STRATEGIC RISK-TAKING IN THE NATIONAL FOOTBALL LEAGUE: A MULTILEVEL MODEL ANALYSIS OF THE RELATIVE STATE MODEL

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Joshua Daniel Gonzales

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Joshua Daniel Gonzales, candidate for the degree of Master of Arts in Experimental & Applied Psychology**,** has presented a thesis titled, ***Strategic Risk-Taking in the National Football League: A Multi-Level Model Analysis of the Relative State Model,*** in an oral examination held on December 17, 2018. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

External Examiner: Dr. Gary Brase, Kansas State University*

Co-Supervisor: Dr. Sandeep Mishra, Faculty of Business Administration

Co-Supervisor: Dr. R. Nicholas Carleton, Department of Psychology

Committee Member: Dr. Thomas Phenix, Department of Psychology

Chair of Defense: Dr. Larena Hoeber, Faculty of Kinesiology & Health Studies

*Via Videoconference

Abstract

Risk-sensitivity theory suggests that decision-makers should choose high-risk (i.e., high outcome variance) options when low-risk options are unable to meet desired goals or outcomes. Experimental results supporting risk-sensitivity theory have been well documented and account for a significant portion of the variance in decision-making under risk (reviewed in Mishra, 2014). However, substantial evidence suggests decision-makers exhibit stable individual differences in risk-taking across context. The relative state model (Mishra, Barclay, & Sparks, 2017) consolidates these differences by positing that risk-taking is a product of one of two interrelated pathways: 1) a need-based pathway characterized by decision-makers acting on disparity between the decision-maker's present and goal states; or 2) an ability-based pathway characterized by risk-taking as an affordance of competitive advantage. The present study was conducted to validate the hypotheses posed in the relative state model and to test whether this framework is applicable to decision-making under risk in a group setting. This study replicates previous findings demonstrating risk-sensitive decision-making in football games (Gonzales, Mishra & Camp II, 2017) and extends them with multilevel analyses. The study also provides evidence indicating teams have risk preferences shaped by relative competitive advantage. Observing these risk-taking patterns in a team sports setting lays the groundwork for a better understanding of risky decision-making in real world group settings.

Keywords: relative state model, decision-making, risk

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Dedication

This thesis is dedicated to Jun Lalin Jr. Thank you for teaching me that a life lived in service of others is a life worth living. The world aches without your presence.

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Introduction

Risk is everywhere: People rarely get to choose between options that only have one possible outcome. Taking a new job could leave you more fulfilled or wishing you had stayed at your old position. A potential partner could end up the love of your life or be just another summer fling. Your investment choices could make you the next Warren Buffet or leave you penniless. In each case, considerations for the risk of your options is paramount.

Researchers in the behavioral sciences typically define risk as outcome variance (e.g., Bernoulli, 1738; Daly & Wilson, 2001; Friedman & Savage, 1948; Mishra, 2014; Real & Caraco, 1986; Rubin & Paul, 1979; Winterhalder, Lu, & Tucker, 1999). Based on the above definition of risk, an option providing a 50% chance of attaining $100 dollars is riskier than an option that provides a 100% certainty of attaining $50. Both options offer the same mean expected outcome of $50, but the decision-maker who chooses the former option opens themselves up to a larger set of potential outcomes, thereby engaging in risk-taking behaviour.

Explanations for when and why risk-taking occurs can seem contradictory. Risk-sensitivity theory hypothesizes that risk-taking should be motivated by need, which is broadly defined as disparity between a decision-maker's present state and their desired or goal state (Mishra & Lalumière, 2010). The theory states that an individual who perceives themselves to be far from a desired goal state (i.e., in a *high need* situation) should choose a high outcome variance option (i.e., high risk option) if a lower risk option would not meet that need. Although humans are generally risk-averse at baseline (Kahneman & Tversky, 1979), risk-sensitivity offers a framework for understanding when decision-makers engage in elevated risk-taking. For example, someone with a pressing $100 debt should choose an option that gives him or her some chance of getting $100, even if that chance is minimal. In the given scenario, choosing a certain $50 option would have deleterious results. Evidence in favour of decision-makers adhering to risk-sensitivity theory in high need scenarios has been well documented in the animal behavior literature and has been extended to humans with experimental research (reviewed in Mishra, 2014). Studies involving naturalistic field data have also shown that organizational groups make risk-sensitive decisions under consideration of multiple needs (e.g., Gonzales, Mishra & Camp II, 2017).

Seemingly opposed to the premise that decision-makers adjust their level of risk-taking in response to acute situational conditions of need, a large body of evidence suggests that decision-makers exhibit stable individual differences in risk-taking (e.g., Bromiley & Curley, 1992; Eysenck & Eysenck, 1977, 1985; Friedman & Savage, 1948; Mishra, 2014; Mishra, Logue, Abiola, & Cade, 2011; Pratt, 1964; Roberts & DelVecchio, 2000; Slovic, 1964; Weber, 1998; Weber, Blais, & Betz, 2002; Zuckerman, 2007). Personality traits such as high sensation-seeking (the search and inclination for varied and novel experiences), low self-control (the inhibitory ability to regulate one's actions), and high impulsivity (the tendency to act with little to no forethought of consequences) have consistently been correlated with various forms of risk-taking. Mishra and Lalumière (2011) found evidence of a single "risky personality" principle component, which explained overlapping variance in self-reported measures of impulsivity, sensation-seeking, and self-control. Evidence for stable individual differences in risk-taking appears to run counter to risk-sensitivity theory, in that risk-sensitivity theory suggests that decision-makers situationally adjust their level of risk-taking depending on their state of need.

To consolidate the seemingly divergent literatures, Mishra, Barclay, and Sparks (2017) posited the *relative state model*. The relative state model suggests that decision-makers engage in risk-taking through one of two non-independent pathways: the need-based pathway and the ability-based pathway. The need-based pathway suggests that decision-makers engage in risk-taking because of competitive disadvantage that prohibits attaining needs and wants by other less risky means. The ability-based pathway suggests that decision-makers take on risk based on having a better chance of successfully engaging in risk-taking relative to the competition, and better ability to realize benefits accordingly. The relative state model has strong theoretical foundations (for a recent mathematical model, see Barclay, Mishra, & Sparks, 2018) and each pathway enjoys substantial empirical support (e.g., Bromiley & Curley, 1992; Bell, 1995; Blais & Weber, 2006; Eysenck & Eysenck, 1977, 1985; Friedman & Savage, 1948; Hanoch, Johnson, & Wilke, 2006; Johnson, Wilke, & Weber, 2004; Mishra, 2014; Mishra, Logue, Abiola, & Cade, 2011; Pratt, 1964; Roberts & DelVecchio, 2000; Slovic, 1964; Weber, 1998; Weber, Blais, & Betz, 2002; Weber & Hsee, 1998, 1999; Weber & Milliman, 1997 Zuckerman, 2007).

Because the model is relatively new, studies have yet to be done to examine the two pathways together in a single naturalistic setting. Furthermore, many decisions are made in group settings and there is very little evidence showing whether or not human groups engage in decision-making under risk consistent with either the need-based or ability-based pathway. The present study examined if the relative state model can account for meaningful variance in group decision-making in a sample of sports plays from a professional league (specifically, American football plays from the National Football League). Sports leagues provide an organizational group context with clear risk-taking parameters and highly controlled real-world conditions (Day, Gordon & Finke, 2012; Katz, 2001; Wolfe et al., 2005). The following (1) reviews literature relevant to understanding risk-taking conceived broadly; (2) reviews key mechanisms involved in group decision-making; (3) provides evidence suggesting that football decision-making is an apt context for examining the relative state model; and (4) presents a study conducted to specifically examine whether football decision-making under risk occurs in accord with the relative state model.

Decision-making under risk

Almost every decision is made with some consideration of risk, where risk is defined as variability in outcome (e.g., Bernoulli, 1738; Daly & Wilson, 2001; Friedman & Savage, 1948; Mishra, 2014; Real & Caraco, 1986; Rubin & Paul, 1979; Winterhalder, Lu & Tucker, 1999). Concepts such as hazard or danger (e.g., McNeil, Frey, & Embrechts, 2005) imply obligatory exposure to negative outcomes and are therefore not equivalent to risk. Importantly, risk explicitly defined as outcome variance includes both positive and negative outcomes and does not imply any pejorative judgement on the valence of possible outcomes.

Outcome variance can be quantified in multiple currencies, usually based on the specific domain or problem being examined. For example, animal foraging studies have typically manipulated risk by changing the yield characteristics of given food patches (e.g., Hurly, 2003; Real & Caraco, 1986). Economic studies have similarly manipulated risk by changing the potential monetary payoffs of stock options (e.g., Xie, Xie, Ren, & Yu, 2009). Risk-taking in one domain can also often affects outcomes in other domains. For example, pathological gambling, a form of risk-taking where decision-makers expose monetary resources to high outcome variance, decreases social status and social support and is strongly associated with poorer physical and mental health (e.g., Ferland et al., 2008; Griffiths, 2004; Korn & Shaffer, 1999; Shaffer & Korn, 2002). Regardless of the specific domain, reckoning with variance is a recurrent problem for both human and non-human animals.

Dual pathways to risk

Who engages in risk-taking, and under what circumstances? Risk-taking has been argued by some to be a product of stable individual differences in "taste for risk", leading to domain-general risk-taking (e.g., Bromiley & Curley, 1992; Eysenck & Eysenck, 1977, 1985; Friedman & Savage, 1948; Mishra, Logue, Abiola, & Cade, 2011; Pratt, 1964; Roberts & DelVecchio, 2000; Slovic, 1964; Zuckerman, 2007). Additionally, risk-taking may change depending on context, implying decision-makers calculate the utility associated with risk-taking dependent on specific domain needs (e.g., Bell, 1995; Blais & Weber, 2006; Hanoch, Johnson, & Wilke, 2006; Johnson, Wilke, & Weber, 2004; Weber, Blais, & Betz, 2002; Weber & Hsee, 1998, 1999; Weber & Milliman, 1997). As an example, someone may have a high tolerance for risk in all aspects of their life, while another person may only take on financial risks when facing an excessive amount of debt.

How can the domain-general and domain-specific accounts of risk-taking be reconciled? The relative state model (Mishra et al., 2017) offers one potential solution.

Mishra and colleagues (2017) posit a need-based pathway where competitively disadvantaged individuals use risk to attain desired results that the individual could not attain through less risky means, and an ability-based pathway where competitively advantaged individuals use risky behavior to attain greater benefits with an increased chance of succeeding and signaling their relative value to others. The two pathways each account for variance in decision-making under risk, but the pathways are argued to be non-independent: both are contingent upon the relative position of the decision-maker compared to their competition. A decision-maker can compute their relative state by weighing the costs and benefits associated with risk-taking using four key variables: (1) the payoff of succeeding; (2) the probability of succeeding; (3) the payoff of failing; and (4) the probability of failure (Barclay et al., 2018; Mishra et al., 2017).

Need-based risk-taking

Need-based risk-taking is founded on risk-sensitivity theory, where decision-making under risk is theorizing to be particularly sensitive to *need* conditions. Need simply describes the disparity between where a decision-maker is (the status quo) and where a decision-maker wants or needs to be (a goal, or desired state) (Mishra et al., 2010; Mishra, 2014). High need describes a situation where there is a large disparity between a decision-maker's present and goal states. That is, a high need condition describes a scenario where less risky options will not meet a salient need, making a successful risk the only outcome in which a decision-maker is fully satisfied. According to risk-sensitivity theory, decision-makers should choose riskier options in high need conditions, even if decision-makers are more likely to attain some non-zero payoff through safer options. (Kacelnik & Bateson, 1997; Mishra & Lalumière, 2010; Mishra, 2014; Stephens, 1981; Stephens & Krebs, 1986).

Risk-sensitivity theory shares common elements with other theoretical frameworks of decision-making under risk, especially expected utility theory and prospect theory (Friedman & Savage, 1948; Tversky & Kahneman, 1981). Expected utility theory posits that decision-makers compute an option's subjective value based on the utility of a decision outcome and the outcome probability, where utility is defined as a measure of happiness, gratification or satisfaction (Friedman & Savage, 1948). Early frameworks of expected utility theory posited three different utility functions describing the relationship between the objective expected value and the decision-maker's perceived utility: risk-indifference, risk-aversion, and risk-preference (von Neumann & Morgenstern, 1944). Risk indifference describes a linear relationship between expected value and perceived utility. Risk-aversion is characterized by diminishing returns, where each additional objective unit of reward has lesser perceived utility. Risk-preference is the inverse of risk-aversion, where each additional objective unit of reward has a larger perceived utility to the decision-maker. von Neumann and Morgenstern (1944) originally posited that a decision-maker would exhibit consistent patterns of behaviour based on these three functions; however, a large body of evidence shows that decision-makers violate the expectations of expected utility theory (e.g., Aktipis & Kurzban, 2004; Allais, 1953; Barrett & Fiddick, 2000; Ellsburg, 1961; Kahneman & Tversky, 1979; Rode & Wang, 2000; Starmer, 2000; reviewed in Wu et al., 2004).

Prospect theory builds upon expected utility theory and posits that decision-makers use several operations over two phases (editing and evaluation) to compute the utility of given options around a reference point (Kahneman & Tversky, 1979).

Outcomes below the reference point are considered losses, and outcomes above the reference point are considered gains. Kahneman and Tversky (1981) derived the reference point around the decision-maker's present state, expectations, and biases. If a decision-maker's present state is below the reference point, prospect theory predicts that the decision-maker will be risk-seeking, were as if they are above the reference point, they will be risk-averse. Prospect theory has substantial empirical support (reviewed in Levin, Schneider, & Gaeth, 1998; for a meta-analysis, see Kühberger, 1998)

Risk-sensitivity theory and prospect theory often make the same predictions under similar conditions (Houston et al., 2014) but, compared to prospect theory, risk-sensitivity theory makes fewer assumptions. In bounded situations (e.g., where resources such as time, money, and mental capacity are limited), decision-makers tend to utilize mental shortcuts (like the satisficing heuristic posited in risk-sensitivity theory) rather than use a cognitively taxing strategy like the explicit computations posited in prospect theory (Gigerenzer & Todd, 1999). Both theories are able to account for need-sensitive risky choice, but risk-sensitivity theory accounts for the bounded (i.e., time limited) nature of decision-making (reviewed in Mishra, 2014).

In contrast to decision-making theories that assume decision-makers focus on maximizing the utility of a currency, risk-sensitivity theory suggests decision-makers focus on satisficing. Risk-sensitivity is a satisficing heuristic, in that risk-sensitivity involves the application of a simple rule of thumb (Simon, 1956). In this framework, decision-makers search through alternatives until an option surpasses the salient need threshold. Once the decision-maker finds an option that passes the need threshold they stop searching for alternatives and select the option that satisfies their need.

Evidence in favour of risk-sensitivity theory has been well documented in animal behaviour. Risk-sensitivity theory was initially conceptualized in the behavioural ecology literature to explain decision-making in foraging animals (Caraco, Martindale, & Whittam, 1980). In the first empirical demonstration of risk-sensitive decision-making, yellow-eyed junco birds were placed in one of two need conditions. In the "positive energy budget" condition (a low need condition), birds were provided with enough food to meet their daily energy requirements. In the second "negative energy budget" condition (a high need condition), birds were given an amount of food that would not meet their daily energy requirements. The birds were then given a choice between two food patches with the same expected value, but differing in variance. The risky patch offered high outcome variance and the safe patch offered low outcome variance. The variance in the riskier food patch afforded the birds in the negative energy budget some chance of meeting their daily energy requirement, whereas the variance in the safer food patch did not include a food value that would provide the negative energy budget birds with enough energy to meet their daily energy requirement. Caraco and colleagues (1980) found that junco birds in the negative energy budget condition were substantially more likely to pick the high-risk patch than birds in the positive energy budget condition. Following Caraco et al.'s (1980) seminal study, risk-sensitivity has been examined extensively in the animal behaviour literature and has received substantial empirical support (reviewed in Kacelnik & Bateson, 1996, 1997; Stephens, 1981; Stephens & Krebs, 1986; but see Kacelnik & El Mouden, 2013).

Risk-sensitivity has also been demonstrated in humans (reviewed in Mishra, 2014). In one example, Mishra and Lalumière (2010) had participants complete the ecological decision task (ECO). Participants in the ECO completed a training phase where four different coloured cartoon trees were randomly presented on a computer screen, each yielding some non-zero number of virtual apples to the participant. To simulate real life foraging conditions, each tree had its own mean and variance for apple yield. There were two trees with different means but the same variance, and two other trees with the same mean but different levels of variance. The simulation allowed participants to experientially learn the yield characteristics of each tree. Participants then completed a decision-making trial phase where they were required to attain a set number of apples to complete the task successfully. The initial trials presented one of the two trees with differing means but the same variance. By the final trial participants were either in a high need condition or a low need condition. In the low need condition, participants were close to the apple threshold needed to "survive" the task, while participants in the high need condition were far from the apple threshold. Participants then had to choose between the two trees with the same mean but differing variances. Consistent with risk-sensitivity theory, results showed that people in the high need condition chose the higher variance option more frequently than people in the low need condition (Mishra & Lalumière, 2010).

Evidence also suggests that groups make risk-sensitive decisions. Gonzales, et al. (2017) demonstrated football teams make decisions consistent with risk-sensitivity theory when attempting to complete goals in the context of a football game. In the study conducted by Gonzales and colleagues (2017), football teams chose higher risk options more frequently (i.e. passing the football) under conditions when lower risk options (i.e.

running the football) were unlikely to satisfy a salient need (measured by yards-to-down and points-to-parity).

Risk-sensitivity theory does not apply in every scenario, just as heuristics more generally are not broadly applicable tools (Gigerenzer & Gaissmaier, 2011). Simon (1990) used a “scissors” analogy to explain that cognitive capability and environmental structure must be considered in tandem (like the two blades of a pair of scissors) to understand the suitability of any given mental strategy. Understanding when a mental model is appropriate is known as *ecological rationality* (Todd & Gigerenzer, 2011). Need-based risk-taking is most applicable to understanding decision-making under risk in contexts that include specific, easily identifiable needs reflecting situations with large disparities between the decision maker’s present state and goal state (reviewed in Mishra, 2014). Contexts with uncertain needs or low variability in need states are not well-suited to being understood by risk-sensitivity theory; still, given that most decisions involving risk are characterized by some clear consideration of where one is and where one would like (or need) to be, risk-sensitivity remains a highly useful motivation-centered framework for understanding risky decisions. Indeed, increasing evidence indicates that decision-makers across diverse taxa are motivated by need thresholds when engaging in risk-taking (e.g., Deditius-Island, Szalda-Petree, & Kucera, 2007; Ermer, Cosmides, & Tooby, 2008; Gonzales, et al., 2017; Mishra, Barclay, & Lalumière, 2014; Mishra, Lalumière, Williams & Daly, 2012; Mishra & Fiddick, 2012; Mishra et al., 2012; Mishra & Lalumière, 2010; Mishra & Novakowski, 2016; Mishra, Son Hing, & Lalumière, 2015; Payne, Brown-Iannuzzi, & Hannay, 2017; Pietras & Hackenberg, 2001; Pietras, Locey, & Hackenberg, 2003; Rode et al., 1999; Wang, 2002; reviewed in

Bateson, 2002; Bateson, & Kacelnik, 1998; Kacelnik & Bateson, 1996, 1997; Kacelnik & El Mouden, 2013; Mishra, 2014; Mishra et al., 2017).

Ability-based risk-taking

Need-based risk-taking assumes the decision-maker is at some competitive disadvantage (i.e., a condition of need) and engages in risk-taking to improve their relative standing. In contrast, ability-based risk-taking suggests that the risk-taker possesses some competitive advantage; the payoff and probability of engaging in risk-taking yields a relatively higher expected value than the expected value of safer options. Risk-taking is a worthy investment for competitively advantaged decision-makers because risk-taking generally yields advantaged decision-makers more benefits over time.

Imagine someone who is trying to decide between becoming a musician or an accountant. Pursuing music has high outcome variance: there is some possibility the individual will attain a lucrative payoff (e.g., becoming a world-renowned artist with resultant rewards), but a much higher likelihood of attaining a low payoff (e.g., very little money and respect with substantial opportunity costs). The musical career choice can be contrasted with the choice to become an accountant, which has low outcome variance (e.g., a stable career with good baseline job prospects). The contrasting choices can be illustrated numerically: the possible "payoffs" of attempting to become a musician ranges from 0 (broke) to 100 (exceptional success), whereas becoming an accountant nearly always result in a "payoff" of 50 (moderate success). Accordingly, choosing a career in music is "riskier" (i.e., higher payoff variance) than choosing a career in accounting (i.e., lower payoff variance). Subsequently, the payoff of successful risk-taking is 100 while the payoff of failure is 0, while the payoff is always 50 for not taking on risk.

The probabilities of success and failure in any domain are necessarily influenced by the relative competitive advantages (or disadvantages) of the decision-maker. The advantages are a product of the interaction of embodied capital (e.g., intelligence, strength), and situational factors, like external endowments (e.g., through a large inheritance). In the above example, a musician would be competitively advantaged if they have nimble fingers (a form of embodied capital) and/or because their parents were able to pay for a very good music teacher (a form of situational endowment). Someone who has neither embodied nor endowed advantages necessarily has a very small chance of becoming a world-famous artist, whereas a skilled musician with bountiful monetary and social resources has a greater chance of success.

The traits and situational factors that give rise to competitive (dis)advantage are domain-specific. Physical and social abilities may be leveraged to better succeed in interpersonal conflicts (Archer, 2009; Fessler et al., 2013; Sell et al., 2012). Intelligence can also be leveraged in risk-taking scenarios, as a more intelligent decision-maker can process information more efficiently and better adapt to environmental changes that may affect the probabilities and payoffs of each option (Taylor & Dunnette, 1974). For example, Smith, Bird, and Bird (2003) observed risk-taking in Meriam turtle hunters. Hunting is a high variance occupation due to the ever-present possibility that a hunter could return having caught nothing. Strength, agility, and dexterity importantly increase the chances of successful hunts. Smith and colleagues (2003) found evidence that top hunters leveraged such assets and were rewarded with more mating opportunities, better quality mates, and higher reproductive success. Regardless of the source, competitive advantage can increase the expected payoffs of risk-taking (Barclay et al., 2018).

Integrating the dual pathways: The psychology of relative state

Competitive advantage and disadvantage must necessarily be understood in relative terms. One's degree of competitive (dis)advantage in any given scenario is a product of the interaction of who one is (embodied capital) and what environment one is making decisions in (situational factors, which include the nature of other competitors). The integration of the embodied and situational factors is known as *relative state* (Mishra et al., 2017). The relative state of a decision-maker varies based on internally or externally determined goal states, as well as embodied characteristics or abilities; therefore, variability in relative state determines both perceived advantage and disadvantage, with resultant influence on risk-taking behavior.

Using an example similar to one given earlier, someone aspiring to be a professional guitarist can experience a competitive advantage based on high hand dexterity and high mental acuity. The dexterity and mental advantages would be a product of the guitarist's embodied capital. Situational factors would then interact with the objective measures of dexterity and intelligence. If the guitarist lived in a small town, the guitarist would likely experience little highly skilled competition. If the same individual were to attend the highly prestigious Berklee College of Music, these competitive advantages would be severely diminished in context. The competition at Berklee would be extremely skilled, and any advantages available to the guitarist through hand dexterity or mental acuity would be diminished, if not outright disappear. The individual in the example would make risky-decisions based on both embodied factors (their ability to play guitar well) as well as situational factors (i.e. being the top guitarist in a small town or being surrounded by other equally skilled guitarists).

The need-based and ability-based pathways differ on at least two key points. First, as need increases, competitively disadvantaged (i.e., need-based) decision-makers appear to place less weight on probability and expected value in their cost/benefit analysis. Risk-taking becomes the only way deprived decision-makers can possibly attain the salient need. In the earlier scenario, a guitarist at Berklee is likely to accept a low paying gig that has some chance of leading to a big showcase opportunity, even if that chance is minimal, because risky behaviour is the only way the guitarist will succeed in meeting their goals. Second, competitively advantaged (i.e., ability-based) risk-takers are taking risks because the probabilities and expected values are in their favour, making risk-seeking behaviour more profitable in the long term (Barclay & Reeve, 2012). For example, a guitarist at Berklee may take a low paying gig *because* there is a high chance the guitarist will be rewarded with a showcase afterwards. The two key differences listed above make a dual-pathway model necessary, even though the paths are complementary.

The relative state model integrates the differences and similarities of the need-based and ability-based pathways. Prior researchers studied each pathway separately and argued for distinct risk-taking phenomena. By integrating the paths, the relative state model allows explanations of overlapping variance in decision-making under risk through a single framework.

Group decision-making under risk

Most research exploring either need-based or ability-based pathways to risk-taking has focused on understanding individual-level decisions (but see Gonzales, et al., 2017). Understanding how individual-level dynamics translate into group settings is also important as groups are a recurrent structure of social life and make systematically different decisions than individuals. Shared mental models and in-group bias commonly emerge in groups and we also see changes in process, motivation, and stress (reviewed in Kerr & Tindale, 2004). These differences can lead to improved outcomes. For example, group decision-making appears to lead to more diverse opinions and allow for problem solving that is not possible at the individual level (Wanous & Youtz, 1986). Rajaram (2011) found evidence that groups are better at identifying incorrect information and rejecting incorrect information than individuals. Unfortunately, groups can also experience process losses (i.e., less than optimal performance induced from group dynamics) due to distraction and a focus on common knowledge, rather than taking advantage of multiple viewpoints (e.g., DiSalvo, Nikkel & Monroe, 1989; Stasser & Titus, 1985; Steiner, 1972). Process losses can also occur when a group is faced with limited time, potentiating inadequate decisions (Zander, 1994).

Given the differences between individual and group behavior, future research should examine whether individual-level decision-making mechanisms generalize to account for group-level decisions in risk-taking contexts. Only one study has investigated group level risk-sensitive decision-making (Gonzales et al., 2017). The authors found evidence that groups make risk-sensitive decisions similar to individuals. That is, under conditions of high need, groups elevate risk-taking. No studies have examined whether groups exhibit risk-taking behaviour based on the abilities of the group’s members, although there is evidence that group identity can lead to elevated risk-taking more generally (Wallach, Kogan & Bem, 1964).

Sports

Organized team sports offer an underutilized tool for studying decision-making behaviour in groups (reviewed in Day, Gordon & Finke, 2012; Katz, 2001; Wolfe et al., 2005). Sports teams, like other organizational teams, require individuals to sacrifice selfish ambitions to meet team superordinate objectives tied to performance outcomes (which in turn are often tied to individual-level compensation; Johns & Saks, 2013). Sports are played in heavily monitored game increments, which provide well-structured problem spaces with clearly defined goals and rules (Simon, 1973). Performance outcomes can be concretely tied to wins, and other performance metrics that are proxies to wins. Leagues measure team performance and individual level performance. Furthermore, advancements in technology such as player movement tracking (e.g., the National Basketball Association's *SportsVU*) provide multiple levels of detailed data. Most professional sports leagues maintain meticulous archives, facilitating data mining for metrics to answer specific research questions. The archives provide substantial statistical power to assess risk-taking in a highly controlled real-world decision-making context.

Football

Need-based risk-taking in football

Football is a sport where teams compete to win games. The present study uses data from the National Football League (NFL), the highest level of professional football in the United States. NFL games are won by the team that is better able to meet or exceed various in-game needs within a 60-minute timeframe. Each NFL game pits two teams against each other. One team is in possession of the ball and is trying to score points (i.e., the offense), while the other team is tasked with stopping the offense (i.e., the defense). The teams alternate between offense and defense based on the team's ability to meet context-specific goals. Defining football in relative state model terms, team goals are considered "needs". The relative state of a team is computed by the team's relative (dis)advantage to the opposing team. The following summary of the game focuses on the actions of the offense as related to the team fulfilling needs.

Teams must choose between two types of plays – low variance (*run*) plays and high variance (*pass*) plays – to satisfy in-game needs. The decisions are influenced by the skillset of the individual members of a team. Ultimately, the task of a head coach is to take advantage of their team's strengths, hide their team's weaknesses, and exploit deficiencies in the opposing team to meet superordinate needs. Therefore, part of the decision-making process of each game is to create a "game plan". The plan involves various team decision-makers mapping out the plays that could and will be used during the game with the intent of maximizing the probability of winning. The head coach typically enlists the help of an offensive coordinator to prepare the game plan, but the entire team is involved. As Billick (1997) notes, "it would be foolish to not utilize [all the coaches'] capabilities by excluding them from the creation and implementation of game plans" (p. 10).

During a game, there is typically a three-way offensive decision-making process between the head coach, offensive coordinator, and the quarterback (the leader of the players on the team's offense). Typically, the offensive coordinator chooses a play from the playbook that the coordinator thinks is most likely to meet the identified needs in a given context. The decision then goes to the head coach who has the option of switching to a play that the head coach believe has a higher chance of success, although the head coach typically trusts the offensive coordinator's preferred decision. The play is then passed along to the quarterback who is in charge of making sure the play is implemented. There are circumstances upon which the quarterback will change the play, but the quarterback is mainly tasked with ensuring the offense implements the group process that led to the coaches' decision.

The only way for an offense to satisfy in-game needs is to gain "yards", an in-game currency obtained by choosing between low risk (running) and high risk (passing) options. The offense is initially given four tries, called "downs", to reach a marker called "the first down marker" (FDM). The FDM is a minimally required reference point, a threshold referred to in the decision-making literature that a decision-maker must reach to "survive" their present conditions (Koop & Johnson, 2010, Wang & Johnson, 2012). In football, an offense must reach the FDM or surrender possession of the ball to the other team. The FDM is typically placed 10 yards away from the offense's initial position. Reaching the FDM is a concrete team goal that remains extremely salient throughout the game. Therefore, decisions to run or pass must be made with the intention to reach or surpass the FDM.

If the offense has only a few yards that need to be gained (e.g., one or two yards) the team is considered to be in a low state of FDM need. If the offense needs to gain many yards (e.g., eight or nine yards) the team is considered to be in a high state of FDM need. The need is moderated by the number of tries (i.e., "downs") an offensive team has to gain the requisite yards. On the first attempt, also known as "first down", the need to add the requisite yards is not particularly salient. When the offense has only one or two attempts remaining (i.e., the offense is on third down or fourth down) the need to gain the necessary yards becomes highly salient, intensifying the relative FDM need state.

If the offense manages to gain the requisite yards to reach the FDM within the allotted tries, the team obtains more opportunities to gain yards (i.e., the team gains a "new set of downs"). Despite having four attempts to reach the FDM, a team typically elects to call a "punt" play (a long kick) on the fourth try if the team does not gain the requisite number of yards on the third try. A team will elect to run a punt play on fourth down instead of a run or pass play because reaching the FDM is not the critical superordinate goal. Winning the game is the ultimate objective. A team attempts to satisfy in-game needs like the FDM to reach the ultimate in-game goal of having more points than the other team at the end of the game. Attaining the FDM on fourth down is not always in support of that larger team goal. The FDM is an important reference point that nonetheless competes with other relevant reference points, most importantly the team's total points scored relative to the opposing team's total points scored.

If the offense proficiently gains yards, the offense reaches an area of the field where the team has the opportunity to score points. Points are scored by "field goals" or by "touchdowns". A field goal is attained when a team kicks the football through a set of upright posts stationed at the opponent's end of the field and is worth three points. A team scores a touchdown by crossing the "end zone" threshold, an area stationed in the opponent's end of the field. The point value of a touchdown ranges from six to eight points, depending on a team's choice (and subsequent success) at either kicking an extra point "field goal" (worth one point) or successfully completing a "two-point conversion" (worth two points).

Teams score points to increase the difference between their score and the rival score. The difference is referred to as the point differential (PD). Like the FDM, PD is a minimum requirement reference point. At the end of the game, if a team has a positive PD (i.e., the team has scored more points than the opposition), the team wins. Otherwise, the team loses (or in rare cases, the game ends in a tie). There is no advantage to winning by more than a single point in the NFL. The PD is the reference point most directly tied to the team's superordinate goal of winning. Therefore, decisions to pass or run are most immediately affected by the PD reference point in need-based risk-taking.

If a team is losing by only a few points, the team is considered to be in a low need PD state. If a team is losing by a large amount of points (e.g., if the team is losing by more than 14 points) the team is considered to be in a high need state. Like the need to gain yards, the need to score points is modified by salience. Rather than being modified by the current down, point salience is mainly attributable to the amount of time left in the game. The current PD will not be especially salient at the beginning of the game. In contrast, a team losing by several points in the fourth and final quarter of the game will be especially aware of the PD.

Teams in the NFL attempt to win as many of their 16 regular season games as possible. If the team wins enough games relative to the other teams in the league, the team reaches another critical reference point: access to the playoffs. Teams in the playoffs then compete for access to the championship game. The two teams accessing the championship game compete to win a trophy awarded to the "best" team in a given year. Since only one champion can be proclaimed each year, NFL games are played under heavy constraints. The game rules are strictly enforced by referees, with all possible data tracked and stored. The heavily controlled environment of an NFL game represents a well-structured problem space where initial states, goal states, and constraints are well defined (Simon, 1973). Consequently, the game distinguishes various need levels of each team, facilitating team distance from increasingly superordinate goals and the ultimate goal of winning a championship.

Using the aforementioned structure and data, Gonzales and colleagues (2017) evidenced that NFL teams make risk-sensitive decisions in line with risk-sensitivity theory. Offenses were found to choose the riskier option (i.e., pass) more frequently if the team has a relatively large number of yards to gain. Offenses also pass with more frequency when down by a relatively large number of points. The correlations between needs and risk-taking were moderated as expected by salience: teams were more risk-sensitive when the team had fewer remaining attempts to complete various goals. The results found by Gonzales et al. (2017) demonstrated that organized groups generally understand the need to switch to risk propensity when far from attaining salient needs (i.e., to pass instead of run when far from attaining a first down and when losing in the fourth quarter of a game).

Ability-based risk-taking in football

Teams have sets of players with variable skill levels. The disparity in aggregate skill levels leads to competitive (dis)advantage among teams, which means some teams are better able to manage risk than others. For example, some teams are able to complete a higher percentage of their passes—that is, the teams experience a higher probability of success in gaining first downs and scoring points. Consequently, advantaged teams regularly experience higher expected value from passing than teams that complete a lower percentage of passes. Some teams will also gain relatively more yards on average from a pass. For example, a quarterback who averages 10 yards per pass attempt provides a competitive advantage relative to a team with a quarterback that only averages seven yards per pass attempt. The advantages of completing a high percentage of passes and passing with a high average yard rate necessarily interact. Having a quarterback who completes a high percentage of passes while also averaging many yards per attempt is extremely advantageous, while having someone who completes a low percentage and averages few yards is highly disadvantageous.

Passing is still riskier than running in all circumstances (due to passes having higher outcome variance), but some individuals (or teams) possess traits or abilities to more successfully “pull off” risk-taking. Teams with either higher completion percentages or higher average yards gained have a higher expected value from risk-taking. According to the ability-based pathway of the relative state model, such teams should exhibit higher general levels of risk-taking than their more deprived counterparts. Competitively advantaged teams are in a superior position to reap the benefits afforded to the team by choosing the riskier pass option, making the chances more likely that the advantaged team will choose that riskier option.

Hypotheses and predictions

The present study was designed to examine whether the relative state model - through the model’s dual need-based and ability-based pathways - can account for risk-taking in a football context. A statistical model accounting for both need-based and ability-based risk-taking should explain variance in decision-making under risk in the NFL given that games are bounded systems with clear inputs for need and ability.

Furthermore, the dual-pathway relative state model suggests that the interaction of need-based and ability-based risk-taking should account for incremental variance in risk-taking above and beyond a model that only includes each pathway independently.

Based on the literature review above, I make the following hypotheses. First, the present study will replicate the findings of Gonzales et al. (2017), showing that football teams engage in elevated risk-taking under conditions of high need, consistent with risk-sensitivity theory. Specifically, teams should, on average, choose the riskier option (pass) more frequently in high need scenarios when the lower risk option (run) is unlikely to meet the salient need. The switch is predicted to happen in one of two specific contexts: (1) when teams are far from attaining requisite yards; and (2) when teams are at a large point disparity. The effects of first down yard disparity and point disparity are predicted to be moderated by the salience of the goal (i.e., when teams have fewer downs left to attempt to reach a first down marker, and when games near conclusion). An interaction effect is also expected, as a team that is high in both yard and point disparity should be exceptionally prone to passing.

Second, I hypothesize that that football decision-makers will take risks consistent with the relative state model's ability-based pathway. Some football teams are competitively advantaged and would benefit from increasing risk-taking relative to others. Decision-making units (i.e., combinations of head coaches, offensive coordinators, and quarterbacks) who experience higher expected values of yards gained through passing (i.e. the higher risk option), should attempt more passes. The expectation that higher expected values lead to more risk-taking should hold for decision-making units that are competitively advantaged regardless of whether the advantage is a product of higher probabilities of success (i.e., higher passing completion rates), higher expected payoffs (i.e., higher average yards gained through passing), or a combination of both.

Finally, I hypothesize that a model including both need- and ability-based pathways will explain more variance than models that account for only one of the two-pathways. For the present examination of football decision-making, the prediction was made that accounting for both need levels and the ability to pass would significantly improve a model predicting risk-taking as measured by the currency of pass percentage. Since the need and ability pathways are related, an interaction between both pathways was predicted to improve the variance accounted for in risk-taking by the final relative state model.

Methods

NFL play-by-play data was obtained from footballoutsiders.com, one of the leading football data analysis groups on the internet. A total of nine years of regular season football data were taken from their website, which was the maximum amount of data available to the public at the time the analyses were conducted. The maximum was used to allow inferences across years and provide variability among coaches and players. The data was transferred from an Excel file into R for analyses using RStudio. All 32 teams in the league were included in the analyses. All regular season games from each season were analyzed. In total, 296,666 offensive plays were analyzed over the nine-year span.

The following measures were used from footballoutsiders.com for each offensive play analyzed: the offensive team, down (one through four), distance (in yards) to attaining a first down (denoted “yards-to-down”), quarter (one through four, plus overtime), and points-over-parity (i.e., score disparity, either positive or negative). The measures listed in the previous sentence were used to predict need-based risk-taking. Ability-based risk-taking was calculated through the average yards gained by decision-making units (i.e., the combined result of combinations of head coaches, offensive coordinators and quarterbacks) and pass completion percentages. Average yards gained and pass completion percentage were calculated across a team's entire year because the individual quarterbacks were not accounted for in the play-by-play dataset for run plays. The average yards gained and passing percentages included sack plays where the intention was to pass, and interceptions, which were coded as zero passing yards.

Footballoutsider.com's measure of a team's passing ability, called *Pass Defense-adjusted Yards Above Replacement* (Pass DVOA), was also included as DVOA has been construed in popular media as a predictive measure of a team's passing ability (Kelly, 2016). Instead of only relying on summary statistics (e.g. total yards), DVOA accounts situational variables ("Methods To Our Madness", n.d.). Based on the work of Palmer, Carroll and Thorn (1989), DVOA assigns each play outcome a value based on total yards gained as well as yards gained towards a first down. Plays are considered successes if the play gains a certain percentage of yards needed on a given down. For first down, 45 percent of the needed yards have to be gained in order for the play to be considered successful. On second down, 60 percent of the needed yards have to be gained for success. On third and fourth down, gaining a new first down is the only way for the play to be considered a success. Essentially, the fewer opportunities left to gain a first down, the higher percentage of first down yardage a team must gain to receive a successful DVOA score.

Fractional points are awarded if the team attains some number of yards (e.g., seven yards on a third down with a ten-yard need is still worth some fractional amount of "success points"). Additional value is given to excess yards gained, and teams are also penalized for negative plays (e.g., turnovers and penalties). Plays that occur in the "red zone" (i.e. the twenty yards closest to the opponents end zone) also receive additional value points and plays that result in a touchdown are also highly valued. The calculated number value is then compared to the average success values of teams that have occurred in similar situations and adjusted for "distance, field location, time remaining in game, and the team's lead or deficit in the game score" ("Methods To Our Madness", n.d.). The measure is also adjusted for the strength of the opposing defense and normalized so that the average is zero. Teams that are better than average have positive percentile scores while teams that are worse than average have negative scores. Since the DVOA statistic accounts for the defense and situational success, DVOA was expected to account for variability above and beyond what passing percentage and yards per attempt would account for.

DVOA has been used frequently in popular media to delineate how well teams are performing (e.g. Barnwell, 2014; Kacsmar, 2017; Kelly, 2016), but DVOA has not been a measure used in studying decision-making in any previous empirical studies to date. Therefore, the validity and reliability of the measure are not well understood. The present study will, in addition to testing the hypotheses provided earlier, provide a first test of whether team quality, as defined by DVOA, predicts risk-taking behaviour.

The actual categorical pass (coded as one) or run (coded as zero) decision that concluded each offensive play was measured. The pass-run variable was the dependent measure of risk-taking for both risk-taking pathways. The head coaches and offensive coordinators for each team were found on pro-football-reference.com and used to control for collective decision-makers' preferences for risk.

In total, eight multilevel models were built. The initial model accounted for baseline variability in risk-taking among all decision-making units (model A). Four models accounted for need-based risk-taking: the first accounted for the need to gain first downs (model B), the second accounted for the need to gain more points than the opposing team (model C), the third accounted for both first down and points over parity (model D), and the fourth accounted for first down, points over parity, and the interaction between both needs (model E). Another multilevel model was built to account for the risk-taking ability of decision-making units (model F). The final two multilevel models were built to account for the need-based pathway and the ability-based pathways together (G), as well as both pathways plus the interaction between the two pathways (model H). The models are summarized in Table 1 below.

Table 1

Summary of Multilevel Models in the Present Study

Multilevel model letter	Multilevel model description
A	Baseline model including team preference for risk based on the head coach and the offensive coordinator
B	Need-based model accounting for the need to gain first downs
C	Need-based model accounting for both the need to outscore the opponent
D	Need-based model accounting for both the need to gain first downs and the need to outscore the opponent
E	Need-based model accounting for both the need to gain first downs and the need to outscore the opponent plus the interaction between the two needs
F	Ability-based model
G	Model that includes all need and ability-based variables
H	Model that includes all need and ability-based variables plus the interaction between all variables

Results

General tests of variance

Independent-samples Kolmogorov-Smirnov were conducted within each NFL season and across all seasons to verify that passing the ball is higher variance (riskier) than running the ball. As predicted, passing the ball resulted in significantly higher variance in yards gained than running the ball in all years, but Mann Whitney U tests did not indicate significant differences between run and pass averages in all years. While the average yards gained collapsed across all years significantly differed, the specific averages in 2007, 2008, 2009, and 2012 did not. The significance of the differences in average yards gained between runs and passes is not accurately reflected in the means (the smallest pass mean across years is 5.77, while the largest run mean is 4.48, suggesting all pass means were significantly different from all run means every year). The medians reflected the significance of the differences between pass and run averages more accurately than the means (i.e. the run and pass means only differed in years where the means were significantly different in the Mann-Whitney-U tests) but not in all years (the medians were not numerically different integers in in 2010, 2013, or across all years analyzed, even though the Mann-Whitney-U test revealed medians to be significantly different in each case). The difference between the mean and median numbers suggests that the yardage data for passing and running is not symmetrical. Table 2 provides a summary of the above data.

Table 2

Summary of the Variance of Passing and Running

Year	Pass SD	Run SD	Difference Between Run and Pass Variances (K-S Independence)	Pass Mean	Run Mean	Run Median	Pass Median	Difference Between Run and Pass Averages (Mann-Whitney-U)
All years	10.02	6.37	p < .001*	6.00	4.36	3	3	p < .001*
2005	9.76	6.14	p < .001*	5.77	4.18	3	2	p = .0038*
2006	9.99	6.21	p < .001*	5.88	4.33	3	2	p < .001*
2007	9.62	6.12	p < .001*	5.94	4.23	3	3	p = .066
2008	10.02	6.45	p < .001*	6.07	4.39	3	3	p = .82
2009	10.46	6.70	p < .001*	6.03	4.44	3	3	p = .19
2010	10.09	6.44	p < .001*	6.03	4.39	3	3	p = .030*
2011	10.38	6.46	p < .001*	6.17	4.48	3	2	p = .0074*
2012	9.99	6.57	p < .001*	6.08	4.46	3	3	p = .22
2013	10.19	6.35	p < .001*	6.02	4.37	3	3	p = .033*

Note. *p < .05.

In short, passing was a riskier option than running when collapsed across all years. Passing was also riskier than running in every individual year, but the magnitude of the differences between running and passing varied from year to year.

Variability in baseline propensity for risk among decision-makers

The first multilevel model (A) was built to account for variability between risk-taking preferences among decision making units. In other words, a statistical model was built to determine if teams differed in their baseline propensities for risk based on the head coaches and offensive coordinators that worked for the team. The decision to pass or run was the dependent variable.

Model A was also used to determine if multilevel modelling was even necessary for the analyses of the present study. If model A accounted for meaningful variance, the results would indicate teams exhibited different preferences for risk based on their head coaches and offensive coordinators, and multilevel modelling would be necessary. If model A did not account for variance (i.e. teams did not differ in their preference for risk based on coaching combinations), logistic regressions would be more appropriate to use for all future analyses.

The necessity of multilevel modelling was assessed using chi-square log-likelihood ratio tests. Two values are produced by a chi-square log-likelihood ratio test: the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The AIC is a goodness-of-fit measure that corrects for model complexity, accounting for parameter estimates. The BIC is comparable to the AIC, but corrects more harshly for the number of parameter estimates, making BIC slightly more conservative (Field, Miles

& Field, 2012). Parameters were estimated using the maximum likelihood method to be able to compare each additional model.

Each model in the present study was built by adding in fixed and random coefficients as appropriate. Models were compared by subtracting the log-likelihood of the newer model from the older model. Smaller values of the goodness-of-fit test indicate a better fitting model, and the effects are represented by the changes between models as indicated by the log-likelihood ratio.

In model A, teams, coaches and offensive coordinators were nested as random hierarchical variables for each play to reflect the general hierarchy of team decision-making. Quarterbacks were not included in the hierarchy because quarterbacks were not recorded on plays where the team decided not to take the risk of passing (i.e. when a team ran the ball). There were 32 teams, 90 head coaches, and 97 offensive coordinators in the dataset. There was a total of 102 combination of teams and head coaches, and 160 combinations of team, head coaches and offensive coordinators.

For the model A chi-square tests, both the AIC and BIC reported similar values. Due to the number of parameters and the large sample size of the present study, only the BIC was reported to assess whether the fit improved with each added predictive variable. The changes in model fit for the nested random variables are summarized in Table 3.

Table 3

Multilevel Model Accounting for Variability in Team Risk-Propensity Based on Their Decision-Making Group

Model	BIC	Log-Likelihood Ratio	Significance
Intercept only	423,078.3		
Random intercept: Teams	422,395.4	$\chi^2(1) = 695.49$	$p < .001$*
Nested random intercept: Coaches within Teams	421,809.1	$\chi^2(1) = 598.94$	$p < .001$*
Nested random intercept: Offensive Coordinators within Coaches within Teams (model A)	421,588.6	$\chi^2(1) = 233.08$	$p < .001$*

Note. *$p < .05$.

Allowing the intercept to vary based on teams, SD = 0.013; 95% CI: 0.005, 0.033, coaches, SD = 0.026; 95% CI: 0.017, 0.039, and offensive coordinators SD = 0.031; 95% CI: 0.025, 0.039, increased the fit of model A, decreasing the BIC on each successive addition. In other words, teams, coaches, and offensive coordinators differed in their baseline preferences for risk. Model A was used as the baseline to which the need-based pathway (models B through E), ability-based pathway (model F), and the non-independent dual pathways (model G and H) models were compared.

Need-based analyses

Yards-to-go analyses. To assess risky decision-making with yards-to-go as the salient need, a multilevel model (B) was built based on the previous baseline model (A) that included the nested random variables of team, head coach, and offensive coordinator. Yards-to-go, down, and the interaction between yards-to-go and down were added as additional predictor variables to complete model B. The decision to pass or run was the dependent measure. The BIC and log-likelihood ratio changes are summarized in Table 4. Parameters were again estimated using the maximum likelihood method in order to be able to compare models.

Yards-to-go, $b = 0.020$; $t(296{,}503) = 28.23$; $p < .001$, and down, $b = 0.15$; $t(296{,}503) = 53.29$; $p < .001$, were both significant predictors of risk-taking. As the number of yards-to-go increased, so too did the decision-maker's likelihood of passing. The same held true for down: as down increased, so too did risk-taking behaviour.

Table 4

Multilevel Model Accounting for the Effect of Yards-to-go as a Need on Risk-taking

Model	BIC	Log-Likelihood Ratio	Significance
Model A	421,588.6		
Model A + Yards-To-Go	419,122.0	$\chi^2(1) = 2,479.23$	$p < .001$*
Model A + Yards-To-Go + Down	399,081.5	$\chi^2(1) = 20,053.01$	$p < .001$*
Model A + Yards-To-Go + Down + Interaction between Yards-To Go and Down (model B)	399,080.6	$\chi^2(1) = 13.56$	$p < .001$*

Note. *$p < .05$.

The interaction between yards-to-go and down was also a significant predictor of risk-taking, $b = 0.001$; $t(296{,}503) = 3.68$; $p < .001$. The interaction was further separated using multilevel models on each down separately. The models separated by down were specified with the same parameters as the final yards-to-go model but excluded the main effect and interaction term involving down. The values of each model are summarized in Table 5 and visualized in Figure 1. The interaction effect appears to reflect differences in the intercept for all downs, while also affecting the slope, most notably on fourth down. In other words, as the number of opportunities to reach the first down marker decreased, decision-makers were more likely to engage in risk-taking based on their yard disparity.

To summarize, the effect of yards-to-go on risk-taking increased as the number of available attempts to gain a first down decreases. Teams are more likely to take on risk the further the team is from a first down. The effect of yards-to-go is especially strong on fourth down, when a team has no further attempts left before turning the ball over.

Table 5

Multilevel Models Accounting for the Effect of Yards-to-go on Risk-taking Separated by down

Down	Intercept	b	t	p
1	0.29	0.020	t(129,619) = 30.35	p < .001*
2	0.38	0.024	t(98,665) = 65.80	p < .001*
3	0.64	0.019	t(63,503) = 60.53	p < .001*
4	0.42	0.046	t(4,236) = 32.12	p < .001*

Note. *p < .05.

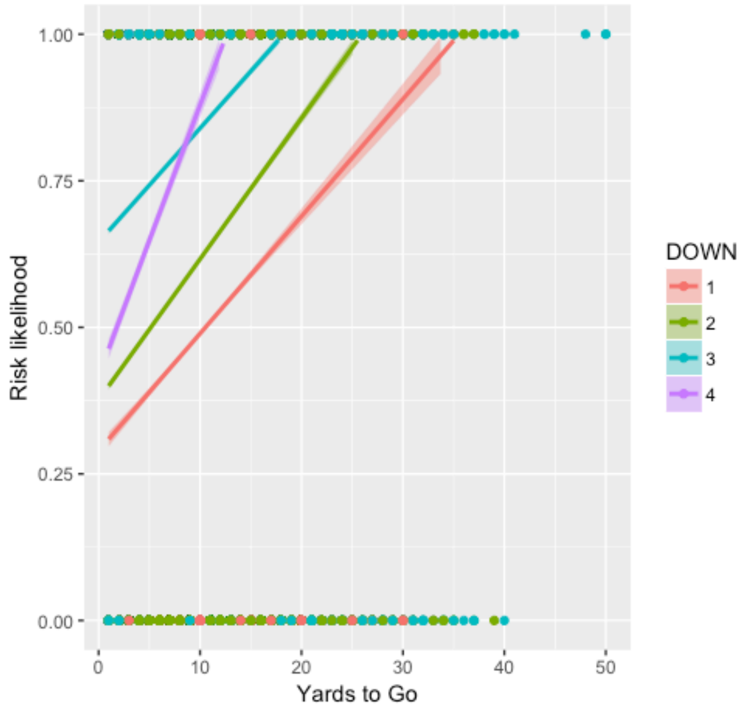

Figure 1. The effect of yards-to-go on risk-taking based on down. The likelihood of risk increases as the number of yards-to-go increases across all downs, but is especially prominent on fourth down.

Points over parity analyses. A multilevel model (C) was built based on the baseline model (A) that included the nested random variables of team, head coach, and offensive coordinator to assess need-based risk-taking with points over parity as the salient need. Points over parity, quarter, and the interaction between points over parity and quarter were added as additional predictor variables to complete model C. The decision to pass or run was the dependent measure. The BIC and log-likelihood ratio changes are summarized in Table 6. Points over parity, $b = 0.007$; $t(296{,}503) = 22.31$; $p < .001$, and quarter, $b = 0.003$; $t(296{,}503) = 4.29$; $p < .001$, were both significant predictors of risk-taking. The more points a team was losing by, the less likely the team was to take on risk. Teams were also less likely to take on risk as the quarters increased (i.e. as the game ends).

Table 6

Multilevel Model Accounting for the Effect of Points Over Parity as a Need on Risk-taking

Model	BIC	Log-Likelihood Ratio	Significance
Model A	421,588.6		
Model A + Points over parity	413,075.9	$\chi^2(1) = 8{,}525.34$	$p < .001$*
Model A + Points over parity + Quarter	412,950.7	$\chi^2(1) = 137.73$	$p < .001$*
Model A + Points over parity + Quarter + Interaction of Points over parity and Quarter (Model C)	410,499.4	$\chi^2(1) = 2{,}463.90$	$p < .001$*

*$p < .05$.

The interaction between yards-to-go and down was a significant predictor but in the opposite direction, *b* = -0.005; *t*(296,503) = -49.74; $p < .001$. To better understand the interaction, multilevel models were built for each separate quarter. The models separated by quarter were specified with the same parameters as the points over parity model but excluded the main effect and interaction term involving quarter. The values of each model are summarized in Table 7 and visualized in Figure 2. The interaction effect reflects differences in both the intercept and slope. In other words, the quarter affected the risk-taking behaviour of decision-makers by changing baseline propensities for risk as well as the likelihood the team would change their mind based on the number of points the team was either leading or losing the game by. Decision-making units were especially prone to increase their risk taking in the fourth quarter, both at baseline and if the team was further from winning the game. The effect of point disparity disappeared in the fifth quarter (i.e. overtime) due to changes in need conditions (i.e. overtime is only played if both teams are tied at the end of the fourth quarter and different rules ascertain whether the leading team wins the game). At any given instance in overtime, teams are either tied or winning by only a small amount (three points).

To summarize, the effect of points to parity on risk-taking increases as the game ends. Teams are more likely to take on risk as the team is losing by more points. The effect of points to parity is especially strong in the fourth quarter, when the game is nearly complete. The effect no longer remained in the fifth quarter (i.e. overtime) because teams only go into overtime if the game is tied at the end of the fourth quarter. Therefore, the conditions necessary to study need-based risk-taking do not exist in overtime.

Table 7

Multilevel model accounting for the effect of points over parity on risk-taking separated by quarter

Quarter	Intercept	b	t	p
1	0.53	-0.002	t(67,771) = -4.18	p < .001*
2	0.61	-0.003	t(79,094) = -15.52	p < .001*
3	0.57	-0.004	t(68,852) = -28.09	p < .001*
4	0.42	-0.01	t(78,399) = -105.23	p < .001*
5	0.53	0.02	t(1,797) = 1.16	p = .24

Note. *p < .05.

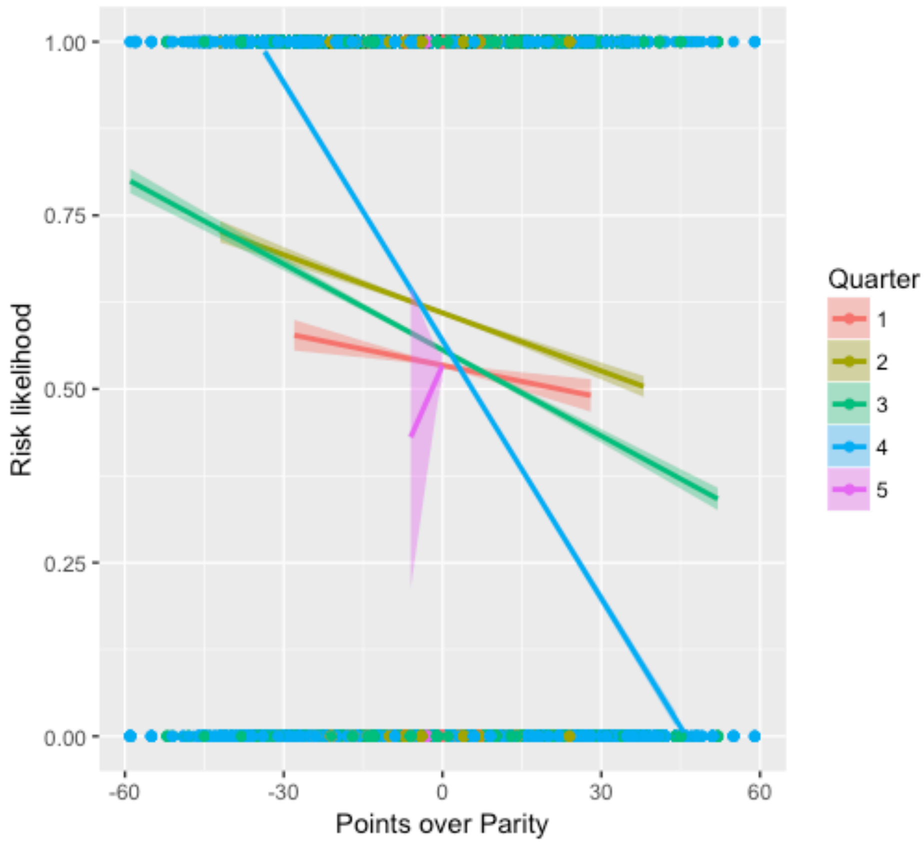

Figure 2. The effect of points over parity on risk-taking based on quarter. Decision makers take on more risk as the team loses by more points. The effect of points over parity is most prominent in the fourth quarter when the game is closest to finishing and disappears in overtime (quarter 5) when the parameters of winning change.

Analyses of combined need-based risk-taking. A multilevel model (D) accounting for both the need to gain yards and the need to gain points was created using the yards (B) and points (C) models created in the previous two sections. Yards-to-go, down, the interaction between yards-to-go and down, points over parity, quarter, the interaction between points over parity and quarter were all predictor variables. The decision to pass or run was the dependent measure.

Model D explained more variance then model B, $\chi^2(3) = 11{,}612.14$; $p < .001$, and model C, $\chi^2(3) = 23{,}030.97$; $p < .001$, did separately. The change between model C and D was larger than the change between model B and D, as indicated by the log-likelihood ratio. The interaction between all need variables was then added as a predictor to all the predictors in model D to create the final need-based pathway model (model E). The interaction in model E created a better fitting model than D, $\chi^2(1) = 137.73$; $p < .001$.

Effectively, using a model that accounted for both needs explained more variance than only accounting for either need. Yards-to-go as a need appeared to have a larger effect, as the change between model C to D was larger than the change between model B to E, as represented by the log-likelihood ratio. Furthermore, including the interaction between all need predictors explains unique variance in risk-taking. The effect of quarter on risk-taking no longer remained significant in the final need model E ($p = 0.95$), but every other variable, including the interaction between all need variables, remained significant predictors of risk-taking. The model changes are summarized in Table 8. The parameters of the final need model are outlined in Table 9.

Table 8

Multilevel Model Accounting for the Effect of Including Both Needs and the Interaction Between All Need Variables in a Multilevel Model

Model	BIC	Log-Likelihood Ratio	p	Model	BIC	Log-Likelihood Ratio	p
Yards-to-go model (B)	399,080.6			Points-over-parity model (C)	410,499.4		
Both needs (D)	387,506.3	$\chi^2(3) = 11{,}612.14$	p < .001	Both needs (D)	387,506.3	$\chi^2(3) = 23{,}030.97$	p < .001
Both needs + interaction (E)	412,950.7	$\chi^2(1) = 137.73$	p < .001				

Note. *p < .05.

Table 9

The Effect of Every Need Parameter and Their Interactions in Model E

	b	t	p
Intercept	0.10	t(296,499) = 11.45	p < .001*
Yards-to-go	0.02	t(296,499) = 27.80	p < .001*
Down	0.15	t(296,499) = 53.78	p < .001*
Points over parity	0.007	t(296,499) = 24.20	p < .001*
Quarter	0.00005	t(296,499) = 0.06	p = 0.95
Yards and Down Interaction	0.002	t(296,499) = 5.40	p < .001*
Points and Quarter Interaction	-0.005	t(296,499) = -56.14	p < .001*
All need variable interaction	0.00005	t(296,499) = 21.19	*p* < .001*

Note. *p < .05.

Ability-based analyses

To assess risky decision-making based on ability, a multilevel model (F) was built based on the previous baseline model (A) that included the nested random variables of team, head coach, and offensive coordinator. Passing yard means, pass completion percentages, and passing DVOA were added as predictors to model A to account for ability-based risk-taking. The decision to pass or run was the dependent variable. The BIC and log-likelihood ratio changes are summarized in Table 10 and the parameters of model E, calculated through the maximum likelihood method, are outlined in Table 11.

Yards per attempt was not a significant predictor by itself ($p = .22$), but became significant, $b = -0.08$, $p < .001$ once completion percentage, $b = -0.08$, $p < .01$ and the interaction with completion percentage, $b = 0.10$, $p < .001$, were included. Passing DVOA was not a significant predictor ($p < .53$). Neither was the interaction with the aforementioned yards per attempt or completion percentage ($p < .91$). Therefore, the DVOA measure was left out of further analyses.

To conclude, decision-makers are more likely to take on risk if the team is more skilled at risk-taking (i.e. the team completes a higher percentage of passes, attains higher yards per pass attempt, or does both) but not all measures thought to describe risk-taking ability were found to be significant predictors. Simple measures of payoff (yards per pass attempt) and probability (passing completion percentage) accounted for unique variance. DVOA, a complex measure that adjusted for situational variables such as opponent quality and position on the football field, did not improve the model fit.

Table 10

Multilevel Model Accounting for the Effects of Ability on Need

Model	BIC	Log-Likelihood Ratio	Significance
Model A	421,588.6		
Model A + Yards per attempt	421,599.7	$\chi^2(1) = 1.51$	$p = 0.22$
Model A + Yards per attempt + completion percentage	421,587.7	$\chi^2(1) = 24.55$	$p < .001$*
Model A + Yards per attempt + completion percentage + interaction (model F)	421,213.1	$\chi^2(1) = 387.25$	$p < .001$*
Model F + passing DVOA**	421,223.9	$\chi^2(1) = 1.76$	$p = 0.19$
Model F + passing DVOA + interaction	421,236.5	$\chi^2(1) = 1.77$	$p = 0.41$

Notes. *p < .05. ** passing DVOA and the interaction with passing DVOA were excluded from further analyses.

Table 11

The Effect of Ability-Based Parameters in Model F

	b	t	p
Intercept	0.76	t(296,503) = 41.01	p < .001*
Yards per Passing Attempt	-0.08	t(296,503) = -19.75	p < .001*
Passing Completion Percentage	-0.08	t(296,503) = -2.46	p = .014*
Yards and Completion Interaction	0.10	t(296,503) = 19.70	p < .001*

Note. *p < .05.

Relative state model analyses accounting for dual pathways

A relative state model (G) was built using both risk pathway models (i.e. models E and F). An interaction between the variables in each separate model were added to create the final relative state model (H). The BIC and log-likelihood ratio changes are noted in Table 12 and the parameters of the final relative state model, calculated through the maximum likelihood method, are outlined in Table 13.

Including both the need variables and the ability variables in a single model (model G) increased the variance explained, although the change in variance explained was larger from model E, $\chi^2(1) = 34{,}721.26$, $p < .001$, than from model D, $\chi^2(1) = 527.83$, $p < .001$. Adding an interaction between all variables (model F) increased the variance explained, $b = -0.000003$, $p = .05$) ($\chi^2(1) = 3.85$, $p = .05$). Quarter ($p = 0.72$) was the only variable that did not significantly predict risk-taking by itself.

In summary, risk-taking was best accounted for when including predictors of need, ability and the interaction between need and ability. The difference in variance accounted for appeared to be larger for predictors of need more than for predictors of ability. The results are consistent with the hypotheses of the relative state model.

Table 12

Multilevel Model Accounting for the Effect of Using Both Pathways Concurrently and the Interaction Between the Pathways

Model	BIC	Log-Likelihood Ratio	p	Model	BIC	Log-Likelihood Ratio	p
Model D (need-based)	387,070			Model E (ability-based)	421,213.1		
Model D + Model E (dual pathway model F1)	386,580	$\chi^2(3)$ = 527.83	p < .001*	Model E + Model D (dual pathway model F1)	386,580	$\chi^2(3)$ = 34,721.26	p < .001*
Model F1 + interaction (Model F)	386,588.8	$\chi^2(1)$ = 3.85	p = 0.050*				

Note. *p < .05

Table 13

The Effect of All Parameters for the Relative State Model including Interactions

	b	t	p
Intercept	0.08	t(296,495) = 4.26	p < .001*
Yards-to-go	0.02	t(296,495) = 27.69	p < .001*
Down	0.15	t(296,495) = 53.70	p < .001*
Points over parity	0.007	t(296,495) = 24.02	p < .001*
Quarter	0.0003	t(296,495) = 0.35	p = 0.72
Yards and Down Interaction	0.002	t(296,495) = 5.65	p < .001*
Points and Quarter Interaction	-0.005	t(296,495) = -56.19	p < .001*
All need variable interaction	0.00006	t(296,495) = 11.36	p < .001*
Yards per Passing Attempt	-0.05	t(296,495) = -13.92	p < .001*
Passing Completion Percentage	0.13	t(296,495) = 4.22	p < .001*
Yards and Completion Interaction	0.08	t(296,495) = 16.45	p < .001*
Interaction between all variables	-0.000003	t(296,495) = -1.96	p = 0.050*

*p < .05

Discussion

The results of the present study demonstrate that groups systematically make decisions sensitive to risk. Independent decision-making units (i.e. the specific combinations of head coaches and offensive coordinators within a team) were shown to have different baseline propensities for risk-taking, suggesting teams have different risk "personalities" – that is, teams have stable individual differences in risk-propensity. Additionally, risk-taking was altered by the needs and abilities of the groups. The present findings provide empirical support for the central predictions of the relative state model (Barclay et al., 2018; Mishra et al., 2017).

The need-based pathway, which has roots in risk-sensitivity theory, states that a decision maker should choose a higher risk option in a high need scenario if an alternative lower risk option is unlikely or unable to meet the salient need threshold (Mishra & Lalumière, 2010). The decision-maker's threshold for risk should increase as need increases. In the present study, group risk-taking was assessed regarding two needs: the need to gain first downs and the need to score more points than their opponent. The decision-making units modified their behaviour to better meet the salient need. The further a team was from attaining a first down, the more likely the team was to take on risk (i.e. pass the ball instead of run). The same applied to point disparity – teams losing by more points would also take more risks. The effect of need increased as need salience increased: the yards-to-go measure accounted for more variability as the number of attempts a team had to attain a first down decreased, and point disparity accounted for more variability as the game came to a close, leaving the team with less opportunities to overcome their deficit. The interaction between all variables was also significant, meaning the needs were not independent of each other.

The relative state model also posits that decision-makers will increase exposure to risk if the decision-maker has an advantage over the competition (Barclay et al., 2018; Mishra et al., 2017). Competitive advantage can come in the form of an increased payoff for successful risk-taking, an increased probability of successfully taking on risk, or both. Increased payoffs for success and increased probabilities of success lead to a higher mean expected outcome for the risky option, making risk a viable long-term option for the decision-maker, as the decision-maker is likely to see increased benefits over an extended period. In the present football study, a team was at a competitive advantage for risk-taking if the team gained more yards-per-pass attempt (increased payoff) or completed passes at a higher completion rate (increased probability). The analysis indicated that teams would increase their risk-taking if the team benefited from a higher mean expected value, whether that was through increased yards-per-pass, a higher pass completion rate, or a combination of the two.

The results of the present study are consistent with both relative state model pathways, in that both need and ability accounted for variance in risk-taking (Barclay et al., 2018; Mishra et al., 2017). Furthermore, the fit of the model was better when both pathways were included versus only including one of the two. The need-based pathway appeared to account for a larger portion of variance in risk-taking than the ability-based pathway in a direct model comparison, but the model that included both pathways accounted for the most variance overall. The interaction between both pathway models was also significant, indicating that the two pathways operate non-independently. Nonindependence of the pathways is fundamental to the relative state model; according to the theory, a decision-maker with a competitive advantage should face fewer high need scenarios because the advantaged decision-maker is better able to leverage their advantage to enjoy superior outcomes (Barclay et al., 2018; Mishra et al., 2017). In the present study, competitively advantaged teams that completed passes at a higher rate and/or with a higher average yards-gained engaged in more risk-taking (i.e. passed more frequently) and should have therefore faced fewer large deficits in yards-to-go and point disparity since the team would have gained more yards in general.

Conditions for generalizability

Behavioural studies are conducted to better understand explain and predict behavior. Research typically involves examination of behavior under constrained conditions, and so results necessarily cannot be generalized broadly. The following section outlines the specific generalizability of the present results.

Clear goals. The need-based pathway investigated in the present study is based on risk-sensitivity theory. Risk-sensitivity assumes there are clear need or goal states to be fulfilled, and that the decision-maker understands the mean expected outcomes of each option, whether intuitively or explicitly. If competitive (dis)advantage is unclear (i.e. if needs, payoffs, and/or probabilities are not accurately perceived by the decision-maker) the relative state model may not best account for behavior. The need-based pathway would not account for variability because high-need states only occur if there is a pressing salient need, but high need states would never be present in an ambiguous setting. Similarly, if a decision-maker is unsure of their competitive advantage, the decision-maker may not be in a position to appropriately leverage the advantage. Ability-based explanations of risk-taking are only relevant in scenarios where there is meaningful variability among decision-makers' abilities. Risk-taking behavior arising from situations and experimental designs where actors all have the same abilities, or the perception of the same abilities, are likely not well-accounted for by the ability-based pathway of the relative state model.

Competition and cooperation. The relative state model is fundamentally about competition. Competition must involve two or more competitors. Football is a head-to-head game that matches a team directly against an adversary. That is, there is the minimum number of adversaries needed for competition, and no more. Therefore, results cannot necessarily be generalized to conditions where more than two decision-makers are competing.

There are many situations where decision-makers can improve their own lives and/or the lives of those around them through cooperation (e.g. Barclay, 2013). In cooperative circumstances, a known short-term loss over a potential risk with high immediate rewards may be more profitable for multiple parties in the long run. Cooperation is not an option for NFL teams, as winning an NFL game necessarily has to come at the expense of the other team in the game. Therefore, the results of the present study cannot be generalized to conditions where cooperation is an option. The exact relationship between competitors (e.g., can multiple people attain their goals through cooperation?) should be explicitly stated in future studies in order to have a better understanding of how the relative state model translates across competitive scenario types.

Model comparisons

In the present study, we compared various patterns of risk-taking behaviour based on the dual-pathway predictions of the relative state model. Other theories of decision-making may also account for patterns of risk-taking behavior. Future studies could compare the relative state model to models based on expected utility theory (Friedman & Savage, 1948) and/or prospect theory (a variation on expected utility theory; Tversky & Kahneman, 1981). Expected utility theory and prospect theory focus on maximizing *utility*, where utility is a general currency that describes some measure of happiness, gratification or satisfaction from behaviour. Expected utility theory and prospect theory are vague with interpretations of utility, making any objective specification of utility complex (Mishra, 2014). If utility can be appropriately operationally defined, models of prospect theory and expected utility could be built for comparison to the relative state model. For example, one could compare the football relative state model from the present study to a prospect theory model that explicitly encodes various football reference points.

Model comparisons might not be useful in all cases. Models that have differences in mechanism but not function are unlikely to be serviceably compared. For instance, there may be no need to distinguish between the results of prospect theory and need-based risk (Houston et al., 2014). The results of a direct comparison between prospect theory and the need-based pathway within a football study would likely yield very similar results, as the needs of a risk-sensitive model and the utility reference points of prospect theory would likely be the same. Prospect theory and the relative state mode only differ on the mechanics of decision-making under risk (the relative state model assumes heuristic-based decision-making, whereas prospect theory relies on the explicit utility calculations of expected utility theory. Comparing models would allow a researcher to observe how ability-based risk-taking interacts with need or reference point models, as ability-based theories serve a different function than theories of risky decision-making that deal exclusively with reference point or need-based risk taking.

Naturalistic setting

Broadly speaking, psychological studies are either experimental or naturalistic. The present study was conducted in a naturalistic setting and is the first investigation to use real-world decision-making to conjunctively study the relative state model's dual pathways. The primary advantage of using data from an extant environment was the fact that the conditions and stakes were non-artificial. Winning football games matters immensely to teams – their entire business is built around the ambition to win games. Nominal amounts of money or additional credit for an undergraduate class are unlikely to have the same influence on behaviour as the rewards provided to the winners of NFL games. In a football context, the individuals involved (including coaches and players), were unlikely to be tempering their risk-taking in-game in order to satisfy a goal that is external to the football game itself. Their income, prestige, and job security are directly affected by their ability to be successful in-game risk-takers. Players who take risks that are detrimental to winning games are punished by their coaches, the team's fans, and the media. Coaches who are perceived to be to be overly risk-prone (or risk-averse) are in danger of getting fired. Because of the high stakes involved, the decision data is not subject to any demand characteristics or extraneous influence outside of the decision context.

Using the archival sports data provided through the National Football League allowed the observation and study of both relative state model pathways in a manner that would be difficult to duplicate in an experimental setting, and potentially impossible in many other naturalistic settings outside of professional sports. Lab-based studies of group decision-making require multiple participants to be present at a single time and, if an individual drops out of a study, the data of the entire group can become invalid. Further, the hierarchy and dynamics of formal groups created by a researcher may not be the same as groups formed more naturally in the real world, such as in a football setting. As always, generalizability and internal validity necessarily trade-off. The data used for the present study was correlational, and so causality cannot be inferred, but future experimental studies would be able to shed light on causal directionality.

Sample size

Small sample size can be a common issue in psychological research, and increasing attention has been paid to concerns of statistical power (Kraemer & Blasey, 2015). The present study does not suffer from limitations of small sample size; a total of nine years of data, including 296,666 offensive plays, was collected and used to analyze decision-making under risk in the present study. Importantly, analyses were split into smaller subsets (i.e. down and quarter), and so the large sample size of plays limits concerns of accurate statistical inference.

Despite the large sample size of risky decisions in the present study, the number of decision-making units examined was necessarily limited. There are only 32 teams in the NFL, requiring caution in making strong between-team inferences from the data. The data was split into specific decision-making units made up of the combination between team, head coaches, and offensive coordinators. In total, there were 160 different decision-making group “units”. Future studies analyzing group level statistics in the NFL should be conservative with their interpretations, as the primary advantages of large play totals afforded by sports leagues reside at the individual play level. For example, the BIC statistic was reported in the present study instead of the AIC in the goodness-of-fit tests for each multilevel model because BIC corrects more severely for the number of parameters. The results at the group level remain important, but the results should not be overstated given the large data sets.

A large sample size of data also makes statistically significant differences more likely, even for small absolute differences with small effect sizes. The difference between effect significance and size was especially important to be aware of in the present study since multilevel model statistics can be difficult to interpret. In the present study, several effect sizes were small but statistically meaningful. The study provides evidence for the predictive utility of the relative state model, but expectations regarding the size of the effects should remain tempered. Further research is needed, but in a competitive setting such as football, even small differences can present competitive advantages with potentially large consequences.

Multilevel modelling

Most statistical models used by psychological researchers assume the data points are independent and homogeneous. Multilevel methodology makes no such assumptions and are built for dependencies between data points within groups. A common example of a scenario where researchers would find multilevel modelling useful is within school settings. Because multilevel modelling allows for related hierarchical data, the results experienced by a single student can be put in the context of who their teacher was. The results of the student can then be contextualized to which classroom a student was in, what school a student went to, all the way up to which school district or even country a student resided in.

NFL data follows a similar structure to the classroom example. Offensive plays are conducted by a team. As an analogy, the offensive coordinator is the “teacher”, the head coach is the “principal” and the team is the “school”. The results of an individual play are controlled for the higher level grouping the result is found in. Each team is trained by a specific coach using a certain offensive coordinator. Therefore, data points are related by specific decision-making units. In the same way that a teacher would affect their students, head coach Bill Belichick affects the New England Patriot team and the team’s on-field decisions. In the present study, the use of multilevel modelling allowed us to control the results of play-by-play data for the variability found among decision-makers (i.e. a team coached by a head coach aided by an offensive coordinator). Using the multilevel model structure demonstrated that risk-taking in a football setting is affected by group dependencies. Dependencies were then controlled for in the baseline multilevel model. Such controls are not possible with such common analyses as linear regression. Hence, using a multilevel model was necessary for the present study.

Measure complexity

The dichotomized dependent measure of risk-taking examined in the present study was simple: passing is simply a higher variance behavior than running. The simplicity of the measure has several virtues. First, the outcome variable could only be one of two results: a risky option or a safer option. Second, the means and variances of both options were easily quantified using conventional statistical measures. Simple measures of need and ability were easy to compute. Needs were based around common football markers and ability was easily computed using risk completion and the payoff of successfully taking on risk (i.e. pass completion percentage and average yards per completion). The simplicity of the measures does not reflect the complexity of many real-life decision-making scenarios, but the results offer an initial basis from which more complex measures can be modeled.

Computing differences in variance, ability, and need can be substantially more difficult in other situations that involve decision-making under risk, even in similar sports settings. For example, in the sport of basketball three-point shots are commonly referred to as riskier than two-point shots, but the operationalization of risk in basketball is not as simple or intuitive as the operationalization of risk in football. There are two possible outcomes for a basketball shot: a make or a miss. The potential results of a two-point shot do not differ no matter where a player shoots the basketball from in the two-point area. Outcome variance does not actually differ; a two-point shot is always worth two points if completed successfully, and is always worth zero if unsuccessful. Contrast the outcome variance of basketball plays to the outcome variance of football plays, where outcome variance in yards attained can technically range from any number of yards between negative 99 to positive 99. Examining the utility of the relative state model in predicting risky decisions in other sports (let alone in other situations) requires careful operationalization of all parameters key to the model (e.g., probability of success/failure, expected value of success/failure).

Model building gets even more complex and difficult to attain when data points are not readily available or collected at every decision point, as is the case with most organizational decisions. For example, risky decisions made within organizations are not always documented or made available to the public as the decisions are in professional sports leagues. Parameters constraining decision-makers and what currencies decision-makers are prioritizing can be unclear. A company for example, might publicly state that their goal is long-term growth, but their actions might reveal a stronger concern with short-term profit. Incongruencies highlight the importance of building models that center on actual behavioral outcomes. Researchers wishing to use naturalistic studies to examine the relative state model in particular need to carefully consider how variables of interest are operationalized (i.e. measures of need and ability, as well as the relative risk of each option).

DVOA

For the most part, the measures used in the present study were simple quantifications. Yards gained, yards-to-go, down, points over parity, quarter, passing percentage, yards-per-pass attempt cannot be broken down into simpler forms. One of the variables used examined in the context of ability-based risk-taking, passing DVOA, was much more complex. The DVOA variable did not prove to be a significant predictor of risk-taking behaviour. Passing DVOA is a composite measure that adjusts for variables such as down, distance, time remaining, field position, score disparity, and opposing defense. The measure rewards teams for performing well in situations that either lead to more scoring opportunities or for actually scoring the football. DVOA is a measure commonly referred to in popular media outlets as a predictor of team quality

(Kelly, 2016) and teams having a relative advantage in DVOA scores were expected to take more risks given DVOA's high perceived value in the sports community.

Despite DVOA's reputation, the results did not show DVOA to be a predictor of actual in-game behaviour. The non-significant finding could mean (a) teams do not understand their relative (dis)advantage, (b) teams do not value what DVOA measures in their in-game decision-making processes, or (c) the measure itself is not predictive of behaviour. The likelihood that teams do not understand relative (dis)advantage is low; the results of the present study show that teams make choices effectively predicted by need and ability consistent with the relative state model. There is a possibility that teams do not account for DVOA in their in-game decision-making processes, as time is limited and the calculations for DVOA are complex calculations that involves the consideration of several variables. The hypothesis that teams do not account for DVOA based on a preference for simplicity is consistent with the bounded nature of real-world decision-making (Gigerenzer & Todd, 1999).

The most parsimonious explanation is that the DVOA statistic is simply not useful for predicting football behavior. DVOA is a commonly used statistic in popular sports media, but has not yet been validated through any scientifically rigorous process. Despite the popularity of DVOA, the results of the present study suggest DVOA should not be used as a predictor of in-game football decision-making. Future research should examine whether other complex measures of ability predict risk-taking behaviour, although bounded rationality suggests more simple measures would be preferred as heuristics over more complex measures in constrained situations (Gigerenzer & Todd, 1999).

Group decision-making

The present study demonstrated that teams exhibit different baseline propensities for risk. What are potential mechanisms that might give rise to team differences? Team differences in risk-propensity may be a product of stable differences in "risky personality" (Mishra & Lalumière, 2011). Such traits as high impulsivity, high sensation-seeking, and low self-control have been associated with higher levels of behavioral risk-taking at the individual level. The individual members of teams likely systematically differed on such stable traits, although differences were not systematically assessed. Group composition clearly affected each team's overall risk-propensity (i.e., propensity to pass over run), but further research is necessary to understand how stable traits among individuals might give rise to group "personalities". More generally, additional research is necessary to understand if individuals show patterns of risk-taking consistent with the relative state model. Prior to the present examination, no empirical study has investigated whether the predictions of the relative state model can account for patterns of risk-taking. The present study is the first to provide evidence in support of the relative state model for *any* human risk-taking behaviour, and further empirical tests are necessary, as summarized below.

Future experimental tests of the relative state model

Future research could examine the interaction of ability-based and need-based risk-taking in experimental designs. According to the relative state model, highly skilled decision-makers who are in a high need situation should be particularly likely to engage in elevated risk-taking. Inversely, decision-makers who have little to no ability and have no pressing need should exhibit the least amount of risk-taking behaviour. High ability decision-makers who are in low need scenarios and low skilled decision-makers in high need scenarios should exhibit moderate risk-taking compared to the two aforementioned decision-making groups. The results of the present study imply that the need-based pathway accounts for more variance than the ability-based pathway. Therefore, there is a possibility that unskilled decision-maker in a high need situation would exhibit more risk-taking behaviour than a highly skilled decision-maker in a low need situation. The predictions are summarized in Table 14.

This set of predictions is consistent with the relative state model predictions outlined by Barclay and colleagues (2018) and offer some direction for future experimental research. For example, the ECO study by Mishra and Lalumière (2010) could be modified to include ability-based risk-taking. In the study, participants were trained to forage from a virtual set of trees that had differing variances and means in yield. Participants were then put in either a low or high need situation, conditions where the participant could either attain their required yield by choosing a low variance tree, or only attain the required yield by choosing the high variance tree. The experimental design was implemented to study need-based risk-taking only. To include ability-based risk taking to study the relative state model, additional parameters would need to be added where participants find themselves either (a) successfully foraging the high variance option at a high rate of success (reflective competitive advantage) or (b) foraging the high variance option with a low rate of success (reflecting competitive disadvantage). Creating successful versus unsuccessful risk-taking group conditions could be done by manipulating the percentage of successful attempts or the yield of successful attempts (although the results of the present study suggest the interaction

Table 14

Predicted results for studies of the relative state model

	High need	Low need
High ability	High risk taking	Medium risk taking
Low ability	Medium risk taking	Low risk taking

between the yield amount and percentage would provide the best measure of ability-based risk-taking). Modifying the procedure developed by Mishra and Lalumière (2010), we would expect that decision-makers who successfully forage with greater returns would take on more risks than decision-makers who do not. Decision-makers with a low ability but who need to forage the high variance tree in order to survive would be expected to take risks at a higher rate than decision-makers who are high in ability but do not need to forage from the high variance tree in order to survive.

The two by two experimental design outlined above could be applied to other studies of decision-making under risk. For example, a future study of stock market choices (similar to Xie et al., 2009) could be modified with the two by two design outlined above. The study could examine ability-based risk-taking based on decision-makers' abilities to choose stocks with a high return, both in terms of the proportion of successful stocks chosen and their average relative return. The need-based pathway of the relative state model could be examined by observing the need levels of decision-makers in terms of how much the decision-maker needs to maintain investments or to overcome debts that have been incurred. The study could also include an interaction effect, looking at the interaction between the ability to choose good stocks and the need to maintain or attain a certain monetary level. A study designed in the above manner would reflect higher contemporary ecological validity than a study of foraging behaviour.

Another area of promising future research is the examination of stable individual differences that may influence risk-taking of different kinds. In the present study, decision-makers exhibited variability in their baseline preferences for risk-taking. The mechanisms of how these preferences were formed (or how they manifest in proximate psychological mechanisms) remains an open question. Future studies should be conducted to better understand the proximate underpinnings of risk preference as related to the relative state model. Future investigations should also explore whether different group structures affect group preference for risk-taking and determine how the risk-preferences of the group's individual members affects the risk-taking behaviour of the group as a whole.

Wins were not an outcome examined in the present study. Future research would benefit from examining whether more need-sensitive or ability-sensitive teams are better able to convert risky decisions into wins. Both pathways are based on the rationale that the decision-makers will gain relatively better positioning by engaging in risk-taking. Are individuals and groups that adhere to the relative state model more likely to increase their chances of attaining resources that increase relative status and further their goals? For example, do teams that better understand the threshold for passing in increasingly high need scenarios win more games? The results of the present study, and the relative state model theory in general, suggest that teams that have a better understanding of their ability to take risks and teams who have a better understanding of when to take on risk are more likely to succeed.

Implications

Examining risk-taking in teams is important because teams and decisions under risk are ubiquitous in organized settings. How a group decides to deal with risk can have major impacts on the group's success at achieving group goals. The same holds true whether the group is a football team, a special military taskforce, a newly formed venture capitalist group, or simply a group formed to complete a classroom project. The results of the present study could help stakeholders better predict when groups will exhibit risky behaviour based on the group's relative state. Predictions could be made by contextualizing need states and determining a group's current ability to take on risk.

Decision-makers who are able to accurately assess patterns of risk-taking are better positioned to advantageously adapt their behaviour based on contextual cues. The ability to adapt could mark the difference between meeting needs and failing to survive. In a football context, accurately understanding patterns of risky behaviour may result in team leaders being better able to influence in-game behaviours, and therefore game outcomes. Coaches who understand when and how other teams take risks have a competitive advantage over opponents who do not understand risk-taking behaviour. If a coaching staff understands the relative state of the competition, the coaching staff can adjust the team strategy to minimize the expected value of the opponent. Many coaches already strategically change their behaviour based on what the coach believes the other team will do, but a more data-driven approach informed by the relative state model may improve the capacity of coaches to use knowledge of opponent tendencies. Better yet, an understanding of the relative state model may also allow coaches to understand the effects of the team's strategy and consider changes in strategy to yield higher gains from plays. For example, a highly skilled risk-taking team that is not taking enough risks based on the expected value of risk-taking can elevate the team's risk profile and reap the resultant benefits, likely winning more games. Strategic change based on the relative state model could have broad implications for sports and gaming strategies as a whole. Individuals and groups who are able to assess need-based and ability-based risk-taking tendencies of themselves and their opponents may have a unique competitive advantage that further increases the expected value of the decision-makers choices.

In more general organizational settings, company leaders could use risk-assessments to better organize and influence the risky behaviours exhibited by the company's employees. Strategic decision-makers could also assess the relative state of the leader's company as compared to competing companies, and adjust the strategy of their company to better reflect the situational (dis)advantages. If used correctly, a better understanding of risk-taking through the relative state model could lead to an increased probability of experiencing desired group outcomes.

Conclusion

The relative state model has only recently been posited to explain risk-taking behaviour. Before the present study, the framework had never been used before to study group decision-making in humans. The present study offers evidence of both need and ability-based factors affecting risk-taking and produces results of risk-taking behaviour in a group setting. The present study helps clarify misunderstandings about the apparent conflict between two theoretical frameworks. Risk-sensitivity assumes strategic flexibility is necessary in all individuals whereas ability-based risk-taking assumes preference regardless of context. The relative state model posits both as viable pathways. As George E.P. Box (1987) once said, "all models are wrong, but some are useful" (p. 424). The present study results indicate that the relative state model could be useful in predicting need and ability based risk-taking, and offers specific conditions under which decision-makers should consider risky behaviour through each pathway, creating harmony in perceived dichotomy.

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