (r=.29, p<.01). As might be expected for subtasks involving fewer responses, these correlations were smaller than those for the overall decision-making competence score. Excluding the most highly correlated task, Applying Decision Rules, left overall scores that were still well correlated over time (r=.35, p<.001).

Discussion

We evaluated the robustness of decision-making competence using two instruments, Y-DMC, designed for young adults, and A-DMC, designed for the general adult population. We reported new data from the CEDAR longitudinal study, adding 416 Y-DMC participants in its age-19 assessment, to our original 110 (Parker & Fischhoff, 2005), and 214 A-DMC respondents in its age-30 assessment, for comparison with our original community sample (Bruine de Bruin et al., 2007). These samples included 146 individuals who completed both Y-DMC at age 19 and A-DMC at age 30. Combined with the earlier studies, these new data allowed us to examine the robustness of the construct across samples and time.

Addressing Aim 1, responses of the Y-DMC expansion sample were similar to those of the original Y-DMC sample, in terms of the internal validity of the six tasks and the results of a confirmatory factor analysis. Responses of the CEDAR A-DMC sample were similar to those of the earlier community sample, in the same ways. The main difference between results with the two scales was that Resistance to Sunk Cost had a significant loading on the A-DMC factor, but not on the Y-DMC factor, presumably reflecting its improved measurement in A-DMC (more items, more response options per item).

Addressing Aim 2, patterns of nomological validity in both new samples paralleled those for the original samples. Participants with higher Y-DMC or A-DMC scores had greater cognitive abilities and more supportive family and social environments, which may promote the development of decision-making competence. They displayed more constructive cognitive styles, which may be expected to reflect concurrent skills. Finally, they reported fewer instances of what may be deemed (at least by some) health-risking and antisocial behavior, potentially reflective of poorer decision making. The pattern of these correlations remained, albeit in weakened form, after controlling for the two measures of cognitive ability, with some of the strongest residual correlations being neighborhood disadvantage, self-reported self-monitoring, and several risk behaviors. The correlations emerged despite the covariates being assessed from 3 to 20 years before or after the DMC measures.

Addressing Aim 3, overall Y-DMC scores at age 19 predicted overall A-DMC scores at age 30. This relationship remained after controlling for the two measures of cognitive ability. This stability occurred despite the Y-DMC and A-DMC assessments using somewhat different instruments. A-DMC sought to improve on Y-DMC by increasing the number of items per task and the number of response options per item. Those changes may account for the highest correlations across time being with the two tasks that were perhaps most similar, Applying Decision Rules and Recognizing Social Norms.

Thus, the construct of decision-making competence captured in these two measures appears to be robust over samples and over time, while showing nomological validity in its correlations with other measures that are plausibly related to the ability to follow traditional normative principles. These results strengthen the case for the external validity of such tasks, when used in behavioral experiments. They also suggest the value of using DMC measures in studies of decision making. Two topics for such research that emerge from the present results are how decision-making competence relates to other cognitive abilities and how social environments (family, neighborhood) and decision-making competence affect one another.[9]

Limitations

The longitudinal data collection conducted by CEDAR created a unique scientific resource that allowed us to examine decision-making competence over time and in the context of a rich suite of other relevant variables and outcomes. CEDAR had a remarkable retention rate (73%), considering the 11-year time span and demands on participants. If that attrition were non-random, then it might bias our results in some way. However, we know of no specific concerns – and are somewhat reassured by the similarities in results across samples and for participants with and without missing covariate data.

To avoid capitalization on chance, we identified the correlates that we would consider in advance and report on all variables that we analyzed. We focused on major patterns, rather than small differences in results (especially given the small size of the Y-DMC initial sample). Nonetheless, our aims required many analyses, suggesting caution in interpreting results beyond the general patterns.

Whereas the Y-DMC and A-DMC assessments were designed to assess the same underlying construct, the specifics of their component measures differ sufficiently so that we can only examine the stability of performance in relative terms (via correlations) and not its absolute level (i.e., are people better decision makers at 30 than at 19). A-DMC is a superior instrument overall, judging by its psychometric properties (although Cronbach's alpha for some tasks remains low). However, its items are designed for adults, whereas Y-DMC is designed for late adolescents. Both have content best suited for North American, English-speaking audiences, which has prompted translations (Bavolar, 2013; Del Missier et al., 2012, 2013, 2015; Mäntylä et al., 2012), whose feasibility is supported by the construct validity of these two measures.

The present analyses consider a unidimensional characterization of decision-making competence, as supported by past research and evaluated with CFA, but do not preclude the potential for multiple dimensions. The original Y-DMC and A-DMC studies reported exploratory factor-analytic solutions that extracted more than one factor, but these factors lacked clear interpretability, due to both the limited number of tasks and cross-loadings across factors. Examining the dimensionality of decision-making competence is an important challenge for future research, using a larger set of tasks tapping different skills. That research might also use Item Response Theory methods at the individual DMC scale level, in order to refine the measurement of component tasks. These methods, given an appropriate item pool, have the potential to create more efficient tests, both in terms of the range of ability levels measured and the length of the test.

As mentioned, the performance standard for both assessments is adherence to traditional normative theories of decision making, for maximizing expected utility. These tasks do not address the question of individual differences in judicious use of heuristic processes, another topic for future research.

Implications and Recommendations

We interpret these results as evidence for the robustness of the decision-making competence construct and its component tasks, as captured in these two related measures. We believe that one contributor to this robustness is that those tasks build on ones developed in behavioral decision research experiments that have refined their format and presentation, while examining the effects of alternative formulations on behavior. That collective experience helped us to create tasks that would be well understood and to situate each in the skills domain that it was meant to represent. A second plausible contributor is that the tasks assess performance, rather than self-reported behavior (Appelt et al., 2011). Although self-report and performance tasks often demonstrate convergent validity, perceived and actual performance can differ (e.g., Parker et al., 2007; Weller et al., 2012).

Behavioral decision research has traditionally viewed decision making through a situational lens, examining how experimental manipulations evoke general cognitive processes. Our results suggest the feasibility and potential value of studying individual differences and their relationships to real-world antecedents, concomitants, and consequences. Moving forward, as a research community, we face the collective challenge of linking research in the lab and the world, across individuals' lives.

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Footnotes

[1] One of the seven Y-DMC tasks, which assessed adherence to the rational-choice axiom of path independence, lacked reliability and validity, hence was dropped from subsequent analyses.

[2] As argued in Parker and Fischhoff (2005), these risk behaviors need not be irrational, if they follow in an orderly fashion from a decision maker's beliefs and values. However, they may reflect poor choices in a society that generally deems them unhealthy, antisocial, or even illegal – an assertion supported by their negative correlation with Y-DMC.

[3] Follow-up assessments are labelled according to their target ages: age 14 (age rage 11.3 - 15.6, M = 13.4, SD = 0.9); age 16 (range 15.5 – 17.7, M = 16.1, SD = 0.4); age 19 (range 17.7 – 20.7; M = 18.9, SD = 0.5); age 22 (range = 20.8 – 23.3, M = 21.9, SD = 0.4); age 25 (range 24.6 – 26.0; M = 24.9, SD = 0.3); age 28 (range = 27.6 – 29.0, M = 27.9, SD = 0.3), and age 30 (range = 29.6 – 31.4, M = 30.0, SD = 0.4).

[4] Parker and Fischhoff (2005) analyzed all available data, two of which were missing at least on task score. Here we consider only the 108 individuals with full Y-DMC data.

[5] Y-DMC results were almost completely unaffected by restricting Y-DMC to only valence framing problems.

[6] Exceptions: The self-monitoring scale was eliminated from the protocol in 2000, hence is available only for 127 participants in the Y-DMC expansion sample and 221 of the total Y-DMC sample. Two covariates, alcohol and marijuana use, were measured at age 22, for which some respondents were not yet eligible. The sample sizes for these tests are 80 for the Y-DMC initial sample, 311 for the Y-DMC expansion sample, and 391 for the total Y-DMC sample.

[7] We previously reported a negative relationship between social support and Y-DMC (Parker & Fischhoff, 2005). In the course of the present analyses, we discovered a coding that had reversed the sign. The relationship is actually positive, as initially hypothesized.

[8] Under/overconfidence is made up of two components: the percentage of the true-false questions that the participant got correct and their average confidence judgment. It is worth noting that these two components correlated strongly across the Y-DMC and A-DMC instruments (percent correct $r = .45$, $p < .001$; average confidence $r=.54$, $p < .001$).

[9] From a measurement perspective, one psychometric issue surrounding DMC, and other broad measures (e.g., Stanovich, West, & Toplak, 2016), is whether the construct should be viewed as reflective (i.e., individual differences in a latent construct causes variation in the tasks used to represent it) or formative (i.e., the tasks define the construct) (Bagozzi, 2007; Edwards, 2001). A case could be made for either perspective (Bruine de Bruin et al., 2007; Stanovich et al., 2017). The DMC measures are formative for those who view decision-making competence as defined by the skills that the tasks represent. Such a definition guided our initial work, reflecting on the skill set that we saw as implicit in the research literature. That set had one omission, decision structuring, which did not lend itself to standardized testing and is also little studied, even though its importance is recognized. The measures are reflective for those who view decision-making competence as defined by a general capability, captured in different ways by different tasks. That position would be supported by the belief that these tasks should correlate with each other in a meaningful way (i.e., show structural validity), unlike those in formative measurement, where tasks are selected to represent different aspects of the construct independently. It would also be supported by the belief that individual tasks would correlate in similar ways with other constructs in a nomological network, whereas one would not necessarily

expect such results with a formative measure. Our results, in general, agree with these expectations, but somewhat modestly. Hence, if one is to consider this a reflective measure, it may cover a broad and diverse domain. We are grateful for the opportunity to administer our measures to CEDAR's intensely characterized samples and examine our construct in relation to its history (with Y-DMC) and future (with A-DMC). We encourage other researchers to seek such collaborations.

Table 1. Decision-making competence tasks used for Y-DMC and A-DMC

Task	Performance Criterion
Resistance to Framing	Consistency in choice across equivalent, positively- and negatively-worded questions
Resistance to Sunk Cost	Considering only future consequences when making choices
Applying Decision Rules	Using specified decision rules in choosing among multi-attribute options
Under/overconfidence	Correspondence between confidence and knowledge
Consistency in Risk Perception	Consistency between risk judgments and probability theory
Recognizing Social Norms	Correlation between judged and measured social norms

Table 2. Characteristics of the Y-DMC and A-DMC samples.

Sample Characteristic	Y-DMC Initial Sample (Age 19)	Y-DMC Expansion Sample (Age 19)	A-DMC Sample (Age 30)
Sample size	108	416	214
% Male	100.0%	56.0%	88.8%
Age			
Age-19 assessment	M = 18.6	18.9	M = 18.7
	(SD = 0.6)	(SD = 0.4)	(SD = 0.6)
Age-30 assessment	M = 30.1	M = 30.0	M = 30.1
	(SD = 0.4)	(SD = 0.3)	(SD = 0.4)
% with high-school diploma or GED:			
Age-19 assessment	56.1%	81.6%	61.0%
Age-30 assessment	95.8%	96.6%	96.2%
% with bachelor's degree or greater,			
age-30 assessment	47.2%	48.7%	47.4%
% Caucasian	86.1%	71.1%	79.1%
% in High-risk Group	36.1%	45.2%	32.7%

Note: Gender and race information is missing for eight Y-DMC respondents and three A-DMC respondents. Education information is missing for one Y-DMC and A-DMC respondent.

Table 3. Single-factor solutions for confirmatory factor analyses of Y-DMC and A-DMC task scores.

Task	Y-DMC (Expansion Sample Only)	A-DMC
Resistance to Framing	.30** (.07)	.40** (.09)
Resistance to Sunk Cost	-.09 (.07)	.31** (.08)
Applying Decision Rules	.75** (.09)	.84** (.17)
Under/overconfidence	.49** (.09)	.17* (.09)
Consistency in Risk Perception	.36** (.08)	.36** (.11)
Recognizing Social Norms	.40** (.07)	.27** (.09)
CFI	.953	1.00
RMSEA	.046	.000
SRMR	.034	.026
χ^2 (df)	16.93* (9)	4.90 (9)

Note. Standardized estimates presented; standard errors for parameter estimates in parentheses. ** $p<.01$. * $p<.05$.

Table 4. Correlations of Y-DMC and A-DMC with covariate measures.

	Y-DMC, pairwise[d]			Y-DMC, controlling for cognitive ability		A-DMC, controlling for cognitive ability
	Initial	Expansion	Combined	Combined	A-DMC[e]	
Sample Size	108	416	524	516	214	211
Cognitive Ability						
ECF[a]	.39***	.42***	.43***	n/a	.30***	n/a
Vocabulary (WISC-R)[a]	.46***	.46***	.47***	n/a	.46***	n/a
Social and Family Influences						
Paternal substance use (yes=1; no=0)[a]	-.37***	-.14**	-.19***	-.08*	-.20**	-.05
Household Socio-Economic Status[a]	.35***	.29***	.30***	.09*	.31***	.05
Neighborhood disadvantage[a]	-.32***	-.43***	-.42***	-.21***	-.42***	-.17**
Social support[c]	.31**	.15**	.18***	.07	.30***	.12*
Positive peer environment[c]	.30**	.13*	.16***	.05	.19*	.08
Cognitive Style						
Polarized thinking[c]	-.30**	-.30***	-.28***	-.09*	-.28***	-.12*
Self-consciousness[b]	.25*	.09⁺	.12**	.10*	.05	.07
Self-monitoring[c]	.20⁺	.22*	.19**	.21***	-.03	-.01
Behavioral coping[c]	.25*	.12*	.14**	.01	.26***	.09
Risk Behavior						
Childhood antisocial disorders [c]	-.23*	-.22***	-.20**	-.08*	-.05	.03
Externalizing behavior[b]	-.29**	-.21***	-.23***	-.09*	-.19*	-.11
Delinquency[b]	-.24*	-.34***	-.33***	-.14**	-.20**	-.05
Ln(# of alcohol uses, typical month)						
Age-16 assessment	-.11	-.11*	-.10*	-.07	.02	.01
Age-19 assessment	-.16	-.03	-.05	-.03	-.16*	-.11
Age-22 assessment	-.01	.13*	.10*	.06	.08	.05
Ln(# of cannabis uses, typical month)						
Age-16 assessment	-.21*	-.19***	-.18***	-.12**	.00	.00

Age-19 assessment	-.11	-.24***	-.21***	-.12**	-.18*	-.08
Age-22 assessment	-.15	-.16**	-.15**	-.07	-.25**	-.13
Ln(# times had sex, last year)[c]	-.19$^+$	-.28***	-.26***	-.14***	-.24***	-.09
Ln(# sexual partners)[c]	-.26*	-.29***	-.29***	-.16***	-.31***	-.15*

Note: Columns 4 and 6 present semipartial correlations, controlling for cognitive ability. Change in R^2 is the square of these semipartial coefficients, and ranges from .00 to .05 for Y-DMC and .00 to .03 for A-DMC.

*** p< .001; ** p < .01; * p < .05; $^+$ p < .10.

[a] Measured at baseline assessment; [b] Measured at age-14 assessment; [c] Measured at age-16 assessment; [d] Measured at age-19 assessment; [e] Measured at age-30 assessment.

The Robustness of Decision-Making Competence

Supplementary Material

This supplementary material contains additional detail regarding the method and results reported in the main manuscript. In particular, it contains sample items for each of the Y-DMC tasks (with notes on how A-DMC differs), descriptive statistics for each Y-DMC and A-DMC component measure and composite scores, and correlations among the DMC component measures.

Task Details and Sample items

Resistance to Framing

Positively- and negatively-framed items are fielded within-subject, but separated by other Y-DMC instruments to reduce memory effects. Resistance to Framing item pairs ask respondents to (a) choose or reject one of two flavors of ice cream, one that tastes good and the other that tastes great but is really bad for you, where consistency means choosing one and rejecting the other (Shafir, 1993); (b) judge whether a condom is acceptable when its efficacy is described by its success or failure rate (adapted from Linville, Fischer, & Fischhoff, 1993); (c) choose between a smaller, more immediate payoff ($100) and a larger ($120), more delayed one (adapted from Roelofsma & Keren, 1995); (d) choose between medical treatments described as lives saved or lives lost (Tversky & Kahneman, 1988); and (e) choose between a gamble with negative consequences and an expenditure described as a sure loss or an insurance payment (Fischhoff, 1993). Items from each pair are separated by other Y-DMC tasks. The Resistance to Framing score is the number of consistent choices (0-5).

The following are verbatim items from Y-DMC, which includes five item pairs.

<u>Problem 2 (negative frame):</u>

Imagine that a type of condom has a 5% failure rate. That is, if you have sex with someone who has the AIDS virus, there is a 5% chance that this type of condom will fail to prevent you from being exposed to the AIDS virus.

Should the government allow this type of condom to be advertised as "an effective method for lowering the risk of AIDS?"   Yes   No

<u>Problem 2 (positive frame):</u>

Imagine that a type of condom has a 95% success rate. That is, if you have sex with someone who has the AIDS virus, there is a 95% chance that this type of condom will prevent you from being exposed to the AIDS virus.

Should the government allow this type of condom to be advertised as "an effective method for lowering the risk of AIDS?" Yes No

A-DMC uses this pair and thirteen others. Seven pairs frame attributes in positive or negative terms (e.g., ground beef described as "80% lean" or "20% fat") and seven describe risky choices in terms of gains or losses (e.g., described in terms of "lives saved" or "lives lost"). A-DMC uses a 6-point itemized-rating response scale.

Resistance to Sunk Cost

The following item is one of two from Y-DMC.

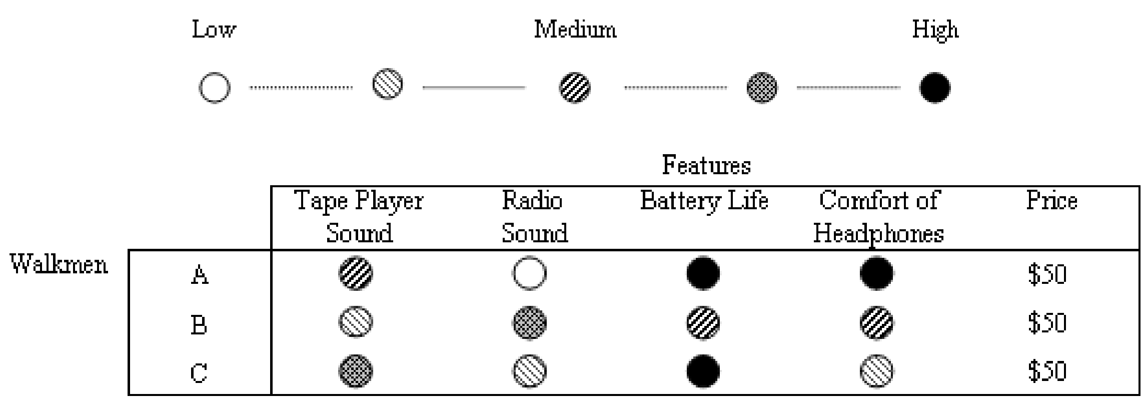
You and your friend have driven half way to a resort. To get a lower price, you have put down a $100 deposit for the weekend there. Even if you cancel, you cannot get the $100 back. Both you and your friend feel sick. You both feel that you both would have a much better weekend at home. Your friend says it is "too bad" you have paid the deposit because you both would much rather spend the time at home, but you can't afford to waste $100. You agree. Do you drive on or turn back?

Drive on Turn back

A-DMC uses this and nine others. Items address varied contexts, some adapted from the sunk-cost literature (Arkes & Blumer, 1985; Baron, Granato, Spranca, & Teubal, 1993; Bornstein & Chapman, 1995; Frisch, 1993), and others created by the authors (Bruine de Bruin et al., 2007). Higher average ratings, across the 10 items, reflect greater resistance to sunk costs. A-DMC uses a 6-point itemized-rating response scale.

Applying Decision rules

The following item is from Y-DMC, which includes seven items.



Bobby has decided to use the following rule. He throws out any Walkman that is below medium in his most important feature, Tape Player Sound. He then throws out any Walkman worse than medium in his next most important feature, Comfort of Headphones.

A-DMC uses ten very similar questions, but displays are numeric (rather than graphical), the choices include more options (to increase difficulty), and choices are among Blu-ray players.

Note that our original A-DMC (Bruine de Bruin et al., 2007) used DVD players, but the technology was updated to Blu-ray players for this study. Our original Y-DMC analysis (Parker & Fischhoff, 2005) used a count to compute performance, but a percentage is used here to increase comparability to A-DMC.

Under/overconfidence

The following are items from Y-DMC, which includes 42 items, grouped into general knowledge, knowledge about alcohol and drugs, and knowledge about sex and HIV/AIDS.

A robin's eggs are orange.

This statement is [True / False].

50% 60% 70% 80% 90% 100%

just guessing absolutely sure

Snorting cocaine can cause lung cancer.

This statement is [True / False].

50% 60% 70% 80% 90% 100%

just guessing absolutely sure

A man can get the AIDS virus (HIV) from having sex with a woman who has it.

This statement is [True / False].

50% 60% 70% 80% 90% 100%

just guessing absolutely sure

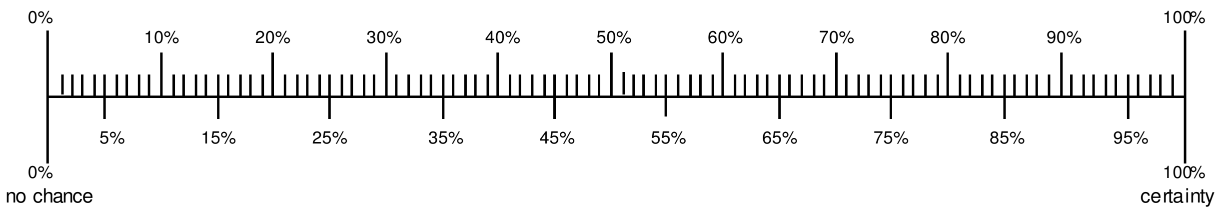
A-DMC uses a similar format, but includes 34 items on a broad range of life topics.

Consistency in Risk Perception

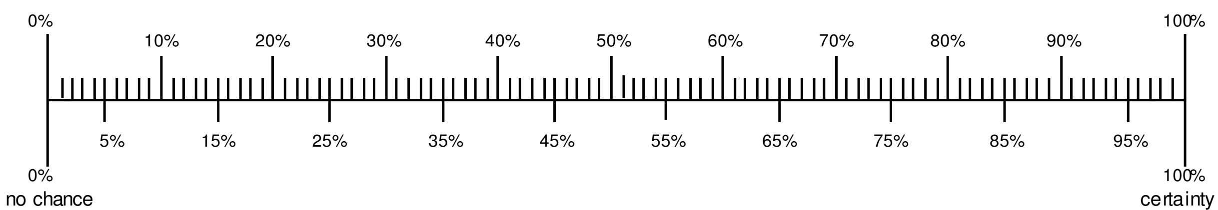
Y-DMC includes five sets of items compared for consistency. Item pairs include nested subset and superset events, for which the former should be judged as less likely (e.g., an event occurring in the next year vs. the next five years; dying in a terrorist attack vs. dying from any cause), complementary events, for which the judged likelihood should add up to 100% (e.g., getting into a car accident while driving vs. being accident free), conjunctions of two events, which should be judged as no more likely than either of the constituent events (getting drunk and having sex vs. either occurring alone), and disjunctions of two events, which should be judged as no less likely than each constituent event (using cannabis or another illegal drug vs. either occurring alone). Each set is scored as whether or not the responses are consistent with the rules of probability theory. The pair below is coded as an error if the judged likelihood of arrest by age 30 is less than the judged likelihood of arrest in the next year.

The following is one of the five Y-DMC item pairs.

What is the percent chance that you will be arrested, whether rightly or wrongly, at least once in the next year?



What is the percent chance that you will be arrested, whether rightly or wrongly, at least once between now and when you turn 30?



A-DMC follows a similar format, but includes 20 consistency comparisons, using time frames of in the next year and the next five years. Our original Y-DMC analysis (Parker & Fischhoff, 2005) used a count, but a percentage is used here to increase comparability to A-DMC.

Recognizing Social Norms

The Y-DMC and A-DMC tasks are identical for Recognizing Social Norms. The task includes questions asking whether each of 16 negative behaviors is “sometimes OK” (yes/no) and questions asking what proportion of “people your age” would say that each behavior is sometimes OK (0 to 100). Sample averages from the first set are compared to the judged percentages from the second set, with the rank-order correlation being the task score. Below are examples from each set.

Do you think it is sometimes OK …
… to steal under certain circumstances?

Yes No

Out of 100 people your age, how many would say it is sometimes OK …

… to steal under certain circumstances?

0 10 20 30 40 50 60 70 80 90 100

No one Everyone

Bruine de Bruin et al. (2007) used age brackets to account for "people your age" when computing the norm for our adult sample. Adult participants in this study all received Y-DMC at age 19 and A-DMC at age 30, making such bracketing unnecessary.

Additional Results

Table S1 provides descriptive statistics for each of the Y-DMC component task scores.

Table S1. Descriptive statistics for Y-DMC

Score	N	Range (potential)	Mean (SD)	Median (IQR)
Resistance to Framing	529	0-5 (0-5)	3.4 (1.08)	3 (3-4)
Resistance to Sunk Cost	530	0-2 (0-2)	.7 (.70)	1 (0-1)
Applying Decision Rules	528	.29-1.00 (.00-1.00)	.89 (.17)	1.00 (.86-1.00)
Under/overconfidence	532	.59-1.00 (.00-1.00)	.92 (.07)	.94 (.89 - .97)
Consistency in Risk Perception	530	.00-1.00 (.00-1.00)	.83 (.20)	.80 (.80-1.00)
Recognizing Social Norms	524	-.34 - .89 (-1.00 - 1.00)	.52 (.22)	.55 (.40 - .67)

Table S2 presents the Cronbach's alphas for Y-DMC by sample.

Table S2. Cronbach's alpha of the Y-DMC task scores across samples.

Task	Y-DMC Initial Sample[a]	Y-DMC Expansion Sample	Y-DMC Total Sample
Resistance to Framing	.30	.19	.22
Resistance to Sunk Cost	.07	.13	.12
Applying Decision Rules	.68	.58	.60
Under/overconfidence	.79	.76	.77
Consistency in Risk Perception	.50	.45	.46
Recognizing Social Norms	.40	.68	.65
Y-DMC Composite	.73	.77	.76

[a] Estimates only include respondents with full Y-DMC data, hence are slightly different from those reported in Parker & Fischhoff (2005), which used all available data.

Table S3 presents the Pearson correlations among the six Y-DMC component task scores. Overall, the mean correlation was .13.

Table S3. Correlations among Y-DMC task measures

	Framing	Sunk Cost	Decision Rules	Under/ overconfidence	Risk Perception
Resistance to Framing					
Resistance to Sunk Cost	.04				
Applying Decision Rules	.21***	-.06			
Under/overconfidence	.23***	-.01	.35***		
Consistency in Risk Perception	.18***	.03	.22***	.23***	
Recognizing Social Norms	.09*	-.03	.28***	.12**	.11*

*** two-sided p-value < .001; ** p < .01; * p < .05; $^{+}$ p < .10.

Table S5 provides descriptive statistics for each of the A-DMC component task scores.

Table S5. Descriptive statistics for A-DMC

Score	N	Range (potential)	Mean (SD)	Median (IQR)
Resistance to Framing	214	1.5 - 5.0 (1.0 - 5.0)	4.1 (.5)	4.2 (3.8 – 4.5)
Resistance to Sunk Cost	214	2.1 – 6.0 (1.0 – 6.0)	4.2 (.7)	4.2 (3.8 – 4.6)
Applying Decision Rules	214	0 – 10 (0 – 10)	6.2 (2.1)	7 (5 – 8)
Under/overconfidence	214	.72 – 1.00 (.00 – 1.00)	.92 (.06)	.94 (.89 - .97)
Consistency in Risk Perception	214	7 – 20 (0 – 20)	15.4 (2.6)	16 (14 – 17)
Recognizing Social Norms	214	-.20 - .88 (-1.00 – 1.00)	.49 (.23)	.52 (.34 - .67)

Table S6 compares the CEDAR A-DMC Cronbach's alphas with those observed by Bruine de Bruin et al. (2007) using a community sample of adults, age 18-88.

Table S6. Cronbach's alpha of the Y-DMC task scores across samples.

Task	CEDAR A-DMC Sample	A-DMC Community Sample[a]
Resistance to Framing	.70	.62
Resistance to Sunk Cost	.55	.54
Applying Decision Rules	.67	.73
Under/overconfidence	.80	.77
Consistency in Risk Perception	.65	.72
Recognizing Social Norms	.57	.64
Y-DMC Composite	.81	.83

[a] From Bruine de Bruin et al. (2007).

Table S7 presents the Pearson correlations among the six Y-DMC component task scores. Overall, the mean correlation was .15.

Table S7. Correlations among A-DMC task measures

	Framing	Sunk Cost	Decision Rules	Under/ overconfidence	Risk Perception
Resistance to Framing					
Resistance to Sunk Cost	.09				
Applying Decision Rules	.35***	.26**			
Under/overconfidence	.03	.05	.15*		
Consistency in Risk Perception	$.11^{+}$	.15*	.28***	.06	
Recognizing Social Norms	.06	.06	.22**	.09	.22**

*** two-sided p-value < .001; ** p < .01; * p < .05; $^{+}$ p < .10.

Table S9 presents the Pearson correlations between each of the Y-DMC component task scores and each of the A-DMC component task scores.

Table S9. Correlations between Y-DMC and A-DMC task and composite measures

Y-DMC	A-DMC						
	Framing	Sunk Cost	Decision Rules	Under/ overconfidence	Risk Perception	Social Norms	A-DMC
Resistance to Framing	.17*	.23**	.22**	.00	.10	.02	.23**
Resistance to Sunk Cost	.02	.17*	.05	.09	.00	-.02	.10
Applying Decision Rules	.24**	.14^{+}	.55***	.12	.14	.24**	.45***
Under/overconfidence	.27**	.09	.21*	-.02	.04	.00	.18*
Consistency in Risk Perception	.01	.12	.21*	.07	.08	.15^{+}	.19*
Recognizing Social Norms	.14	.12	.19*	.04	.26**	.29***	.33***
Y-DMC	.28***	.29***	.48***	.10	.20*	.23**	.50***

*** two-sided p-value < .001; ** p < .01; * p < .05; $^{+}$ p < .10.

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