Supporting preventative medicine decisions: An extended dual processing model that incorporates a cultural worldviews perspective

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Abstract

This thesis extends the dual processing model for decision threshold analysis to include the influence of an individual's risk perception as informed by their cultural worldviews. The Extended Dual Processing Model (DPM+) integrates cultural worldviews and risk perception into decision threshold analysis by way of an individual's 'type I system' reasoning. DPM+ offers a prescriptive explanation of how people of differing cultural worldviews may have different decision thresholds. DPM+ is contextualized for decision-making relative to preventative medicine. This thesis makes three important contributions: first, it presents a comprehensive scoping review of decision thresholds in medical decision making. Second, it theoretically extends the dual processing model to include risk perception as informed by a cultural worldviews dimension, forming the DPM+. Finally, the thesis demonstrates a proof-of-concept analysis of the practical application of DPM+, which demonstrates how DPM+ can prescriptively explain heterogeneity in decision thresholds according to cultural worldview.

Chapter 1: Introduction and Problem Statement & Objectives

Chapter Summary

In this chapter we introduce the concept of decision thresholds and preventative medicine. Within this chapter we establish following general objectives for this thesis: 1) to identify the various non-expected utility theories that are used in decision threshold analysis, 2) to theorize an extended dual progressing model (DPM+) for decision thresholds in medical decision-making that incorporates perceived risk as informed by cultural worldview, and 3) to provide a proof of concept of DPM+ that demonstrates how DPM+ can prescriptively explain heterogeneity in decision thresholds according to cultural worldview.

Introduction

People are often faced with decisions that have uncertain outcomes as they relate to taking preventative action with respect to their overall health and wellbeing. For example, people often face the question(s): should they wear a facemask inside a public place? Should they become vaccinated/ vaccinate their children against known illnesses? Should they engage in safe sex practices (e.g., use condoms)? Should they proactively engage in cancer screening? And the list goes on. Interestingly, people frequently make different decisions (e.g., they decide to become, or not become, vaccinated; they choose to participate, or not participate, in cancer screening; they wash, or do not wash, their hands; they wear, or do not wear, a facemask in a public place; they engage, or do not engage, in safe sex practices, etc.). Generally, it is believed that these differing decisions can be attributed to individual differences in subjective judgements that result in different decision thresholds (B. Djulbegovic et al., 2012a). Understanding how individuals determine their decision thresholds may have the potential to reduce variation within medical decision-making by understanding the cognitive mechanisms that inform people's decisions (Cheyne et al., 2012; B. Djulbegovic et al., 1999a). Such variation may be explained by individual differences in assessments about the benefits and harms of particular decisions, or subjective risk-assessment judgements (Cheyne et al., 2012; B. Djulbegovic, van den Ende, et al., 2015b). This research seeks to explain, prescriptively, how heterogeneity in decision thresholds can be explained according to an individual's cultural worldview when making preventative medicine decisions[1].

[1] "Preventative medicine includes all measures which limit progression of disease at any stage of its course. A distinction is usually made between 'primary prevention', in which measures are applied to prevent the occurrence of a disease, and 'secondary prevention', where a disease or its

A decision threshold dichotomizes a decision into taking, or not taking, an action depending on how chances of action's outcome are positioned in reference to a decision threshold. Illustratively, a decision threshold, "is like a line in the sand, when the assessed level of risk in a particular case crosses the threshold the decision maker will take action" (Cheyne et al., 2012, pp. 2–3). Importantly, the, "development of [the] threshold model is considered as one of the most important advances in medical decision-making" (B. Djulbegovic, Hozo, Mayrhofer, Ende, et al., 2019, p. 186). Specifically, the threshold model of decision-making (the threshold model) stipulates that an individual should act when the perceived benefits of acting outweigh the consequences of not acting (B. Djulbegovic et al., 1999a; B. Djulbegovic, Hamm, et al., 2015a; Pauker & Kassirer, 1980, 1975b)[2]. The notion of a decision threshold would be familiar to those acquainted with a courtroom setting, where phrases such as "beyond a reasonable doubt" (i.e., typical of a criminal proceeding) or "preponderance of evidence" (i.e., typical of a civil setting) articulate different cut-offs (probabilities) for how compelling the evidence ought to be to warrant action (Brand & Finkel, 2019; Dekay, 1996; Weiss, 2003b, 2003a). A decision threshold is typically quantified as a continuous numerical value between 0 and 1. Effectively, a decision threshold embodies a, "judgment regarding the desired balance between false positives and false negatives (e.g., convicting the innocent and letting the guilty go free, respectively)"(Weiss, 2003a, p. 29). In simple language, a decision threshold is reflective of a particular point of indifference where an individual is indifferent to taking action or not taking action (B. Djulbegovic, van den Ende, et al., 2015b). Effectively, practice variation in medicine can, in part, be attributed to individual differences in subjective judgements that result in different decision thresholds (B. Djulbegovic et al., 2012a). To this end, it is believed that improving our understanding of decision thresholds has the potential to reduce the variation within medical decision-making by understanding the cognitive mechanisms that inform people's decisions (B. Djulbegovic et al., 1999a).

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complications are halted or averted at any point after the onset of disease. Primary prevention comprises the manipulation of man's environment, his water supply, the air he breathes, and also the manipulation of man himself by such measures such as immunization against infection disease. Secondary prevention includes therapy to prevent the spread of disease to non-affected individuals, identification of those in the early stages of a disease process when treatment should be most effective, and lastly the prevention or delay of the consequences of clinically advanced disease by both therapy and rehabilitation" (Clarke, 1974, p. 65).

[2] The threshold model of decision-making is different than the threshold hypothesis (Slovic et al., 1977). Under the threshold hypothesis, it is postulated that when the probability of loss is below a certain threshold that people will treat those probabilities as if they were zero (Slovic et al., 1977).

Recent research has demonstrated that decision thresholds have an important role in consumer decisions. For example, Robinson and Botzen (2018) evidence that an individual's decision threshold is a significant predictor of an individual's intention to purchase flood insurance. Decision thresholds have also been demonstrated to be consistent with patient values and preferences within the clinical context (B. Djulbegovic et al., 2016). For example, Djulbegovic and colleagues (2016) demonstrated that for end-of-life care decisions (i.e., deciding between palliative/ hospice care and life-prolonging treatment), when the affective system (i.e., 'type I system' reasoning) dominates the deliberative system (i.e., 'type II system' reasoning), that patients decisions are consistent with the course of action that is determined by the decision threshold (i.e., as informed by the patient's weighing of the anticipated regret of acts of omission versus commission) (B. Djulbegovic et al., 2016). This is consistent with the theory of the dual processing model for decision thresholds when 'type II system' reasoning is dominated by the 'type I system' reasoning thinking (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a).

The cognitive science literature increasingly accepts that, "medical decisions can be truly consistent with patient's values and preferences only if they take into account both affect-based (type 1) and analytical (type 2) cognitive processing" (B. Djulbegovic et al., 2016, p. 28). To estimate individuals' implicit decision thresholds, we leverage the dual processing model (DPM) of decision threshold analysis for medical decision-making (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a). The DPM for decision thresholds incorporates 'type I system' reasoning (i.e., affectively driven, fast, intuitive) with 'type II system' reasoning (i.e., analytical, calculative, deliberative) to establish an individual's implicit decision threshold (B. Djulbegovic et al., 2012a; Kahneman, 2011; Tsalatsanis et al., 2015a). Within the DPM for decision thresholds, people are perceived to employ 'type I system' reasoning and 'type II system' reasoning (i.e., to varying degrees), which subsequently informs an individual's decision threshold (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a). The DPM for decision thresholds also recognizes the affective influence that anticipated regret has on people's decisions and intentions (Zeelenberg, 1999; Zeelenberg et al., 1996; Zeelenberg & Pieters, 2007) and incorporates anticipated regret (i.e., as a facet of 'type I system' reasoning) through a ratio of anticipated regrets of benefits and harms (i.e., anticipated regret of forgoing beneficial treatment vs anticipated regret of experiencing an adverse event from treatment) (B. Djulbegovic et al., 2012a, 2018; Tsalatsanis et al., 2015a). Importantly, anticipated regret has been found to have an impact on a wide range of behaviors, including health behaviours (Brewer et al., 2016), and is generally perceived that, "people tend to avoid decisions that they anticipate might subsequently lead to regret" (Nordgren et al., 2007, p. 535; Zeelenberg et al., 1996).

There is limited research on how people use decision thresholds to inform their decisions relative to preventative medicine decisions. Unlike end-of-life decisions that are affect dominated and may be predisposed to convergent decisions as a result of protected values (i.e., values for human and animal life, human rights, etc. that people think of as absolute and are not to be traded off for anything else (Ritov & Baron, 1999)), preventative medicine decisions are more divergent and are subject to a combination of 'type I system' reasoning and 'type II system' reasoning. For example, for preventative medicine decisions, such as whether or not to offer a young woman the HPV vaccine (Kahan, Braman, Cohen, et al., 2010; Ziarnowski et al., 2009), the literature shows that, "higher anticipated inaction regret was associated with higher vaccination intentions" (Ziarnowski et al., 2009, p. 413) (i.e., inaction regret is equivalent to greater perceived treatment benefit). Consequently, the literature translates anticipated regrets into decision thresholds as informed by the ratio of anticipated regret of net benefits relative to the anticipated regret of harms. For example, relative to the HPV vaccine those with higher anticipated regret of net benefits relative to their anticipated regret of net harms have lower decision thresholds. Simultaneously, there is a considerable body of scientific evidence available that evaluates the efficacy and safety of the HPV vaccine (Lu et al., 2011), which subsequently inform an individual's 'type II system' reasoning. Importantly, we do not observe a random distribution of vaccine intentions across the population (Kahan, Braman, Cohen, et al., 2010). If vaccine intentions were randomly distributed across the population, we would have no reason to suspect that underlying mechanisms were informing individual's decision-making; instead, we observe similar phenotypes/ groups of people making similar decisions as it pertains to the HPV vaccine. Instead, the literature evidences that cultural cognition theory and cultural worldviews, "seem to generate divergent perception of the risk and benefits of the HPV vaccine" (Kahan, Braman, Cohen, et al., 2010, p. 514) and may subsequently explain why individuals of different cultural worldviews make different preventative medicine decisions as it pertains to the HPV vaccine.

Cultural cognition theory postulates that, "people analyze and evaluate risk with respect to how they are valued culturally, including how they fit into our conception of an 'ideal society'" (Yang, 2016, p. 1080). Cultural worldview moderates the affective appraisal of the perceived benefits and consequences through assigning social meanings and/or group values to objects, states of affairs or actions (Kahan et al., 2006; Kahan, Jamieson, et al., 2017). Specifically, cultural values are seen to shape an individuals' perception of the consequences associated with their decision (Kahan et al., 2006). For example, it has been demonstrated that, "disagreements about the risks and benefits of the HPV vaccine are shaped by cultural values" (Kahan, Braman, Cohen, et al., 2010, p. 512). In the same study, individuals who were more hierarchical reported greater perceived risk and lesser perceived risk as they became more egalitarian (Kahan, Braman, Cohen, et al., 2010).

Relative to DPM for decision thresholds, Djulbegovic and colleagues (2016) call for additional research to evaluate if, "cultural background, religion, race, and ethnicity affect regret" (B. Djulbegovic et al., 2016, p. 35). The authors postulate that these factors will not have an effect because, "regret is a unique human emotion, which appears to be easily understood by people of all races and background" (B. Djulbegovic et al., 2016, p. 35). Within the DPM for decision thresholds, an individual's 'type I system' reasoning is believed to be insensitive to probabilities and, consequently, "every outcome with nonzero probability gets equal weight in this system" (Mukherjee, 2010, p. 245). This doctoral research challenges this assumption and extends the dual processing model of medical decision-making and decision threshold analysis by incorporating risk perception as informed by an individual's cultural worldview. To incorporate risk perception as informed by cultural worldview into decision threshold analysis, we propose the extended dual processing model for decision thresholds (DPM+).

Problem Statement and Objectives

The literature on decision threshold analysis recognizes that the DPM for decision thresholds within medical decision-making is the dominant explanation of how physicians make decisions (Tsalatsanis et al., 2015a) because it incorporates both 'type I system' reasoning and 'type II system'. Despite the importance of decision-threshold analysis (Hozo et al., 2018a), there has been limited research (B. Djulbegovic, van den Ende, et al., 2015b) that explores the employment of the

DPM for decision thresholds at a patient/ individual level, and there is a void of research on how the DPM for decision thresholds can be applied to preventative medicine decisions.

The current version of the DPM for decision thresholds does not explain how the estimation of decision thresholds might systematically differ between individuals. For example, the DPM for decision thresholds does not adequately explain why we see phenotypes of people (e.g., those who are vaccinate hesitant/ resistant) making the same preventative medicine decision (i.e., to remain unvaccinated). The authors of the DPM for decision thresholds postulate that because, "regret is a unique human emotion, which appears to be easily understood by people of all races and background" (B. Djulbegovic et al., 2016, p. 35) that cultural background and other demographic factors are unlikely to affect an individual's decision threshold. In this research we challenge this assertion by drawing on the cultural cognition theory and the body of literature that demonstrates that individuals of different cultural worldview have different perceived risks of the harms and benefits associated with particular decisions (Kahan et al., 2006). Moreover, Dekay and colleagues (2002) articulate that, "different stakeholders can have very different values, beliefs, and preferred decision-alternatives" (Dekay et al., 2002, p. 403), and consequently, decision-makers may have different decision-thresholds because they have different estimates of the perceived risk associated with the benefit and cost of avoiding/ engaging in an activity (Dekay et al., 2002).

This research contributes to the academic scholarship within decision-analysis and decision support relative to the DPM for decision thresholds in preventive medicine decisions. The research proposes an extension to the DPM of decision-threshold analysis to prescriptively explain how individuals of different cultural worldview arrive at different decision thresholds for preventative medicine decisions. Specifically, we posit that the influence of cultural worldview and risk perception ought to be included within the 'type I system' reasoning as people of different cultural worldviews are expected to have different perceived risks and, consequently, do not weigh possible outcomes equally. Because the proposed extension of the DPM has the potential to contribute to future development of decision-support tools for patients, physicians and/or health policy makers, the proposed research leverages a methodology and method that are consistent with those in the information systems discipline. This thesis is organized around three primary contributions, including: a scoping review, a theoretical extension of the DPM for decision thresholds (DPM+), and a proof of concept evaluation showing that DPM+ explains decision threshold heterogeneity for preventative medicine decisions:

1. Scoping Review (Chapter 4)

The scoping review focuses on how decision thresholds have been previously conceptualized relative to medical/ health related decisions. It addresses the following primary research objective:

> **Scoping Review Objective 1A**: to identify and categorize what theories have been developed to inform or estimate decision threshold(s) within medical decision-making.

In addition to the objective listed above, we explore the following secondary objective:

> **Scoping Review Objective 1B**: to identify what consideration(s) an individual's contextual (e.g., age, gender, specialities, years of practice) and subjective factors (e.g., attitudes, emotions, preferences, risk perceptions, values) have been given relative to decision thresholds within the medical decision-making literature.

2. Theoretical Extension of the Dual Processing Model (DPM+) for Decision Thresholds (Chapter 5)

This research theorized an extended Dual Processing Model (DPM+) for decision thresholds with particular focus on preventative medicine decisions. This theoretical contribution proposes a prescriptive model that identifies how an individual's cultural worldview informs the perceived risks of the anticipated benefits and harms associated with a particular decision. A differential in the weighing of the perceived benefits and costs of a decision, will ultimately change ratio of benefits relative to harms within the 'type I system' reasoning of the DPM+ and will affect the decision threshold. The consideration of cultural worldview helps explain why individuals of similar worldview tend to make similar decisions as it relates to preventative medicine. DPM+ makes the following proposition to revise the original DPM model for decision thresholds:

> Proposition 1: We challenge the assertion that lay-individuals weigh outcomes equally within their 'type I system' reasoning and contend that the inequal weighing of outcomes, informed by an individual's risk perception as influenced by their cultural worldview, can

prescriptively describe why different phenotypical groups of people make different decisions.

3. DPM+ Proof of Concept Evaluation (Chapter 6)

This research provides a proof of concept evaluation of the DPM+ by drawing data from the literature and demonstrating how an individual's cultural worldview informs an individual's decision threshold. Consequently, patients of different cultural worldviews have different implicit decision thresholds by virtue of different weighing of anticipated regrets of perceived benefits and harms. We conduct this evaluation through a Monte Carlo simulation model that estimates decision-thresholds. The Monte Carlo simulation model parameters were informed by secondary data sources that connected cultural worldview to perceived benefits and perceived costs.

Chapter 2: Background Literature

Chapter Summary

This chapter provides a brief overview and synopsis of the relevant literatures that inform this dissertation. The following concepts will briefly be discussed: regret theory, decision-thresholds, risk perception and cultural cognition theory. These concepts are relevant to the DPM of decision threshold analysis, as well as the proposed DPM+. The concept of decision thresholds is expanded in greater detail in Chapter 4.

Theoretical Background: Regret Theory

Under the traditional approach to decision-making, decisions are expected to be driven by expected utility theory (Von Neumann & Morgenstern, 1947) where a 'rational' decision is one that maximizes the expected utility of the final assets (Bell, 1982; Loomes & Sugden, 1982). However, a considerable body of literature has recognized that people do not always make decisions in a manner that is consistent with maximizing expected utility (e.g., when considering monetary gambles) (Bell, 1982; Loomes & Sugden, 1982). When making decisions under uncertainty, the literature has observed that people/ decision-makers often violate the axioms of expected utility theory to avoid the potential of experiencing decision regret once the relevant outcomes of the uncertain decision are learnt (Bell, 1982). This paradox led to the development of regret theory in the early 1980s (Bell, 1982, 1983, 1985; Loomes & Sugden, 1982; Sugden, 1985).

Bell (1982) and Loomes and Sugden (1982) are commonly cited as the pioneers of regret theory. Regret theory is presented by both Bell (1982) and Loomes and Sugden (1982) as an alternative explanation to prospect theory (Kahneman & Tversky, 1979). In their proposal of regret theory, Loomes and Sugden (1982) position that regret theory, relative to prospect theory, is a simpler way to explain decision-making under uncertainty. Regret theory assumes that for any given decision, and for every individual, there is a choiceless utility function, which allows people to compare the decisions of what occurred versus what could have occurred had a different decision been made (Loomes & Sugden, 1982). In the event that a different decision would have resulted in a better outcome, the individual may experience regret in their decision (Loomes & Sugden, 1982). Specifically, regret can be measured as, "the difference between the utility of the action taken and the utility of the action that in retrospect should have been taken" (Hozo et al., 2018a, p. 68).

Alternatively, if their decision resulted in a better outcome than the outcome associated with the alternative decisions, the individual would rejoice knowing they had taken the best decision (Loomes & Sugden, 1982). Loomes and Sugden (1982) argue that individuals are regret adverse and, "will accept small-stake large-prize fair gambles ($p<0.5$) but reject large-stake small-prize fair gambles ($p>0.5$)" (Loomes & Sugden, 1982, p. 814). They highlight that this type of behaviour is emblematic of purchasing insurance, which, "typically involves paying a small premium to avoid a small probability of a large loss" (Loomes & Sugden, 1982, p. 814). Consequently, Loomes and Sugden (1982), similar to Bell (1982), also propose a modified utility function to incorporate the affective responses of regret and rejoicing (Loomes & Sugden, 1982). Regret theory is based on two assumptions: 1) that people experience the emotions of regret and rejoicing, and 2) people try and anticipate these emotions when making decisions under uncertainty (Loomes & Sugden, 1982).

Specifically, regret is a cognitively based emotion that refers to the affective reaction of unfavourable outcomes, alternatively rejoicing/ elation refers to the reaction to felicitous outcomes (Landman, 1987b; Zeelenberg & Pieters, 2004). Unlike other emotions, "regret is uniquely tied to the making of decisions: no decisions, no regret" (Zeelenberg & Pieters, 2007, p. 17). Regret can be experienced in two ways: 1) regret can be experienced, ex-post, once the outcomes of a decision have become known (e.g., "I wish I had made a different decision given the outcome"), and 2) regret can be anticipated, ex-ante, before the decision is made and is a reflection of how a person anticipates feeling if an undesirable outcome were to occur (e.g., "If I make this decision then there is the possibility that this undesirable event occurs) (Zeelenberg, 1999; Zeelenberg et al., 1996). Within medical decision-making most decisions cannot be reversed (e.g., surgery cannot be undone, a vaccine cannot be ungiven) and consequently decision-making is informed by anticipatory (ex-ante) regret (B. Djulbegovic et al., 2014a). Within the field of medical decision-making, there is interest in how anticipated regret informs our decisions and intentions (Brewer et al., 2016).

Since the inception of regret theory, scholars have sought to improve their understanding of how regret informs decision-making (Connolly et al., 1997; Nordgren et al., 2007; Ritov & Baron, 1990; Weinstein et al., 2007; Zeelenberg, 1999; Zeelenberg et al., 1996). Regret is often identified as a driver of 'irrational' decision-making given its' tendency to influence people to make decisions that are inconsistent with expected utility theory (Sugden, 1985). Other scholars maintain that because anticipated regret causes people to think more elaborately before making their decision, that regret can also induce rational decision-making (Zeelenberg, 1999). Universal to the regret literature is the recognition that, "regret is not only an affective reaction to bad decision outcomes or processes, but also that it is a powerful force in motivating and giving direction to behavior" (Zeelenberg & Pieters, 2007, p. 3). Given the importance of understanding regret, regret research can be found in many different domains, including: economics, psychology, medicine, law, organizational behaviour, and other related disciplines (Zeelenberg & Pieters, 2007).

Theoretical Background: Decision Threshold Models

Decision thresholds are dynamic and subject to change based on an individual's subjective judgements and values (Dekay et al., 2002); representing the point at which an individual is indifferent to taking action or not taking action (Dekay et al., 2002; B. Djulbegovic et al., 2012a; B. Djulbegovic, van den Ende, et al., 2015b). Decision thresholds have been demonstrated to underpin decision-making (B. Djulbegovic et al., 2014a). Although highly relevant to decisions, little research is dedicated to decision thresholds within the decision-making literature (Felder & Mayrhofer, 2018a). Where there is research on decision thresholds, most of the focus is on: 1) medical decision-making (B. Djulbegovic et al., 1999a, 2012a, 2014a; B. Djulbegovic, van den Ende, et al., 2015b; Tsalatsanis et al., 2015a), 2) consumer behaviour within the insurance industry (Botzen et al., 2015; P. J. Robinson & Botzen, 2018, 2019, 2020), and 3) precautionary policy and legal contexts (Dekay, 1996; DeKay, 2009; Dekay et al., 2002, 2009).

We focus our research on decision thresholds relative to individual decision-making within the context of preventative medicine decisions and the medical decision-making literature. The decision threshold approach to decision making was first used in medical decision-making by leveraging the axioms of expected utility theory (Pauker & Kassirer, 1980, 1975b). As the field developed, and it was observed that people are frequently violating the axioms of expected utility theory (Bell, 1982; Kahneman & Tversky, 1979; Loomes & Sugden, 1982; Tversky & Kahneman, 1974), other decision threshold models (e.g., regret based models, acceptable regret models, hybrid models, dual processing models (B. Djulbegovic, van den Ende, et al., 2015b)) have been conceptualized to substitute the expected utility approach of threshold-model decision-making within a medical decision-making context.

Decision thresholds underpin medical decision-making, and have, "practical implications for the practice of medicine and medical education" (B. Djulbegovic et al., 2014a, p. 7). In fact, it is postulated that practice variation in medicine and subsequently health care expenditure can be attributed to differential decision thresholds (Cassel & Guest, 2012; B. Djulbegovic et al., 2014a). Moreover, the, "development of [the] threshold model is considered as one of the most important advances in medical decision-making" (B. Djulbegovic, Hozo, Mayrhofer, Ende, et al., 2019, p. 186). Across the medical decision-making literature, there are three general models that have been widely used to determine decision thresholds: 1) expected utility models, 2) regret based models, and 3) dual processing models (B. Djulbegovic, van den Ende, et al., 2015b). We provide a summary of each of these decision-threshold models below.

Expected Utility Models

Pauker and Kassirer (1975) are commonly credited as one of the first to introduce the decision-threshold approach as a decision-making tool for therapeutic decision-making in the face of diagnostic uncertainty. Pauker and Kassirer (1975) focus their attention on physicians who are commonly faced with situations where confirmatory diagnostic studies are unavailable (or impractical) and the physician is faced with a decision of whether or not to administer a certain drug or carry out a certain procedure on a patient (Pauker & Kassirer, 1975b). Pauker and Kassirer (1975) use expected utility theory to calculate the expected value of the benefits and costs of treatment in a given disease and contrast the estimated probability of disease against the calculated threshold level. Using the utility estimates of each possible outcome, Pauker & Kassier (1975) estimate the threshold in the following way:

$$Threshold = \frac{1}{1 + \frac{U(TP) - U(FN)}{U(TN) - U(FP)}} = \frac{1}{1 + \frac{Benefits}{Costs}}$$

Equation adapted from: (Pauker & Kassirer, 1975b)

Accordingly, the threshold-model of decision-making (i.e., the above equation) works in the following way: if the estimated probability of disease is greater than the threshold (i.e., P(disease) > Threshold) then treatment should be given/ applied (Pauker & Kassirer, 1975b). Alternatively, if the estimated probability of disease is less than the threshold (i.e., P(disease) < Threshold) then treatment should be withheld (Pauker & Kassirer, 1975b). When the probability of disease is equal to the threshold, it is interpreted as an indifference to treatment and withholding treatment (Pauker & Kassirer, 1975b).

The above threshold equation is comprised of the following elements: U(TP) is the utility of a true positive outcome, U(FN) is the utility of a false negative outcome, U(TN) is the utility of a true negative outcome, and U(FP) is the utility of a false positive outcome. For both true positive and true negative outcomes, these outcomes are consistent with the scenario where the decision-maker made a judgement that was consistent with the "true state of affairs". False positives and false negative outcomes are misclassification errors that occur when the judgement made by the decision-maker was inconsistent with the "true state of affairs".

To explain misclassification errors, we use an illustrative example of potable (safe) drinking water; misclassification errors throughout the rest of this thesis should be interpreted in a similar manner. If one were to determine if drinking water is free from E. coli and safe to drink, a false positive would occur in the event where the decision-maker erred in determining the water was potable (i.e., safe to drink) when they should not have (i.e., E. coli was present). Alternatively, a false negative would occur in the scenario where the decision-maker erred in wrongfully determining that the water was contaminated with E. coli, when the water was safe to drink (see Table 1). A true negative would be determining the water was unsafe to drink when it was unsafe to drink. Consequently, the "benefit" (relative to this example) would be the benefit of drinking the water when it is safe (i.e., Benefit = U(TP) - U(FN)), and the "cost" would be not drinking the water when it is unsafe (i.e., Cost = U(TN) - U(FP)) (Dekay et al., 2002).

Table 1- Example of Misclassification Errors

		True State of Affairs	
		Safe to Drink	Unsafe to Drink
Action/ Decision/ Hypothesis/ Verdict	Safe to Drink	True Positive	False Positive
	Unsafe to Drink	False Negative	True Negative

Pauker and Kassirer (1980) expand their earlier research (1975) on the decision-threshold approach to therapeutic decision-making for physicians and demonstrate how the threshold-model can be used to estimate thresholds associated with additional testing and treating a patient's condition relative to the perceived probability of disease (Pauker & Kassirer, 1980)

Regret Based Models

Djulbegovic and colleagues (1999a) discuss how people commonly violate the axioms of expected utility theory in favour of minimizing anticipated regret. Consequently, the authors explore the role of anticipated regret in medical decision-making and revise the expected utility threshold model of clinical decision making in favour of a threshold model for physicians that incorporates expected regret (B. Djulbegovic et al., 1999a). Leaning on an approach that is informed by regret theory (i.e., comparing the obtained outcome with the next best alternative had a different decision been made (Bell, 1982; B. Djulbegovic et al., 1999a)), the estimate for the benefits and costs (i.e., risks) are calculated in the following fashion, which can be subsequently substituted into the threshold equation as per Pauker & Kassier (1975):

$$Risks = Rg(NoR_x, D-) = U(NoR_x, D-) - U(R_x, D-)$$

$$Benefits = Rg(R_x, D+) = U(R_x, D+) - U(NoR_x, D+)$$

(B. Djulbegovic et al., 1999a)

In the above equation 'risks' (also interpreted as 'net-risks') are equivalent to the regret of no treatment when the disease is not present (i.e., $Rg(NoR_x, D-)$). $Rg(NoR_x, D-)$ is reflective of the utility of no treatment when the disease is not present (i.e., $U(NoR_x, D-); true\ negative$) minus the utility of treatment when the disease is not present (i.e., $U(R_x, D-); false\ positive$). Alternatively, 'benefits' are equivalent to the regret of treatment when the disease is present (i.e.,

$Rg(R_x, D+)$). $Rg(R_x, D+)$ is reflective of the utility of treatment when disease is present (i.e., $U(R_x, D+); true\ positive$) minus the utility of no treatment when disease is present (i.e., $U(NoR_x, D+); false\ negative$). (B. Djulbegovic et al., 1999a).

Djulbegovic and colleages (1999) explore the clinical scenario where a physician might be able to reasonably accept a wrong decision (e.g., treatment of a non-life-threatening condition) and subsequently revise the threshold model to accommodate for what they refer to as 'acceptable regret'. Acceptable regret (i.e., Rg_0) can be interpreted as the, "level of regret which the decision maker can comfortably tolerate" (B. Djulbegovic et al., 1999a, p. 257). Acceptable regret occurs in situations where an individual can tolerate wrong decisions and can tolerate some error or burden of making a wrong decision (B. Djulbegovic et al., 1999a). Djulbegovic and colleagues (1999) estimate the threshold of acceptable regret through the following equations[3]:

$$Threshold_{NoRx} = \frac{Rg_0}{Benefit}\ ; Threshold_{Rx} = 1 - \frac{Rg_0}{Risks}$$

Equations from: (B. Djulbegovic et al., 1999a)

In the above equation, Rg_0 is the level of acceptable regret a decision maker can comfortably tolerate. $Threshold_{NoRx}$ is reflective of the decision threshold for which a decision-maker would withhold treatment (i.e., NoRx). Alternatively, $Threshold_{Rx}$ is reflective of the decision threshold for which a decision-maker would pursue treatment (i.e., Rx). Djulbegovic and colleagues articulate that the acceptable regret for treatment and the acceptable regret for foregoing treatment need not be the same (B. Djulbegovic et al., 1999a). Because the threshold probability to withhold treatment is a function of the acceptable regret relative to the benefit of the treatment, and alternatively, the treatment threshold is a function of the acceptable regret relative to the risks of the treatment, allowing for the acceptable regret to differ between treatment and withholding treatment potentially explains research that has shown, "people may be more willing to accept regret that results from inaction (errors of omission) than from action (errors of commission)" (B. Djulbegovic et al., 1999a, p. 256).

[3] $Rg_0 = Acceptable\ Regret;\ T_{NoRx} = Threshold\ for\ No\ Treatment;\ T_{Rx} = Threshold\ for\ Treatment$

Dual Processing Models

Basinga and colleages (2007) postulate that, “clinicians do not have the time or perhaps interest to perform complicated mathematical calculations. However, they probably use a kind of intuitive threshold they cannot make explicit but that is based on their knowledge and/or perception of about the harm and benefit of a treatment” (Basinga, Moreira, Bisoffi, Bisig, & Van den Ende, 2007, p. 54). This gives license to the hybrid decision threshold model, which requires the decision-maker to insert their subjective weights of outcomes (e.g., morbidities, mortalities) (B. Djulbegovic, van den Ende, et al., 2015b). The hybrid decision-threshold model evidences that intuitive judgements regarding decision thresholds may be higher than decision thresholds that are calculated using the expected utility theory approach (Basinga, Moreira, Bisoffi, Bisig, & Van den Ende, 2007; Van den Ende et al., 2010). The hybrid approach is generally considered a version of the DPM of decision-threshold analysis; DPM decision threshold model has become the preferred approach to decision-thresholds analysis that incorporates the considerations of the hybrid approach to decision-threshold analysis (B. Djulbegovic, van den Ende, et al., 2015b).

Djulbegovic and colleagues (2012) propose the DPM for decision thresholds in medical decision-making (B. Djulbegovic et al., 2012a). DPM for decision thresholds is also known as the dual system model for medical decision making (DSM-M) (B. Djulbegovic et al., 2012a); hereafter, we refer to the concept as DPM for decision thresholds. In development of the DPM for decision thresholds the authors highlight that dual processing theory is, “widely accepted a dominant explanation of cognitive processes that characterizes human decision-making” (B. Djulbegovic et al., 2012a, p. 1). The dual processing approach to cognition is relatively uncontested as the dominant mechanism for reasoning within the sociology and cognition literatures (Kahneman, 2011; Lizardo et al., 2016; Strandell, 2019; Vaisey, 2009) Relative to thresholds established by expected utility models and regret based models, DPM of decision thresholds have been demonstrated to be more consistent with physician decision-making preferences (B. Djulbegovic et al., 2014a). Under dual processing theory, it is presumed that people make decisions by leaning on a combination of ‘type I system’ reasoning (i.e., affectively driven, fast, intuitive) and ‘type II system’ reasoning (i.e., analytical, calculative, deliberative) (see Table 2) (Croskerry, 2009b, 2009a; B. Djulbegovic et al., 2012a; Kahneman, 2011; Tsalatsanis et al., 2015a).

Table 2- Principal Characteristics of 'Type I System' and 'Type II System' Reasoning

Cognitive Style	**Type I System Reasoning** *Heuristic, Intuitive*	**Type II System Reasoning** Systematic, Analytical
Computational Principle	Associative	Rule Based
Responsiveness	Passive	Active
Capacity	High	Limited
Cognitive Awareness/ Control	Low	High
Automaticity	High	Low
Rate	Fast	Slow
Reliability	Low	High
Errors	Relatively Common	Rare
Effort	Low	High
Emotional Attachment	High	Low
Scientific Rigor	Low	High

Table adapted from: (Croskerry, 2009a, p. 1023)

The DPM for decision threshold analysis this is informed by the dual system model (Mukherjee, 2010) and is made relevant to medical decision-making through linking the dual system model to the threshold concept of decision-making (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a). Specifically, the DPM adds a threshold that is calculated through a combination of 'type I system' reasoning and 'type II system' reasoning (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a). Effectively, the DPM incorporates 'type I system' reasoning by using anticipated regret as a proxy of the affect and/or emotion that is commonly used in 'type I system' reasoning (B. Djulbegovic et al., 2012a). The DPM also incorporates 'type II system' reasoning through an expected utility theory approach (B. Djulbegovic et al., 2012a). Finally, 'type I system' reasoning and 'type II system' reasoning are combined in a manner that the complement of 'type II system' reasoning is reflective of the involvement of 'type I system' reasoning (B. Djulbegovic et al., 2012a; Mukherjee, 2010; Tsalatsanis et al., 2015a). See Figure 1 for decision tree structure associated with the DPM for decision thresholds.

Figure 1- Dual Processing Model of Decision-Making

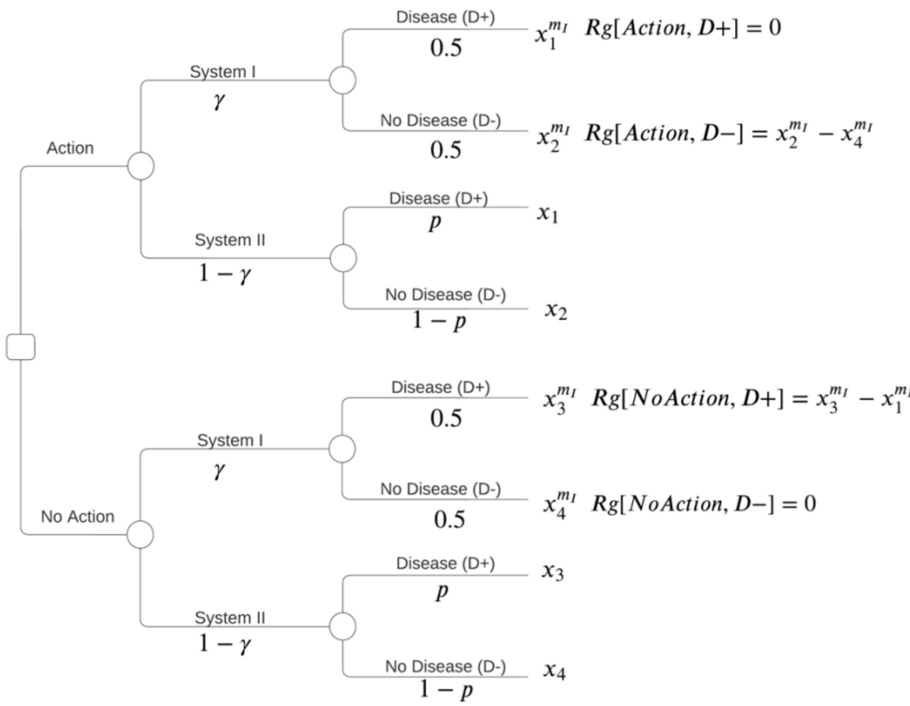

Figure adapted from: (B. Djulbegovic et al., 2012a, p. 3)

As per Mukherjee's (2010) dual system model, the DPM generalizes that there are 4 major categories that define the involvement of 'type I system' reasoning: a) affect, b) evolutionary hard-wired processes (e.g., those responses that are responsible for automatic responses to potential danger) c) processes from 'type II system 'reasoning that have been over-learned can be relegated to System I, and d) the effects of tacit learning (B. Djulbegovic et al., 2012a). As a product, the DPM calculates a decision threshold through a combination of 'type I system' reasoning and 'type II system' reasoning through the following equation:

$$P_t = \frac{1}{1 + \frac{B_{II}}{H_{II}}}\left[1 + \frac{\gamma}{2(1-\gamma)}\left(\frac{H_I}{H_{II}}\right)\left(1 - \frac{B_I}{H_I}\right)\right]$$

Equation from: (B. Djulbegovic et al., 2012a, p. 4)

In the above equation, P_t represents the calculated decision threshold. Similar to the threshold as calculated by expected utility models, if the estimated probability of disease is greater than the threshold (i.e., P(disease) > Threshold) then treatment should be given/ applied (Pauker &

Kassirer, 1975b). Alternatively, if the estimated probability of disease is less than the threshold (i.e., P(disease) < Threshold) then treatment should be withheld (Pauker & Kassirer, 1975b). The parameter γ represents the amount of involvement of an individual's 'type I system' reasoning relative to their involvement of 'type II system' reasoning (i.e., 1 – γ = involvement of 'type II system' reasoning) (B. Djulbegovic et al., 2012a). The parameter B_{II} represents the benefits as determined by 'type II system' reasoning and can be calculated as followed: $B_{II} = U(TP) - U(FN)$. The parameter H_{II} represents the harms as determined by 'type II system' reasoning and can be calculated as followed: $H_{II} = U(TN) - U(FP)$. The parameter B_I represents the anticipated regret of benefits as determined by 'type I system' reasoning and can be calculated as followed: $B_I = U(TP)^{m_I} - U(FN)^{m_I}$; where m_I reflects an individual's risk attitude. The parameter H_I represents the anticipated regret of harms as determined by 'type I system' reasoning and can be calculated as followed: $H_I = U(TN)^{m_I} - U(FP)^{m_I}$. (B. Djulbegovic et al., 2012a). Within the above equation, the function of $(1 - \frac{B_I}{H_I})$ is particularly informative of the decision threshold. When this function is positive, the decision threshold increases with increasing involvement of 'type I system' reasoning. When the function is negative, the decision threshold decreases with increasing involvement of 'type I system' reasoning.

The DPM for decision-thresholds model has largely been used as a model of physician decision-making for decisions related to: diagnostic testing (B. Djulbegovic, van den Ende, et al., 2015b; Tsalatsanis et al., 2015a), clinical treatment decisions (B. Djulbegovic, Hamm, et al., 2015a; Singh et al., 2020), and prescription of medications (Poss-Doering et al., 2020).

Theoretical Background: Risk Perception & Cultural Cognition

Risk research was established during the 1960s and 1970s through studies that predominately focused on understanding the risks associated with nuclear energy, chemical toxicity and environmental hazards (Hansson, 2012). Risk research and risk analysis was initially dismissive the role of individual values (Hansson, 2012); even on value-laden issues such as risk acceptability (Hansson, 2012). As the field evolved, the role that values have, even in defining risk, within the risk assessment/ management enterprise have been recognized as important to understanding (and defining) risk (Fischhoff et al., 1984, 2011; Hansson, 2012; Siegrist & Árvai, 2020). The research on risk has ascertained that the role of perception (i.e., also referred to as "subjective risk"

(Fischhoff et al., 1984)) is important because the manner in which people perceive risk, "influences individual behavior as well as the acceptance of- and commitment to- specific technologies, polices, and norms" (Siegrist & Árvai, 2020, p. 2192).

Slovic, Fischhoff and Lichtenstein (1981) advance the risk perception literatures' understanding of the psychometric paradigm of risk perception. Slovic and colleagues (1981) highlight that when lay people are asked to evaluate risks that rarely rely on statistical evidence, but rather, "rely on inferences based on what they remember hearing or observing about the risk in question" (Slovic et al., 1981, p. 1). Consequently, lay people are prone to reliance on heuristics (e.g., availability[4], overconfidence[5], and the desire for certainty[6]) in their appraisal of risk (Slovic et al., 1981). Slovic and colleagues (1981) provide instructive insight that lay people do not equate risk in a manner that is reflective of their judgements on annual fatalities and instead, "incorporate other considerations besides annual fatalities into their concept of risk" (Slovic et al., 1981, p. 7). Building off the work of Fischhoff and colleages (1978), Slovic and colleagues (1981) identify two dimensions as strong predictors of risk perception: 1) unknown risk, and 2) dread risk (Slovic et al., 1981).

Traditionally, the risk perception literature was dominated by two streams of thought: 1) the rational weigher theory[7], and 2) the irrational weigher theory[8]. However, Douglas and Wildavsky (1982) introduced a third stream that has become known as the cultural theory of risk perception. Within this approach to understanding risk perceptions, cultural worldviews are arranged through

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[4] The **availability heuristic** occurs when some judges an event as likely/ frequent (or conversely unlikely/ infrequent) based on the ease of imagination or ability to recall a past occurrence (Slovic et al., 1981).

[5] **Overconfidence** can manifest in variety of different ways within risk perception including: 1) "failure to consider the ways in which human errors can affect [sic] technological systems", 2) "overconfidence in scientific knowledge", 3) "insensitivity to how a technological system functions as a whole", and 4) "failure to anticipate human response to safety measures". (Slovic et al., 1981, p. 4).

[6] The **desire for certainty** reflects that people have difficulty operationalizing uncertainty (even in simple gambles). Consequently, people frequently deny the uncertainty (i.e., treat it as a certainty) to help simplify the decision (Slovic et al., 1981).

[7] The **rational weigher theory** of risk perception is based in neoclassical economics and, "asserts that individuals, over time and in aggregate, process information about risky undertaking in a way that maximizes their expected utility" (Kahan, 2008, p. 745)

[8] The **irrational weigher theory** of risk perception, "asserts that individuals lack the capacity to process information that maximizes their expected utility. Because of constraints on information, time, and computational power, ordinary individuals must resort to heuristic substitutes for considered analysis; those heuristics, moreover, invariably cause individuals' evaluations of risks to err in substantial and recurring ways" (Kahan, 2008, p. 746).

a group/grid analysis of social relationships (Johnson & Swedlow, 2021). Group refers to the, "extent to which relational patters were bounded ('us' vs. 'them')" (Johnson & Swedlow, 2021, p. 430), whereas, grid refers to the, "extent to which relations were prescribed (e.g., what you can do in a given social situation is determined by your rank, role, gender, other critical attribute [sic], rather than by your individual preferences or decisions)" (Johnson & Swedlow, 2021, p. 431). As a product of the group/grid analysis of social relationships Douglas and Wildavsky (1982) postulated that people subscribed to four distinct ways of life/ worldviews: hierarchism, egalitarianism, individualism, and fatalism (see Table 3) (Johnson & Swedlow, 2021).

Table 3- Worldviews and Level of Group/ Grid Commitment

Worldview	**Level of Group**	**Level of Grid**
Hierarchism	High	High
Egalitarianism	High	Low
Individualism	Low	Low
Fatalism	Low	High

Wildavsky & Dake (1990) demonstrate that perceptions of the risks associated with technology are influenced by both cultural biases and political orientation and can be predicted given the worldview of the individual. The authors claim that relative to other variables (e.g., knowledge, personality, political orientation and/or other demographic variables) that, "cultural theory provides the best predictions of a broad range or perceived risks" (Wildavsky & Dake, 1990, p. 51). Moreover, the authors also reflect that cultural biases outperform both public policy stances and self-rated political orientation as it relates to predicting risk preferences (Wildavsky & Dake, 1990). Wildavsky and Dake (1990) position that cultural conflict is the source of trust and distrust in our societal institutions, which influence people's perceptions of the perceived dangers associated with technology. Ultimately, it is postulated that because, "cultural theory generates clues to the propensities of those with various worldviews to underestimate or overestimate specific kinds of risks" (Wildavsky & Dake, 1990, p. 57) that the insight of cultural theory could be used strategically in risk communication programs (Wildavsky & Dake, 1990).

The cultural evaluator theory of risk perception positions that individuals act rationally and that they are not necessarily concerned with maximizing their welfare/ utility, but instead individuals adopt their perception of risk relative to their values and identities (Kahan, 2008). Under the cultural evaluator theory of risk perception, "when an individual is assessing what position to take on a putatively dangerous activity, she is, on this account, not weighing (rationally or irrationally) her expected utility but rather calculating the *social meaning* of that activity" (Kahan, 2008, p. 749, emphasis in original). Unlike the irrational weigher theory that treats affect as heuristic and source of error, the cultural evaluator theory, "views emotions as enabling individuals to perceive what stance toward risk coheres with their values" (Kahan, 2008, p. 750). According to the cultural weigher theory, "when people draw on their emotions to judge the risk that such an activity poses, they form an expressively rational attitude about what it would *mean* for their cultural worldviews for society to credit the claim that that [sic] activity is dangerous and worthy of regulation" (Kahan, 2008, pp. 750–751, emphasis in original). Effectively, under the cultural weigher theory:

> "If individuals' factual beliefs are expressive of cultural worldviews, then experts who treat those beliefs as 'blunders' unentitled to normative respect in a 'deliberative democracy' are necessary shielding regulatory law form citizens' versions of the good society."
>
> (Kahan, 2008, p. 761)

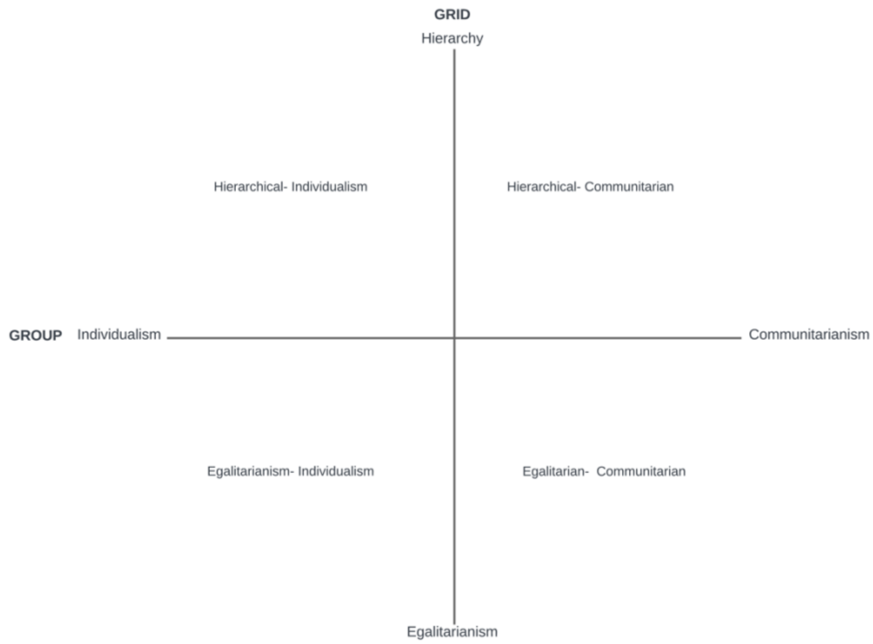
For example, people who subscribe to an egalitarian cultural worldview are typically sensitive to environmental and technological risks (Kahan, 2008). In contrast, people who tend to subscribe more to an individualist cultural worldview express greater concern for preserving individual autonomy as well as the free market enterprise and more commonly dismiss concerns about risks such as nuclear waste disposal and climate change (Kahan, 2008). It is the general trend of correlated factual beliefs between seemingly unrelated risks of lay people that lead us to believe that there are extraneous factors influencing risk perception that fall beyond the irrational weigher theory. Central to the cultural weigher theory of risk perception is the notion that emotions play a central role to risk perception as a source of rational expression of values, whereas the irrational weigher theory of risk perception views emotions as a source of bias and error (Kahan, 2008).

Kahan (2012) characterizes cultural cognition theory as a "conception" of cultural theory as per Douglas and Wildavskey (1982) (Kahan, 2012). Similar to cultural theory, the cultural cognition theory measures cultural worldviews, subscribes to the notion that culture shapes individuals' perceptions of risk, and seeks to improve the management of risk through gaining insight into individuals' perceptions of risk (Kahan, 2012; Kahan et al., 2005). However, cultural cognition theory seeks to combine a version of cultural theory with the psychometric paradigm as per Slovic and colleagues (1987) (Kahan, 2012). Relative to the role of affect and risk perception within cultural cognition theory, emotion is perceived as entering into risk judgements in a way that helps people to, "evaluate the social meaning of a particular activity against a background of cultural norms and to express the values that define their identities" (Finucane, 2012, p. 680). Consequently, rather than interpreting affect as a heuristic within the risk perception model, within cultural cognition affect/ emotion is perceived to enable "a person to identify a stance that is 'expressly rational' for someone with commitment to particular worldviews" (Finucane, 2012, p. 680; Kahan, 2008). In more recent work, Kahan and colleagues (2017) have specified that cultural cognition theory and the affect heuristic are complementary to each other (Kahan, Jamieson, et al., 2017). Specifically, where the affect heuristic articulates that people's perceptions of risk are complementary to how they feel about risk, cultural cognition theory explains the values individuals assign to risks as determined by their, "social meanings the valence of which determines whether group members' affective appraisals are positive or negative" (Kahan, Jamieson, et al., 2017, p. 3).

Unlike cultural theory, cultural cognition theory uses two continuous attitudinal scales: 1) "hierarchy-egalitarianism", and 2) "individualism-communitarianism" (see Figure 2) (Kahan, 2012). The scale related to "hierarchy-egalitarianism", seeks to measure, "a person's relative orientation toward high or low 'grid' ways of life" (Kahan, 2012, p. 730), whereas the scales related to "individualism-communitarianism" includes, "items that determine a person's relative orientation toward weak or strong 'group' ways of life" (Kahan, 2012, p. 730). Cultural cognition theory also differs from cultural theory to the extent that cultural theory prescribes that there are four/five ways to live life within the group-grid characterization of cultural theory (Johnson & Swedlow, 2020, 2021)[9], whereas cultural cognition theory (because of the use of continuous scales), "there can be an infinite number of ways of life formed by congregations of persons around any coordinate in the group-grid map" (Kahan, 2012, p. 734).

[9] It should be noted that, "scholars using CT do not claim that its [(cultural theory's)] two-dimensions (grid and group) are the *only* dimensions of cultural variation or the only sources of variation in RA [(risk analysis)]" (Johnson & Swedlow, 2021, p. 429, emphasis in original) but they are the most dominant.

Figure 2- Dimensions of Cultural Cognition Theory



Figured modified from: (Kahan, 2012, p. 727)

Effectively, because cultural cognition theory allows heterogeneity within the characterization of 'ways of life', individuals can form, "risk perceptions characteristic of their groups in proportion to the strength or degree of attachment to the cultural groups with whom they are most closely affiliated" (Kahan, 2012, pp. 734–735). Cultural cognition theory also deviates from classical cultural theory to the extent that cultural cognition theory uses individual-level measures of worldviews, similar to Dake (1991), as a potential explanatory variable of risk perception, whereas Douglas and Wildavsky (1982) aggregate worldviews as reflective of the larger group and/or organization for which individuals associate with (Kahan, 2012).

In the exploration of cultural cognition theory, Kahan and colleagues have undertaken the exploration of cultural cognition of variety of topics including: abortion (Kahan et al., 2005), climate change (Kahan, 2013b), gun control (Kahan et al., 2005), nanotechnology (Kahan et al., 2007), nuclear power (Kahan et al., 2011), vaccines (Kahan, Braman, Cohen, et al., 2010; Kahan, 2013a), public health threats (e.g., Zika virus) (Kahan, Jamieson, et al., 2017), amongst others (Johnson et al., 2020; Kahan, 2012). In virtually all of these instances, Kahan and colleagues have demonstrated that cultural worldviews (i.e., as measured with the continuous scales associated with cultural cognition theory) explained the variation in risk perception amongst individuals' better than other characteristics such as: education, gender, income, race, personality type and ideology (Kahan, 2012). For example, Kahan and colleagues have observed that cultural worldviews have on the perceptions of technological and environmental risks, concluding that:

> "The more egalitarian and solidaristic individuals were, the more concerned they were about global warming, nuclear power, and environmental pollution generally; the more hierarchical and individualistic they were, the less concerned there were about these asserted dangers. Indeed, cultural worldviews predicted individual beliefs about the seriousness of these risks more powerfully than any other factor, including gender, race, income, education and political ideology".
>
> (Kahan & Braman, 2006, p. 156)

While the merits of using cultural cognition theory relative to cultural theory to explain risk perception have been debated (Johnson et al., 2020; Johnson & Swedlow, 2020, 2021), the literature has generally recognized the attempt of cultural cognition theory, "to show how cultural biases and psychological mechanisms interact to strengthen cultural biases" (Johnson & Swedlow, 2021, p. 434). Specifically, cultural cognition theory demonstrates how psychological mechanisms interact, and strengthen, cultural biases through: identity-protective cognition, biased assimilation and group polarization, cultural credibility, cultural availability and cultural identity affirmation (see Table 4 for definitions)(Johnson & Swedlow, 2021; Kahan, 2012).

Table 4- Psychological Mechanisms in Cultural Cognition Theory

Term	**Interpretation**
Identity-Protective Cognition	"Refers to the tendency of people to fit their views to those of others with whom they share some important, self-identifying commitments.[…] Forming beliefs at odds with those held by members of an identity-defining group can thus undermine a person's well-being- either by threatening to drive a wedge between that person and other group members, by interfering with important practices within the group, or impugning the social competence (and thus the esteem-conferring capacity) of a group generally" (Kahan, 2012, p. 740).
Biased Assimilation	Refers to the tendency of individuals, "to harden their views when exposed to a portfolio of arguments that variously support and challenge their views" (Kahan, 2012, p. 742).
Group Polarization	Refers to, "when *groups* of individuals who are motivated to persist in opposing beliefs are exposed to balanced information, they don't converge in their views" (Kahan, 2012, p. 742).
Biased Assimilation and Polarization	Refers to a "dynamic that characterizes information processing. When individuals are unconsciously motivated to persist in their beliefs, they selectively attend to evidence and arguments, crediting those that reinforce their beliefs and dismissing as non-credible those that contravene them" (Kahan, 2012, p. 742).
Cultural Credibility	Refers to the hypothesized tendency of individuals to impute the shorts of qualities that make an expert credible- including knowledge, honesty, and shared interest- to the people whom they perceive as sharing their values" (Kahan, 2012, pp. 749–750).
Cultural Availability	Refers to the tendency of individual to be, "more likely to notice or to assign significance to evidence relating to expert opinion when it supports than when it contradicts their own cultural predispositions" (Kahan, 2012, p. 749).
Cultural Identity Affirmation	Refers to when individuals are, "more open to culturally threatening 'facts' if they are conveyed so as to affirm rather than undermine one's world view" (Johnson & Swedlow, 2021, p. 435; Kahan, 2012).

Differences in risk perception (and perceived benefits) according to cultural worldviews can be observed across a wide array of hazards (see Figure 3) (Xue et al., 2014). For example, Kahan and colleagues (2009) observed that a majority of those who had a cultural worldview of an hierarchal-individualism orientation perceived the benefits of nano technology to be greater than the perceived risks, alternatively a majority of individuals who had a cultural worldview of an egalitarian-communitarian orientation perceived the risk to be greater than the perceived benefits. In a different study, Kahan and colleagues (2010) observed that relative to the HPV vaccine, individuals with a cultural worldview of hierarchical orientation reported greater perceived risks than those with a cultural worldview of an egalitarian orientation. Across a wide array of hazards, individuals with cultural worldviews of a strong, individualism and/or hierarchism orientation tend to perceive environmental risks to be lower, whereas individuals with a cultural worldview that is more egalitarian perceive greater environmental risks (Xue et al., 2014). Across hazards, individuals of a cultural worldview that is of hierarchical orientation are often, "reluctant to acknowledge risks because doing so would invite regulation (a threat to autonomy and the pursuit of personal financial gain), and potentially undermine existing power structures that favour social and financial elites" (Xue et al., 2014, p. 256). Moreover, because people with a cultural worldview that has a strong hierarchical orientation prioritise the maintenance of social categories, they may "perceive diseases as less severe and have lower risk perceptions because they credit the social order, and the protection it extends to them" (Chen et al., 2020, p. 338). Relative to perceived risk of disease, individuals with a hierarchical worldview were observed to have lower perceived risks of disease than those individuals whose worldview was more egalitarian (Chen et al., 2020). Alternatively, those individuals who have an orientation that is more egalitarian in nature, "tend to be inherently suspicious of the underlying motives driving commerce and industry and, as such, perceive activities associated with these sectors to be a greater threat to the environment" (Xue et al., 2014, p. 256).

Figure 3- Risk Perceptions and Cultural Worldviews

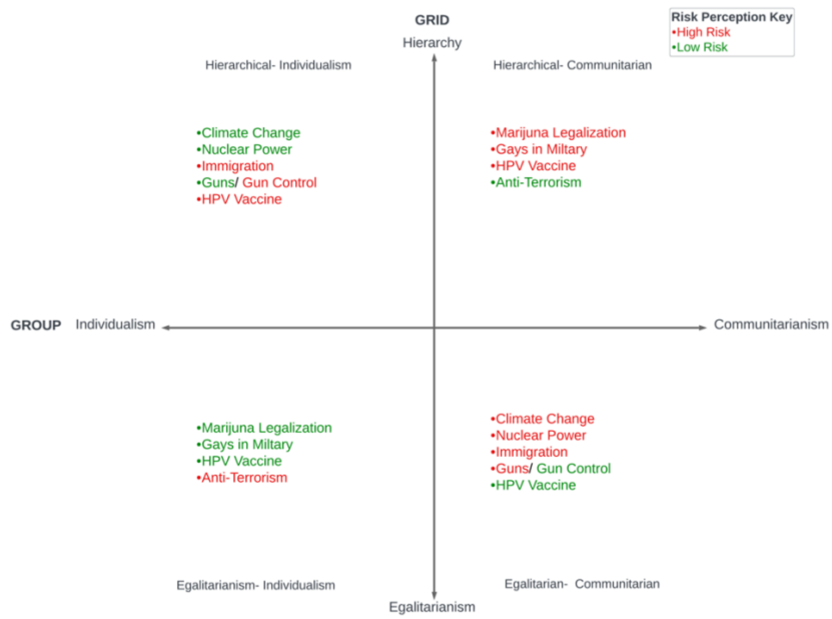


Figure Modified From: (Kahan, Jamieson, et al., 2017, p. 10)

Chapter 3- Methodology and Methods

Chapter Summary

In this chapter we first provide a summary of the methodology and research paradigm that underpins this research. Then, we summarize the methods for achieving each of the research objectives, while detailed discussions of the methods as they pertain to scoping review methods and the proof-of-concept Monte Carlo simulation can be found in Chapter 4 and Chapter 6, respectively.

Methodology

The main objective of this thesis is to theorize the DPM+ and demonstrate that this model can, prescriptively, explain decision heterogeneity between individuals of differing cultural worldviews by virtue of differing decision thresholds. DPM+ extends the dual processing model as per Djulbegovic and colleagues (2012) and Tsalatsanis and colleagues (2015) to include risk perception as determined by an individual's cultural worldview, as per Kahan (2012), on an individual's 'type I system' reasoning (B. Djulbegovic et al., 2012a; Kahan, 2012; Tsalatsanis et al., 2015a). Because the DPM+ informs how an individual's risk perception (i.e., as informed by their cultural worldview) informs their decision threshold, these insights can be leveraged to create decision support systems/ tool that complement decision-making and/or health policy creation. In consideration of the potential implications of the DPM+ for decision-support system, it is appropriate to adopt a research methodology that is applicable for information systems (IS) design. To this end, the research described in the thesis adopts a design science methodology (Hevner et al., 2004; Markus et al., 2002; Walls et al., 1992).

Within the IS literature, design science methodology is perceived as a problem solving paradigm and, "seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished" (Hevner et al., 2004). Design science as a research paradigm is intended to, "describe the world as acted upon (process) and the world as sensed (artifacts)" (Hevner et al., 2004, p. 78). As a product, "as design is 'a plan of something to be done or produced'" (Walls et al., 1992, p. 42), whereas, as a process view of, "design is 'to plan and proportion the parts of a machine or structure that all requirements will be satisfied'" (Walls et al., 1992, p. 42). Within the design science methodology, artifacts are created through the use of, “existing *kernel theories* that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem solving capabilities of the researcher” (Hevner et al., 2004, p. 76; emphasis in original; Markus et al., 2002; Walls et al., 1992). The definition of an artifact in IS literature has been one of considerable debate (Lee et al., 2015; Matook & Brown, 2017). Lee and colleagues (2015) propose a general IS artifact that encapsulates: technology artifacts, information artifacts and social artifacts (Lee et al., 2015) and such interpretation is adopted in this research. The DPM+ for preventative medicine decisions is an IS artifact that encapsulates information and social artifacts (Lee et al., 2015). For more a more detailed discussion of the characterizations of IS artifacts please see Appendix 1.1- Characterization of IS Artifacts.

The DPM+ pertains to explain how individuals have different decision-thresholds and provides insight for decision-makers as it relates to what types of risk communication strategies might be advisable to encourage someone to revise their decision threshold (i.e., raise or lower). This is consistent with IS design science to the extent that IS design methodology, “is prescriptive and evaluative, rather than solely descriptive, explanatory, or predictive” (Markus et al., 2002, p. 181). Moreover, a goal of IS design science is to stimulate future research to validate the model (Markus et al., 2002). Because the proposed research does not seek to empirically validate the model through primary data collection, the development of the DPM+ meets the design science criterion of stimulating future research (Markus et al., 2002).

According to Walls and colleagues (1992), design science can be characterized by seven statements, for which we present how the thesis research reflects these characterizations (see Table 5):

Table 5- Characterizations of Design Science

Characterization of Design Science	Interpretation	Thesis Research
1) "Design theories must deal with goals as contingencies" (Walls et al., 1992, p. 40)	Goals are intrinsic to design theories, whereas goals are commonly extrinsic to explanatory and predictive theories. "For example, F = MA is a natural science law; a corresponding design rules might be: 'If your goal is to accelerate mass M=m at rate A=a, then supply force F=f" (Walls et al., 1992, p. 41).	The thesis research seeks to explain the variation in preventative medicine decisions by virtue of differing decision-thresholds. The research proposes that differing anticipated regret(s) of perceived benefits and costs are a product of cultural worldviews.
2) "A design theory can never involve pure explanation or prediction" (Walls et al., 1992, p. 41)	If a design theory is explanatory, then it explains what properties a theory must have or how it should be constructed. Alternatively, if a design theory is predictive, it should predict to what extent the specified goal will be achieved based on the properties prescribed by the theory (Walls et al., 1992).	The DPM+ explains how cultural worldviews moderate the anticipated regret of the perceived costs and benefits associated with the decision, which consequently affects the decision-threshold.
3) "Design theories are prescriptive" (Walls et al., 1992, p. 41)	Design theories are intended to, "integrate explanatory, predictive, and normative aspects into 'can' and 'will' design paths that realize more effective design and use" (Walls et al., 1992, p. 41).	The DPM+ is a prescriptive model.
4) "Design theories are composite theories which encompass kernel theories from natural science, social science and mathematics" (Walls et al., 1992, p. 41)	Within design theories, "the prescriptive plane provides the common group for integrating these different types of theories" (Walls et al., 1992, p. 41).	The DPM+ draws on several theories including: expected utility theory, regret theory, affect heuristic, and the cultural cognition thesis.
5) "While explanatory theories tell 'what is', predictive theories tell 'what will be', and normative theories tell 'what should be', design theories tell 'how to/ because'" (Walls et al., 1992, p. 41)	Design theories are focused on addressing how a specified goal is achieved, whereas normative theories identity which goals should be sought (Walls et al., 1992).	The DPM+ seeks to explain why people of different cultural worldview make differing preventative medical decisions.
6) "Design theories show how explanatory, predictive or normative theories can be put to practical use" (Walls et al., 1992, p. 41)	"If an artifact which embodies the laws of interaction of an explanatory or predictive theory is designed and constructed, and that artifact satisfies its design requirements, then it provides a measure of empirical support for the theory" (Walls et al., 1992, p. 41).	By embedding the cultural cognition thesis into the DPM+ we can demonstrate how differing decision-thresholds can be a product of the effect that cultural worldviews have on anticipated regret of perceived benefits and costs relative to a decision.

7) "Design theories are theories of procedural rationality" (Walls et al., 1992, p. 41)	Design theories may borrow from theories born in the natural and social sciences. It is the application of these theories and the testing of theories through the use of the scientific method that encapsulate design theories. (Walls et al., 1992).	This criterion is met by virtue of our intention to test and provide proof of principle for the enhanced dual processing model.

Methods

Hevner and colleagues (2004) provide a conceptual framework and guidelines for understanding, executing and evaluating research within a design science methodology (Hevner et al., 2004). The thesis research follows these guidelines for this method as presented in Table 6.

Table 6- Design Science Research Guidelines

Guideline	Description	Thesis Research
Guideline 1: Design as an Artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	The DPM+ is the artifact.
Guideline 2: Problem Relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems.	The DPM+ is constructed to consider cultural worldview relative to preventative medicine decisions.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.	The scoping review provides an important evaluation as it relates to the types of decision threshold models, and how (if at all) cultural worldview can be incorporated into a prescriptive decision threshold model. The proof of concept for the DPM+ is an important evaluation of the theoretically proposed DPM+. We seek to provide proof of concept for the DPM+ through the employment of a Monte Carlo simulation that will simulate decision-thresholds by creating parameter estimates based on corresponding probability distributions.
Guideline 4: Research Contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.	DPM+ can be applied to preventative medicine decisions at an individual level. This finding contributes to the field of health informatics by providing a prescriptive understanding of individual decision-thresholds that is important when developing decision support systems designed to assist with individual level decision-making as well as risk communication strategies.
Guideline 5: Research Rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.	The scoping review (chapter 4) leverages rigorous methodology to ensure that the scoping review is replicable, transparent, reduce error, and increase the reliability (Munn et al., 2018; Peters, Godfrey, et al., 2020; Peters et al., 2021). The DPM+ (chapter 5) draws on the solid theoretical foundations. The proof of concept (chapter 6) of the DPM+ uses a Monte Carlo simulation technique and is parameterized by information that is substantiated in the peer-reviewed academic literature.

Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ended while satisfying laws in the problem environment.	DPM+ was theorized in response to the identified gaps through a comprehensive and thorough review of the literature for decision thresholds. The proof of concept draws on secondary data from the literature to parameterize the values within the DPM+ to provide proof of concept regarding the role of cultural worldview.
Guideline 7: Communication of Research	Design science research must be presented effectively both to technology-orientated as well as management-oriented audiences.	Upon completion, the chapters will be developed into manuscripts for submission to peer-reviewed journals. Finally, other types of knowledge translation activities (e.g., publications in the Conversation) may be sought to disseminate the findings to a lay audience.

Table adapted from: (Hevner et al., 2004, p. 83)

Chapter 4: Scoping Review

Chapter Summary

Chapter 4 contains a scoping review of non-expected utility decision threshold models that are used within medical decision-making. The scoping review protocol follows a scoping review methodology as defined by the Johanna Briggs Institute (JBI) Scoping Review Network's JBI Scoping Review Methodology Group (Munn et al., 2022; Peters et al., 2021; Peters, Marnie, et al., 2020; Tricco et al., 2018) and was pre-registered on Open Science Framework Registries (OSF) (a data repository used to pre-register scoping reviews) (Foster & Deardorff, 2017; Kolaski et al., 2023; *Open Science Framework*, n.d.). The findings of this scoping review report that threshold models that are informed by regret theory are the most common non-expected utility threshold models within medical decision-making. This scoping review identifies theoretical underpinnings and methodological approaches that are used in understanding decision thresholds within medical decision-making. Finally, the scoping review identifies contextual and subjective factors that inform an individual's decision threshold at the same time revealing that no decision threshold models have incorporated cultural worldviews.

Introduction

Djulbegovic and colleagues (2015) observed that "little empirical work has been published on the threshold models, or using the threshold concept as a theoretical platform to investigate clinical decision-making" (B. Djulbegovic, van den Ende, et al., 2015b, p. 491). Such observation was further confirmed by Ebell and colleagues (2015) and by Felder and Mayrhofer (2018) and it constitutes a starting point for this scoping review. Herein, we explore the literature related to decision thresholds and medical decision-making. As expected utility (expected value) threshold models are generally well established within the medical decision-making literature (B. Djulbegovic, van den Ende, et al., 2015b; Pauker & Kassirer, 1980, 1975b), we focus specifically on decision threshold concepts, models, or theories that are not based on expected utility theory and/or do not share the same general structure as the work of Pauker and Kassirer (1975, 1980)(i.e., non-expected utility decision threshold models). We conducted a scoping review to add to the body of scientific knowledge, not only by providing an update to the corpus of publications on decision thresholds within medical decision-making, but also to extend the scope to include literature (where available) on how non-physicians (i.e., allied health professionals, lay-persons/ patients, etc.) use decision thresholds in medical decision-making.

We take this opportunity to briefly differentiate between Chapter 2 and Chapter 4. Chapter 2 presents the background literature relative to the main bodies of literature that inform DPM+. Chapter 4 is a scoping review that is focused on the decision threshold literature within medical decision-making. Specifically, Chapter 4 identifies that gap(s) within the literature on decision thresholds within medical decision-making, which inform(s) the theorization and development of DPM+ as presented in Chapter 5.

Scoping Review Objective

As stated on p. 15, the objectives of this review are:

> **Scoping Review Objective 1A**: to identify and categorize what theories have been developed to inform or estimate decision threshold(s) within medical decision-making.

In addition to the objective listed above, we explore the following secondary objective:

> **Scoping Review 1B**: to identify what consideration(s) an individual's contextual (e.g., age, gender, specialities, years of practice) and subjective factors (e.g., attitudes, emotions, preferences, risk perceptions, values) have been given relative to decision thresholds within the medical decision-making literature.

Methods

The scoping review adopted a methodology as defined by the Johanna Briggs Institute (JBI) Scoping Review Network's JBI Scoping Review Methodology Group to ensure transparent and replicable results (Munn et al., 2022; Peters et al., 2021, 2022; Peters, Godfrey, et al., 2020; Peters, Marnie, et al., 2020; Tricco et al., 2018). As per the JBI scoping review guidelines (Peters et al., 2022), a scoping review protocol was preregistered using the Open Science Framework (OSF) (Scarffe & Coates, 2023) (See Appendix 1.2, 1.3, 1.4, 1.5); the OSF is an online repository that was developed by the Centre for Open Science and is commonly used to pre-register scoping reviews (Foster & Deardorff, 2017; Kolaski et al., 2023; *Open Science Framework*, n.d.).

Munn and colleagues (2018) indicate that it is appropriate to pursue a scoping review method when the purpose of the review is to, "determine the scope or coverage of a body of literature on a given topic and give clear indication of the volume of literature and studies available as well as an overview (broad or detailed) of its focus" (Munn et al., 2018, p. 2). Importantly, scoping reviews ought to be "informed by an a priori protocol, systematic and often include exhaustive searching for information, aim to be transparent and reproducible, include steps to reduce error and increase reliability (such as the inclusion of multiple reviewers), [and] ensure the data is extracted and presented in a structured way" (Munn et al., 2018, p. 5). Because this review sought to identity the various decision threshold concepts, models, or theories that have been used in medical decision-making, but not necessarily to answer specific research questions or produce a critically appraised and synthesis of the literature, a scoping review was considered to be an appropriate approach (Munn et al., 2018).

Eligibility Criteria

Participants, concept, and context

This scoping review focused on decision threshold models relative to decisions made by individuals (e.g., physicians, allied health professionals, lay individuals, etc.), within the field of medical decision-making. We excluded decision threshold models related to decisions made at the policy level (e.g., cost-effectiveness analysis and willingness to pay thresholds).

Types of sources

The scoping review included a search for relevant articles on the databases of: MEDLINE (Ovid), SCOPUS, and ProQuest (Dissertations & Theses). MEDLINE (Ovid) and SCOPUS databases were searched for articles indexed on these databases up until July 10th, 2023; ProQuest (Dissertations & Theses) was search for articles indexed up until August 23rd, 2023.

This scoping review considered all study designs, including quantitative, qualitative, mixed-method study designs, as well as those papers that contribute to the theoretical understanding and advancement of decision thresholds. Reviews meeting eligibility criteria were included, as well as theses and commentaries/ opinion papers. News and social media sources were not searched.

Search Strategy

The search strategy was designed to comprehensively identify literature published in academic sources on decision thresholds within medical decision-making. The comprehensive search strategy was developed around the concept of non-expected utility decision thresholds within the context of medical decision-making. An initial unstructured search of MEDLINE (Ovid) was undertaken to identify seed articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index (MeSH) terms used to describe the articles were used to develop a full search strategy for the MEDLINE (Ovid) database. Because SCOPUS does not include MeSH terms or related index terms and uses different search syntax, the MEDLINE search strategy was translated to search the SCOPUS database (see Appendix 1.3- Scoping Review: Search Strategy). These were retrieved from the ProQuest database and used a simple search strategy of "decision threshold" in either the title or abstract.

Broadly, our search strategy sought to identify articles where the term "decision thresholds", and other like terms (e.g., therapeutic thresholds, diagnostic thresholds, treatment thresholds, probability thresholds, standard of proof, etc.), appeared within the title or abstract of an article within the context of "medical decisions" or other like terms (e.g., clinical decisions, health decision, clinical reasoning, etc.). To increase the flexibility of our search strategy, we incorporated proximity indicators such that the terms "decision" and "threshold" (and other similar combinations) only needed to appear within 3 words of each other. For example, if an author wrote the following in the title or abstract, "the threshold for the decision…", it would be included within the search. Within the search strategy, we also used 'wildcard' operators to capture singularities and pluralities of the same word (e.g., probabilit* would return results for the terms: "probability" and "probabilities"; judg* would return results for the terms: "judge", "judges", "judged", "judgements", "judging", "judgingly"). Full search strategies used can be found in Appendix 1.3- Scoping Review: Search Strategy.

Source of Evidence Selection

Articles were included if they are published in English, are accessible online through the University of Ottawa library, the library at Clarkson University[10] or available for download (i.e., free of charge).

All articles identified during the search were exported as a .ris file and imported into Zotero, a free, open source, citation management system (Vanhecke, 2008; *Zotero*, n.d.). Duplicates were removed using the Zotero Duplicates Merger plug-in (Frangoudes, 2021/2022). Once the duplicates were identified, a singular file of articles from MEDLINE and SCOPUS was imported into COVIDENCE (Veritas Health Innovation, 2022) where additional duplicates may be detected and removed by that software and/or by the reviewers. COVIDENCE is a, "web-based systematic review program that aims to make evidence synthesis a more proficient process" (Babineau, 2014, p. 68). Access to COVIDENCE was provided under license from the University of Ottawa.

The titles and abstracts of the articles identified in our search were reviewed by two independent reviewers (Andrew Scarffe (AS) and Alison Coates (AC)[11]) using the Title and Abstract Screening criteria described below and in Appendix 1.4- Scoping Review: Screening Guidelines. Any disagreements were discussed and resolved through consensus. Full text files for all the articles included through the initial screening stage were reviewed by the same two independent reviewers (AS and AC) using the Full Text Screening criteria described below and in Appendix 1.4- Scoping Review: Screening Guidelines. Disagreements were flagged and resolved through a consensus discussion. Both sets of screening criteria (i.e., title and abstract screening criteria, and full-text screening criteria) were piloted in a subset of the articles as described in Appendix 1.4- Scoping Review: Screening Guidelines.

[10] The library at Clarkson University was used a complementary library to the University of Ottawa library. Alison Coates (the secondary reviewer as part of the scoping review) is a part-time lecturer at Clarkson University and had access to their library.
[11] AC is a doctoral candidate in management with a concentration in health systems at the Telfer School of Management at the University of Ottawa.

Screening Criteria

Title and Abstract Screening

Since our scoping review broadly sought to understand the different types of theories that have been used to estimate decision thresholds, our screening criteria was similarly broad. Given that the literature on our topic transcends disciplinary boundaries, we kept our title and abstract screening criteria purposefully conceptual rather than concrete in order to be inclusive of fields using different terms to capture the same or similar ideas. Because our inclusion and exclusion criteria were broad, we provided detailed screening implementation guides to help the reviewer determine which records were relevant to our stated objectives (Table 7 provides a summary of the inclusion/ exclusion criteria; see Appendix 1.4- Scoping Review: Screening Guidelines.).

Pilot Testing- Title and Abstract Screening: Inclusion/ Exclusion Criteria

Prior to starting title and abstract screening, the screeners (AS and AC) conducted a pilot test of the title and abstract inclusion/exclusion criteria to ensure inter-rater agreement. To conduct this pilot test, the 25 "most relevant" articles (i.e., as identified by COVIDENCE) were independently reviewed by the screeners. The pilot test was informed by the screening guidelines as seen in Appendix 1.4- Scoping Review: Screening Guidelines.

In this pilot test we sought to achieve an inter-rater agreement that is reflective of "substantial agreement" (i.e., Cohen's Kappa value ≥ 0.61) (Cohen, 1960; McHugh, 2012). We report that after the first pilot test of the title and abstract screening inclusion/ exclusion criteria for 25 "most relevant" articles, we achieved inter-rater agreement of 84% and a Cohen's Kappa value of approximately 0.64 (i.e., $\kappa = 0.6429$). Therefore, additional pilot tests were not required relative to the title and abstract screening inclusion/ exclusion criteria. Title and abstract screening for all included articles proceeded the pilot test and followed the title and abstract screening guidelines as identified in Appendix 1.4- Scoping Review: Screening Guidelines.

Full-Text Screening

At the full-text review stage, our inclusion and exclusion criteria for full-text inclusion were directly aligned with the identified objectives of this scoping review. The inclusion and exclusion criteria for the full-text screening stage can be found in Table 7 (more detailed full-text screening guidelines can be found in Appendix 1.4- Scoping Review: Screening Guidelines).

Pilot Testing- Full Text: Inclusion/ Exclusion Criteria

After the title and abstract screening, and prior to commencing the full-text screening, the screeners conducted a pilot test of the full-text inclusion/exclusion criteria to ensure inter-rater agreement. The inclusion/ exclusion criteria for the full-text screening were consistent with the screening criteria for the title/abstract screening. However, the inclusion/ exclusion criteria at the full-text review stage were more explicit given the benefit of appraising the entire article wholistically based on the full-text; this narrowing of inclusion/ exclusion criteria is consistent with JBI scoping review methodology. To conduct the full-text inclusion/ exclusion criteria pilot test, the first 10 articles when sorted by alphabetically by authors last name (i.e., sorted A to Z) were independently reviewed by the screeners; this pilot test was informed by inclusion/ exclusion criteria (see Table 7 for a summary of criterion) and the screening guidelines relative to the full-text screening phase (see Appendix 1.4- Scoping Review: Screening Guidelines).

To ensure inter-rater agreement with the full-text inclusion/ exclusion criteria, we sought to achieve an inter-rater agreement that was reflective of "substantial agreement" (i.e., Cohen's Kappa value ≥ 0.61) (Cohen, 1960; McHugh, 2012) relative to the inclusion/ exclusion decision. Relative to the "exclusion reason" (i.e., the reason identified for why the article was excluded) we sought to achieve an inter-rater relative agreement of at least 60%. We report that after the first pilot test of the full-text screening guidelines (i.e., as described above) we had a relative agreement of 100% and a Cohen's Kappa value of 1.0 (i.e., $\kappa = 1.0$). We also report an inter-rater relative agreement relative to the "exclusion reason" to be 75%. Consequently, additional pilot tests were not required, and we proceeded to complete the full-text screening for all included articles.

Data Extraction

Within the JBI scoping review methodology, detailing of the data extraction is important to demonstrate that, "the authors have carefully considered what data are required to be extracted from the included evidence sources to answer the review's questions/s" (Peters et al., 2022, p. 946). To this end, we detail the data extraction process. Data was extracted from each included article by one reviewer (AS). Prior to full data extraction, a data extraction pilot test of 10 articles was performed and discussed with the other reviewer (AC). Minor modifications to the data extraction tool (e.g., ordering of characteristics, framing of characteristics, etc.) were made after discussion of the pilot test results. Extracted characteristics included: author details, title of the journal, country of study (i.e., where applicable), the objective of the article, article type (e.g., empirical, conceptual/ theoretical, review, etc.), theoretical underpinning (if any), contextual/ subjective factors (if any), types of decision threshold (e.g., treat/ not treat; test/ not test, etc.), relevant decision threshold equations (if any), the decision-maker (e.g., physician, nurse, patient, guardian/ caregiver, etc.), type of medical decision (e.g., coronary artery disease, stroke, COPD, etc.), authors' conclusions, as well as relevant references (see *Identifying Additional Literature*).

Data extraction was completed in Zotero so that relevant annotations identified within the articles could be easily exported. A custom Google form was created to systematically, and consistently, extract the relevant data from each article.

Identifying Additional Literature

The reference lists of all records that met the full-text inclusion criteria were scanned according to the title and abstract for possible inclusion in the scoping review. All of the potentially suitable articles were assessed using inclusion/exclusion criteria and suitable ones were loaded into the full-text review stage in COVIDENCE.

Table 7- Summary of Inclusion/ Exclusion Criteria Based on Screening Phase

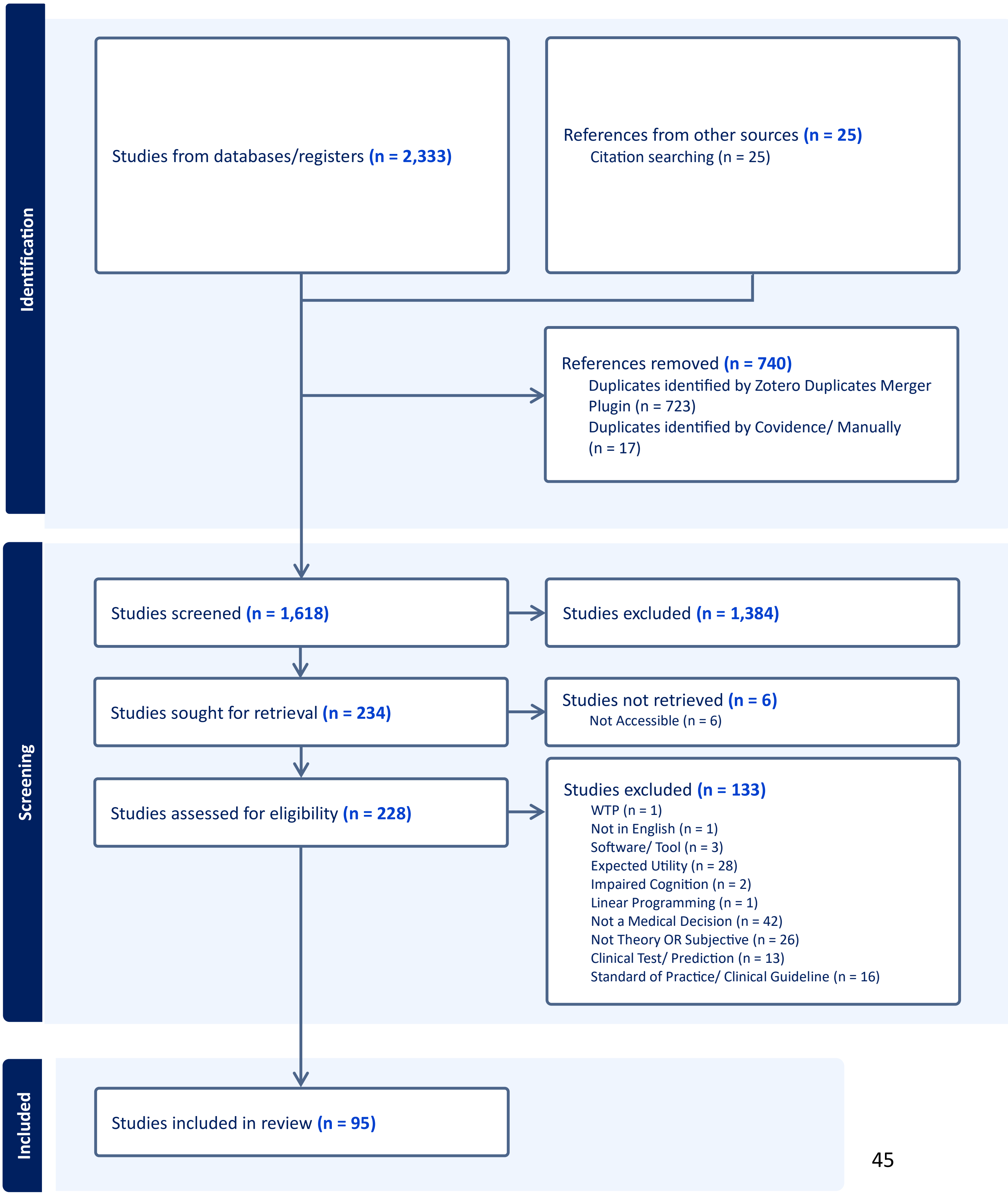
Screening Phase	Inclusion	Exclusion
Abstract and Title	• Refers to, or implies, the cognitive process of using or establishing decision thresholds. AND • Involves health-related decision-making processes by humans about humans.	• Not in English. OR • Decisions do not involve humans. OR • Article tests the performance or quality of clinical parameters or tests without a human subjective element. OR • Article refers to purely to economic evaluation.
Full-Text	• The **focus** of the article is about understanding/ explaining/ informing how individuals make health related decisions when faced with uncertainty. AND • The **process/ theory/ calculation** in which the decision threshold is estimated is **explicitly stated and/or referenced** relative to the decision. OR • The article discusses the influence that individual **subjective judgments** (e.g., **attitudes/ emotions/ preferences/ risk perceptions**) has/have on an individual's decision threshold relative to the decision.	• Not available online through the University of Ottawa library, the Clarkson University library, or available for download on the internet. OR • The article is not in English. OR • The article is solely about a **standard of practice** or **clinical guideline** for which the concept of a decision threshold(s) is mentioned by not thoroughly discussed and/or is arbitrarily chosen. OR • The article is solely about a **clinical outcome assessment/ clinical test/ prediction model** and/or the decision threshold(s) is arbitrarily chosen. OR • The article is solely about the development/ evaluation of a **software/ tool/ decision aid** for a specific disease. OR • The article is solely about economic evaluation and establishing a decision threshold based on a willingness-to-pay for an intervention at a population level that is not specific to an individual and/or does not explore how the willingness to pay threshold ought to be established. OR • The article discusses decision thresholds within the context of an **individual experiencing impaired cognition** impacting the individual's ability to make decisions (e.g., concussion, anxiety, etc.).

		OR • The article calculates/ explores the concept of decision threshold(s) solely based on **expected utility threshold models.** OR • The article calculates/ explores the concept of decision threshold(s) solely based on **linear programming**.

Results

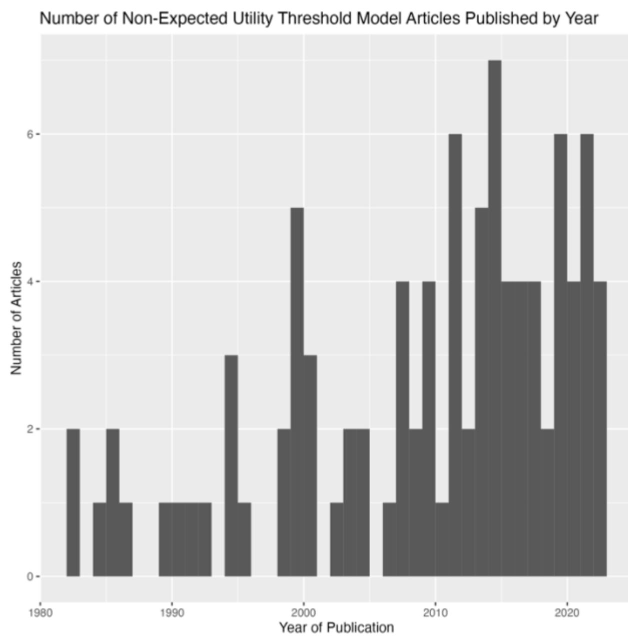
A total of 2,358 articles were identified for inclusion in the scoping review, with ultimately, 95 articles passing all criteria and being included in the analysis (see Figure 4 for PRISMA flow diagram).

Figure 4- PRISMA Flow Diagram



The number of articles discussing non-expected utility decision threshold models within the context of medical decision-making increased slowly from 1982 to 2000 (n= 21). We observed and that most of the articles were published since 2010 (n = 59; 61.5%) (see Figure 5).

Figure 5- Number of Included Articles by Year Published



Within the included articles, 95 articles were published across 64 different journals, for which the greatest number of articles are published in the journal Medical Decision Making (n=12). Approximately 43% (n=41) or the articles were found in the following 9 journals (see Table 8); all other included articles were the sole article published in the respective journals that were included in the review. A summary of all included articles can be found in Appendix 1.6- Scoping Review: Summary of Included Articles.

Table 8- Distribution of Records by Popular Journals

Journal	**# of Records Included**
1. Medical Decision Making	12
2. BMC Medical Informatics and Decision Making	8
3. Journal of Evaluation in Clinical Practice	6
4. Medical Hypotheses	3
5. PLoS ONE	3
6. BMJ	3
7. Implementation Science	2
8. Health Economics	2
9. Health Services Research	2

Theoretical Paradigms

Of the 95 included articles, 64 articles identified a theoretical paradigm in their approach to decision thresholds (see Table 9). Within the 64 articles identified in Table 9, an "X" is reflective of the use of that identified theoretical paradigm relative to the discussed decision threshold concept within the article and a short summary of each theoretical paradigm is provided following the table.

The remaining 31 articles (i.e., not identified in Table 9) discuss the concept of decision thresholds within various medical decision-making applications but did not reference or explicitly state a theoretical paradigm that was used to derive the decision threshold.

Table 9- Common Theoretical Paradigms of Non-Expected Utility Decision Thresholds

Article (*Denotes a review or commentary)	Regret Theory	Dual Processing Theory	Hybrid Theory	Info-Gap Theory	Information Theory	Signal Detection Theory	Regression (Logistic/ Ordinal) Method	Net-Benefit	Other
(Christensen-Szalanski et al., 1982)							X		
(Eisenberg & Hershey, 1983)							X		
(Hartz et al., 1986)							X		
(M. J. Young et al., 1986)							X		
(M. Young et al., 1987)							X		
(Feinstein, 1985)	X								
(Asch et al., 1990)					X				X
(Sainfort, 1991)									X
(Plasencia et al., 1992)							X		
(B. Djulbegovic et al., 1995)					X				
(Glasziou & Irwig, 1995)								X	
(Verp & Heckerling, 1995)			X						
(B. Djulbegovic et al., 1999a)	X								
(Hozo & Djulbegovic, 1999)			X						
(B. Djulbegovic et al., 2000)			X						
(Van Hoe & Miserez, 2000a)			X						
(Sinclair et al., 2001)									X
(Sonnenberg, 2004b)									X
(Basinga, Moreira, Bisoffi, Bisig, & Van Den Ende, 2007)			X						
(Hozo & Djulbegovic, 2008)	X								
(Hozo et al., 2008a)	X								

Article (*Denotes a review or commentary)	Regret Theory	Dual Processing Theory	Hybrid Models	Info-Gap Theory	Information Theory	Signal Detection Theory	Regression (Logistic/ Ordinal)	Net-Benefit	Other
(Moreira et al., 2009)	X		X						
(Thompson et al., 2008)						X			
(Ben-Haim et al., 2009)				X					
(Boland & Lehmann, 2010)							X		
(Tsalatsanis et al., 2010a)	X								
(Tsalatsanis et al., 2011)	X								
(Cheyne et al., 2012)						X			X
(B. Djulbegovic et al., 2012a)	X	X							
(Mohan et al., 2012)						X	X		
(Pines et al., 2012)			X						
(Lazarus & Ost, 2013)*									
(Vickers et al., 2013)								X	
(B. Djulbegovic et al., 2014b)	X	X							
(Felder & Mayrhofer, 2014a)			X						
(Hernandez et al., 2014)	X								
(Sreeramareddy et al., 2014)	X		X						
(Tsalatsanis et al., 2015a, p. 201)		X							
(Cucchetti et al., 2015)	X								
(B. Djulbegovic, Hamm, et al., 2015a)*	X	X	X						
(B. Djulbegovic, van den Ende, et al., 2015b)*	X	X	X						
(Ebell et al., 2015)							X		
(Sonnenberg, 2015)*			X						
(Courbage & Rey, 2016)			X						
(Sheldrick et al., 2016)	X								X
(Vickers et al., 2016)								X	
(Tsalatsanis et al., 2017)	X								
(Hozo et al., 2017a)	X					X			X
(Hozo et al., 2018a)	X								
(Ebell et al., 2018a)							X		
(Felder & Mayrhofer, 2018b)									X
(Fujii & Osaki, 2018)	X								
(B. Djulbegovic, Hozo, Mayrhofer, van den Ende, et al., 2019)			X						
(Boyles et al., 2020)*	X	X							
(De Alencastro et al., 2020)							X		
(M. Djulbegovic et al., 2020)*			X						
(Patel et al., 2021)							X		
(Courbage & Peter, 2021)			X						
(Cai et al., 2022)							X		
(Wen et al., 2022)	X								
(Sevim & Felder, 2022)			X						
(Cucchetti et al., 2023a)	X								
(B. Djulbegovic et al., 2023)	X								X
(Taylor et al., 2023a)							X		
Total	**23**	**6**	**17**	**1**	**2**	**4**	**14**	**3**	**9**

Regret Theory

Our review identified that regret theory is the most common theoretical paradigm for non-expected utility decision thresholds within medical-decision making (i.e., regret-based thresholds models). We identified 23 articles that acknowledge and or account for the influence of an individual's regret on their decision thresholds. Djulbegovic and colleagues (1999) revise the expected utility threshold model (Pauker & Kassirer, 1980, 1975b) to incorporate regret. Djulbegovic and colleagues (1999) also propose the concept of "acceptable regret", which simplifies the decision threshold equation. Acceptable regret can be interpreted as the, "level of regret which the decision maker can comfortably tolerate" (B. Djulbegovic et al., 1999a, p. 257).

Dual Processing Theory

Within our review we identified six articles that adopted a theoretical paradigm of dual-processing theory/ dual systems model (hereafter, dual processing theory) relative to decision thresholds. Djulbegovic and colleagues (2012) were the first to apply dual processing theory to decision thresholds within the context of medical decision-making. Djulbegovic and colleages (2014) sought to explore which decision threshold theory/ approach (i.e., expected utility theory, regret theory, or dual processing theory) best explained physician decision making. This paper provided two important contributions to the literature on decision thresholds: 1) it provides, "empirical evidence that physicians appear to make their decisions according to the threshold model" (B. Djulbegovic et al., 2014b, p. 7), and 2) "physicians' decision-making seems to more compatible with the dual processing model than with either EUT [(expected utility theory)] or a simple regret model" (B. Djulbegovic et al., 2014b, p. 9).

Of the six articles that identify dual processing theory as a theoretical underpinning for decision thresholds, two articles explored dual processing theory from a theoretical/ conceptual angle using hypothetical vignettes to illustrate its' potential application (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a), three articles were reviews (Boyles et al., 2020; B. Djulbegovic, Hamm, et al., 2015a; B. Djulbegovic, van den Ende, et al., 2015b), and one article explored the explanatory power of dual processing theory relative to expected utility theory and regret theory decision threshold models (B. Djulbegovic et al., 2014b).

Hybrid Theory

The hybrid theory is another common paradigm for non-expected utility decision thresholds. However, despite its frequent use, the interpretation of what constitutes a 'hybrid theory' of decision thresholds, and how it differs from decision thresholds as determined by expected utility theory (EUT), is less defined. In broad terms, the literature describes the hybrid threshold model as retaining, "the original EUT formulation but asks the decision-maker to weigh health outcomes (morbidities and mortalities) differently when they occur in patients with and without disease" (B. Djulbegovic, van den Ende, et al., 2015b, p. 488). Across the articles that were identified as having a 'hybrid' theoretical paradigm, this was the best explanation for what constituted hybrid theory.

Within our review 16 articles were identified to use a 'hybrid theory' relative to the decision thresholds. Within the included articles, the challenge of defining what constituted a hybrid theory approach was apparent. For example, Djulbegovic and colleagues (2000) demonstrate how, "outcomes expressed as morbidity or mortality can be in integrated within a patient's value judgements to arrive at the optimal clinical decision" (B. Djulbegovic et al., 2000, p. 7). Alternatively, others scholars have stated that within the hybrid model, individuals are believed to, "use a kind of intuitive threshold they cannot make explicit but that is based on their knowledge and/or perception of about the harm and benefit of a treatment" (Basinga, Moreira, Bisoffi, Bisig, & Van den Ende, 2007, p. 54). Basinga and colleagues (2007) provide an example of how a hybrid threshold model would calculate the associated decision threshold that incorporates a weighed value of morbidity with respect to mortality and weighed value of provoked death relative to natural death to incorporate a decision-makers preference.

Within other hybrid theories the element of patient choice is incorporated into the threshold equation (B. Djulbegovic, Hozo, Mayrhofer, van den Ende, et al., 2019; M. Djulbegovic et al., 2020). For example, in estimating the decision threshold Djulbegovic and colleagues (2020) propose a modified threshold formula, where the quotient of absolute risk of a major adverse event occurring and relative risk ratio is multiplied by a constant that "refers to the patient's relative value of avoiding treatment harms[…] with respect to the impact of disease without treatment" (M. Djulbegovic et al., 2020, p. 16).

Info-Gap Theory

Ben-Haim and colleagues (2009) posit that the decision maker often faces an 'information-gap' between what is known about a patient and what ought to be known in order to reliably choose a threshold. Unlike decision threshold models that are established by minimizing Bayesian risk, the info-gap decision thresholds paradigm seeks to establish, "a threshold for which the Bayesian risk is acceptable under the widest possible range of error in our knowledge about the patient. This strategy is called robust-satisficing: to be robust to information-gaps while also satisfying critical requirements" (Ben-Haim et al., 2009, p. 190). Within the info-gap decision threshold model, when the robustness is equal to zero, then the threshold is set to the Bayesian risk (Ben-Haim et al., 2009). Of particular interest is the incorporation of the decision-makers 'values' relative to the importance of missed detection (i.e., false negative) and false alarm (i.e., false positive) within the estimation of Bayesian risk (Ben-Haim et al., 2009, p. 190). Within the articles identified by this scoping review, this was the only one article of info-gap theory being applied to decision thresholds within the context of medical decision-making. The article by Ben-Haim et al. (2009) does not validate the info-gap approach to decision thresholds, but instead expresses, theoretically, its potential application and uses a hypothetical vignette of diagnosing diabetes as a potential application of the model.

Information Theory

Information theory is used infrequently in the medical decision-making literature and is most commonly used in fields of such as: economics or engineering (Diamond et al., 1981). Information theory, "values proportional changes in probabilities rather than absolute changes"(Asch et al., 1990, p. 49) relative to the sensitivity and specificity of a given test. Within information theory, uncertainty is defined as, "the expected information content of a message that reveals with perfect accuracy whether a particular event did or did not occur" (Asch et al., 1990, p. 49). In brief, "information theory provides a constructive criterion for setting up probability distributions on the basis of partial knowledge" (Jaynes, 1957, p. 620).

Within our review, we identified two articles that used information theory to complement their approach to decision thresholds. Asch and colleagues (1990) incorporate prognostic information (i.e., "defined as the expected deviation from the prior probability of disease" (Asch et al., 1990, p. 47)) into decision threshold analysis, by way of information theory, and subsequently adds an additional two ‘management strategy zones’: 1) test but without treatment anyway, 2) test but treat anyway, in addition to the three standard management strategy zones of: withhold treatment, test, and treatment (Asch et al., 1990). Within information theory, this uncertainty (i.e., known as entropy in the field of thermodynamics) (B. Djulbegovic et al., 1995) can be expressed in terms of the benefit/risk ratio of a particular therapy (B. Djulbegovic et al., 1995). In other words, “entropy can also be interpreted as a measure of choice” (B. Djulbegovic et al., 1995, p. 505). The articles by Asch and Colleagues (1990) and Djulbegovic and colleagues (1995) incorporate information theory into the classic expected utility threshold model by Pauker & Kassirer (1980, 1975b) doing so from a ‘theoretical’ perspective and do not seek to validate their new approach to decision thresholds.

Signal Detection Theory

Signal Detection Theory (SDT) provides a paradigm to extend the concept of decision thresholds by providing a mechanism to contrast ‘signal’/ ‘hit’ (i.e., true positives and false negatives) and ‘noise’/ ‘miss’ (i.e., false positives and true negatives) relative to a decision (Cheyne et al., 2012; Hozo et al., 2017a; Mohan et al., 2012; Thompson et al., 2008). Within a healthcare setting, “the hit rate is called sensitivity (S) and 1- sensitivity is the false-negative rate (FN) the noise distribution is composed of true negatives (correct rejections) and false positives; their rates are called specificity (C) and false alarm rate (FA), respectively” (Hozo et al., 2017a, pp. 50–51). Signal detection analysis provide a comprehensive paradigm against which it is possible to determine the threshold against which an individual makes a decision/ takes action (Thompson et al., 2008).

Our review identified four articles that referenced SDT relative to decision thresholds. Across the three of the four articles, three of articles used SDT as a methodology to elicit an individual’s decision threshold when presented with hypothetical vignettes (Cheyne et al., 2012; Mohan et al., 2012; Thompson et al., 2008). In the three articles that used SDT to explore decision thresholds from an empirical perspective, SDT was applied to the following hypothetic decisions: nursing decision-making (Thompson et al., 2008), decisions of midwives and obstetricians to transfer patients in labour from rural maternity care (Cheyne et al., 2012), and physician trauma triaging (Mohan et al., 2012). In the fourth article, Hozo and colleagues (2017) addressed to the role of SDT from the theoretical perspective and identify the link between decision threshold models and

SDT, fast-and-frugal decision trees (FFT) and evidence accumulation theory (EAT) (Hozo et al., 2017a).

Regression (Logistic/ Ordinal)

Our review identified 14 articles that reference a regression paradigm for decision thresholds. We observed that linear or logistic regression was a common method to derive at decision thresholds. Unlike many of the other theories (e.g., regret theory, dual processing theory, info-gap theory, etc.) that be used to inform decision thresholds in an ex-ante fashion, those thresholds that are identified through regression (logistic/ ordinal) are almost exclusively decision thresholds that are determined ex-post. Within articles that use a regression paradigm for decision thresholds, Eisenberg and Hershey (1983) are commonly cited for their four-step method for calculating the test and test-treatment thresholds within medical decision-making:

1) Have the clinician identify their prior probability
2) Have the clinician choose one of three options: 1) test, 2) treat, or, 3) do neither.
3) Give the clinician new information and ask for a revised probability for the diagnosis under consideration; and,
4) Have the clinician selection one of three options: 1) test, 2) treat, or 3) do neither, based on the revised probability.

(Eisenberg & Hershey, 1983, p. 157)

Young and colleagues (1986) build on Eisenberg & Hershey (1983) and propose three different approaches to estimating the decision threshold: 1) modal distribution, 2) the unweighted midpoint, 2) the weighted midpoint. Plasencia and colleagues (1992) elaborate on the logistic function as proposed by Hartz and colleagues (1986), and reduce the dependencies on the approach proposed by Young and colleagues (1986). Specifically Plasencia and colleagues (1992), provide a regression paradigm that can account, "for other factors that may influence disease probability, or threshold, at which a particular proportion of physicians makes a decision"(Plasencia et al., 1992, p. 205).

Ebell and colleagues (2015) modify the logistic model proposed by Plasencia and colleagues (1992) to estimate thresholds for both testing and treatment decisions. They explore testing and treatment thresholds for: influenza, acute coronary syndrome, pneumonia, deep vein thrombosis, and urinary tract infection (Ebell et al., 2015). Ebell and colleagues (2015) are commonly cited for their use of online clinical vignettes, which (at the time) provided a novel way to explore test and treatment thresholds for common conditions.

Net Benefit

We identified three articles (n=3) that specifically explored the concept of decision thresholds through a net-benefit approach. Although commonly the net-benefit approach is synonymous with expected value theory, the articles included in this review adopt a modified net-benefit approach. For example, Glasziou and Irwig (1995) propose a net-benefit approach to decision thresholds that incorporates a weighting function for specific patient values for specific outcomes. Vickers and colleagues (2013) and Vickers and colleagues (2018) both explore a net-benefit approach relative to the selection of diagnostic tests and incorporate a decision threshold approach into the net-benefit equation alongside specificity and sensitivity.

Other Theoretical Paradigms

Our review identified a number of other theoretical paradigms that were associated with just one publication. They include: linear information theory (Asch et al., 1990), generalized linear receiver operator characteristic (GROC) curves (Sainfort, 1991), rituals (Sonnenberg, 2004b), social judgement theory (Cheyne et al., 2012), the general assessment and decision making model (Cheyne et al., 2012), systems dynamics (Sheldrick et al., 2016), fast-and-frugal decision trees (Hozo et al., 2017a), evidence accumulation theory (Hozo et al., 2017a), therapeutic risk thresholds (Felder & Mayrhofer, 2018b), and smooth ambiguity model (Sevim & Felder, 2022).

Contextual and Subjective Factors that Influence Decision Thresholds

The second objective of the scoping review was to identify contextual and subjective factors that influence decision thresholds. Of the 95 articles included in the scoping review, 42 articles consider/ discuss various contextual and/or other subjective factors that have the potential to influence an individual's decision threshold(s).

We separate the results of this section. First, we report the contextual factors that were identified to influence an individual's decision threshold to a statistically significant level, and second, we report the subjective factors that were identified to influence decision thresholds to a statistically significant level.

Contextual Factors

Our review identified, two broad categories of factors that were found to be influential regarding an individual's (i.e., health care provider, lay-person, etc.) decision threshold: 1) person-specific factors, and 2) occupation related factors (see Table 10). Each of the features within person-specific factors, and occupation related factors, are described below.

Person-Specific Factors

Age

Five articles identified that age significantly influences decision thresholds. For example, Brundage and colleagues (2001) report that older participants have a tendency to have higher treatment thresholds for accepting chemotherapy treatments. Similarly, van Overbeeke and colleagues (2021) observed that a patient's age had a significant effect on the patient's decision threshold required to switch therapies relative to the treatment of haemophilia.

Gender

Three articles identified that gender significantly influences decision thresholds. In a study on physician decisions related to appendicitis, it was found that physician treatment thresholds are typically higher when the patient is a woman than it is for male patients (De Alencastro et al., 2020). From a physician perspective, relative to trauma triaging decision-making male physicians were found to have higher decision thresholds than women (Mohan et al., 2012).

Education Level

One article identified that education level significantly influences decision thresholds. Brundage and colleagues (2001) report that patients who had no post-secondary education had higher decision thresholds relative to the decision of whether or not to start chemotherapy for cancer treatment (Brundage et al., 2001)

Country

Five articles identified that people living in different countries often have decision thresholds that are significantly different from each other. For example, Ebell and colleagues (2015) observe that physicians in the United States have higher treatment thresholds than physicians from Switzerland for patients with acute coronary syndrome. Similarly, Thompson and colleagues (2008) observed that nurses from Australia had less of a decision tendency to act than nurses from the United Kingdom, Canada, and the Netherlands.

Physician vs. Patient

Three articles identified that the decision thresholds of the physician and the patient can differ significantly. In a study focused on patient perceptions about treating hepatitis C, "patients' stated thresholds for accepting antiviral therapy were significantly higher than hepatologists' estimates of their decision thresholds" (Cotler et al., 2001, p. 2732). Douglas (2012) reported a statistically significant different treatment thresholds for hip fractures between physicians and patients.

Similarly, van der Keylen and colleagues (2022) observe a statistically significant treatment threshold for femoral neck fractures between physicians and lay-persons.

Occupation Related Factors

Academic Practice vs. Non-Academic Practice

Winkenwerder and colleagues (1993) explore factors that explain the differences in decision making between experts and internists relative sexually transmitted diseases/ sexually transmitted infections. One of the findings of this study identified a statistically significant difference between those physicians who were full-time non-academic practitioners versus full-time academic practitioners (Winkenwerder et al., 1993).

Differences in Speciality

Nine articles identified that differences in speciality often results in decision thresholds that were significantly different from each other. For example, Cucchetti and colleagues (2023) found a statistically significant difference in decision thresholds across: oncologists, gastroenterologists, and surgeons (Cucchetti et al., 2023a). In another study, differences between oncology subspecialists, those physicians who were practicing radiation oncologists had lower treatment thresholds than medical oncologists (Ng et al., 2004). Similar finding were reported for the differences in specialities by Winkenwerder and colleagues (1993), Hanson and colleagues (1996), Mohan and colleagues (2012), and Cucchetti and colleagues (2015).

Trainee/ Resident/ Fellow vs. Attending Physician/ Consultant

Two articles identified that differences between trainees/ residents and attending physicians/ consults often results in decision thresholds that were significantly different from each other. Di Stefano and colleagues (2021) report that registrars/ fellow often have lower treatment thresholds for pre-mature infants than consultants (i.e., they are willing to treat pre-mature infants that were born at a lower gestational age). Similarly, Stojan and colleagues (2022) observed that medical students and residents typically have lower treatment thresholds than faculty/ attending physicians.

Years in Practice

Five articles identified that the number of years in practice results in decision thresholds that were significantly different from each other. This finding is complementary to the contextual factor of *Trainee/ Resident/ Fellow vs. Attending Physician/ Consultant* to the extent that typically physicians progress to the position of attending physician/ consultant with more years in practice. Relative to the number of years in practice, Cai and colleagues (2022) observe that, relative to the treatment of influenza, “the treatment threshold for clinicians practicing more than 10 years was lower than for those practicing less than or equal to 10 years” (Cai et al., 2022, pp. 4–5). Similar findings are observed in the other listed studies.

Primary Care vs. Non-Primary Care

Two articles identified that the setting where care was delivered (i.e., primary care vs. non-primary care) significantly influenced the decision threshold. Ebell and colleagues (2018) observed that physician’s treatment threshold for patients suspected of community-acquired pneumonia was higher for physicians not in a primary care setting (Ebell et al., 2018a). Similarly, Cai and colleagues (2022) report that for the treatment of influenza, physicians in a primary care setting had a higher treatment threshold compared to non-primary care clinicians (Cai et al., 2022).

Proximity to Tertiary Care Centres/ Acute Services

Complimentary to the contextual factor of *primary care vs. non-primary care* the environmental contextual factor of *proximity to tertiary care centres/ acute services* was observed to significantly influence the decision threshold in five articles. Cheyne and colleagues (2012) observed that a midwives’ decision threshold relative to transferring a patient to obstetric services when experiencing a challenging childbirth is influenced by the proximity to acute service provision. Mohan and colleagues (2012) observed that physicians, “working at a non-trauma centre without an established affiliation with a trauma center compared to physicians working at non-trauma centers with an affiliation had higher decisional thresholds” (Mohan et al., 2012, p. 7).

Volume of Practice

Two articles identified that the volume of patient encounters influences the decision threshold. Cucchetti and colleagues (2023) observed that “responded working in low/medium surgical volumes settings had slightly higher regret of commission versus respondents working in high/

very high surgical volumes. This translated into the highest threshold mortality with upfront surgery in respondents working in the low/medium surgical volume settings" (Cucchetti et al., 2023a, p. 1424). Douglas (2012) observed that when physicians had a greater number of consultations for advice on skeletal health, these physicians also had lower decision thresholds.

Table 10- Studies reporting statistical significance

Contextual Factor	Source
Person-Specific Factors	
Age	(M. Young et al., 1987)
	(Steel, 2000)
	(Brundage et al., 2001)
	(De Alencastro et al., 2020)
	(van Overbeeke et al., 2021a)
Gender	(Steel, 2000)
	(Mohan et al., 2012)
	(De Alencastro et al., 2020)
Education Level	(Brundage et al., 2001)
Country	(Sreeramareddy et al., 2014)
	(Thompson et al., 2008)
	(Ebell et al., 2015, 2018a)
	(De Alencastro et al., 2020)
Physician vs. Patient	(Cotler et al., 2001)
	(H. Douglas, 2012)
	(van der Keylen et al., 2022)
Occupation Related Factors	
Academic Practice vs. Non-Academic Practice	(Winkenwerder et al., 1993)
Differences in Speciality	(M. Young et al., 1987)2024-01-22 9:06:00 PM
	(Winkenwerder et al., 1993)
	(Hanson et al., 1996)
	(Steel, 2000)
	(Ng et al., 2004)
	(Mohan et al., 2012)
	(H. Douglas, 2012)
	(Cucchetti et al., 2015, 2023a)
	(Taylor et al., 2023a)
Trainee/ Resident/ Fellow vs. Attending Physician/ Consultant	(Di Stefano et al., 2021)
	(Stojan et al., 2022)
Years in Practice	(Winkenwerder et al., 1993)
	(Hanson et al., 1996)
	(Thompson et al., 2008)
	(Cai et al., 2022)
	(Taylor et al., 2023a)
Volume of Practice	(H. Douglas, 2012)
	(Cucchetti et al., 2023a)
Primary Care vs. Non-Primary Care	(Ebell et al., 2018a)
	(Cai et al., 2022)
Proximity to Tertiary Care Centres/ Acute Services	(Mohan et al., 2012)2024-01-22 9:06:00 PM
	(Cheyne et al., 2012)
	(Ebell et al., 2018a)
	(Di Stefano et al., 2021)

So far, we have discussed contextual factors that were reported in the literature as having statistically significant influence of decision thresholds (see Table 10). However, there are other studies that considered similar contextual factors but either did not find statistical significance or did not test for such. There studies were not included in Table 10 and are reported in Table 11.

Table 11-Studies not reporting statistical significance

Contextual Factors	**Source**	**Result/ Study Type**
Demographic Factors	(McAlister et al., 2000)	Measured; Non-Significant
Age	(Cahan et al., 2003)	Measured; Non-Significant
	(H. Douglas, 2012)	Measured; Non-Significant
	(Nair et al., 2017)	Measured; Non-Significant
Gender	(Brundage et al., 2001)	Measured; Non-Significant
	(Cahan et al., 2003)	Measured; Non-Significant
	(H. Douglas, 2012)	Measured; Non-Significant
	(Lahaye et al., 2014)	Discussed; Not Measured
	(Nair et al., 2017)	Measured; Non-Significant
Country	(Ng et al., 2004)2024-01-22 9:06:00 PM	Measured; Non-Significant
Role in Decision-Making (Ownership of Decision)	(Brundage et al., 2001)	Explored Qualitatively
	(Greenfield et al., 2005)	Explored Qualitatively
	(Mohan et al., 2012)	Discussed; Not Measured
Pre-Existing Comorbities	(Malhi et al., 2010)	Explored Qualitatively
	(Ost & Gould, 2012)	Review
	(Lazarus & Ost, 2013)	Review
Occupation Related Factors		
Academic Practice vs. Non-Academic Practice	(Ng et al., 2004)2024-01-22 9:06:00 PM	Measured; Non-Significant
Differences in Speciality	(Cahan et al., 2003)	Measured; Non-Significant
	(Cheyne et al., 2012)	Measured; Non-Significant
Trainee/ Resident/ Fellow vs. Attending Physician/ Consultant	(Winkenwerder et al., 1993)	Measured; Non-Significant
	(Connors & Siner, 2015)^	Discussed; Not Measured
Years in Practice	(Sreeramareddy et al., 2014)	Measured; Non-Significant
	(Di Stefano et al., 2021)	Measured; Not Reported
Access to Tools/ Resources (e.g., imaging)	(Ost & Gould, 2012)	Review
	(Lazarus & Ost, 2013)	Review
	(Boyles et al., 2020)	Review
Knowledge of Advanced Techniques	(Ost & Gould, 2012)	Review
	(Lazarus & Ost, 2013)	Review
Primary Care vs. Non-Primary Care	(Cahan et al., 2003)	Measured; Non-Significant

Subjective Factors

We identified several subjective factors that had a statistically significant influence on decision thresholds that we categorize in three broad categories of: 1) Perceived Health factors, 2) Personal factors, and 3) Perceptive factors (see Table 12).

Perceived Health Factors

Health Status

Cotler and colleagues (2001) identify that, "current state of health, and HCV-related functional status showed a significant relationship between patients' decisions to take treatment and their stated threshold for accepting therapy"(Cotler et al., 2001, p. 2733).

Perceived Severity/ Risk of Disease

Four articles identify that an individual's perceived severity of disease and/or their perceived risk of disease has implications on their associated decision threshold. Of the identified articles, two articles reported a statistically significant relationship between perceived severity/ risk of disease of disease and decision thresholds (Lahaye et al., 2014; Taylor et al., 2023a). Lahaye and colleagues (2014) noted that how patients perform on various clinical tests that serve as proxies for their risk of disease have a significant relationship with the decision threshold. Moreover, Taylor and colleages (2023) observe that, "there was significant variation in treatment thresholds by severity subgroup" (Taylor et al., 2023a, p. 178). The other two articles discussed the potential effects that the perceived severity/ risk of disease might have on an individual's decision threshold but did not measure this effect (Connors & Siner, 2015; Nair et al., 2017)

Perception of Adverse Events Associated with Treatment

Eight articles discussed the effects of the perception of adverse events associated with treatment and its potential influence on an individual's decision threshold. The general observation was that when an individual has a negative perception of adverse events that might occur that are associated with treatment then they will have a higher decision threshold (i.e., increasing a perceived false positive, increases the decision threshold). However, only two articles empirically demonstrated the significant relationship between the perception of an adverse event associated with treatment (Cotler et al., 2001; Nair et al., 2017). The remaining six articles that discussed the influenced that the perception of adverse events associated with treatment did so through qualitative study (n=1)

(Greenfield et al., 2005), by review (n=1) (Ost & Gould, 2012), or did not measure the relationship but spoke to its potential impact within the discussion of decision thresholds within the articles (n=4).

Familiarity with the Disease/ Previous Experience

An individual's familiarity with the disease and/or previous experience with the illness is anticipated to have an effect on an individual's decision threshold. In total, eight articles discussed the influence that one's familiarity with the disease/ previous experience with the illness relative to an individual's decision threshold. Of the eight articles, only two articles observed a statistically significant relationship between familiarity with the disease an individual's decision thresholds. Ng and colleagues (2004) and Billington and colleagues (2020) found this relationship to be statistically significant (Billington et al., 2020; Ng et al., 2004). For example, Ng and colleagues (2004) observe that, "physicians with more experience in handling second malignancy cases had a higher threshold for adding radiation therapy to chemotherapy alone based on improvement in relapse risk" (Ng et al., 2004, p. 265). Similar findings were reported for Billington and colleagues (2020). Alternatively, Brundage and colleagues (2001) and Douglas (2012) measured this relationship but did not report a statistically significant relationship. Of the remaining four articles, two articles explored this concept qualitatively and reported directionally similar decision thresholds to Ng and Colleagues (2004) and Billington and colleagues (2022). The remaining two articles , discussed the relationship but either did not measure it (McAlister et al., 2000) or measured it, but did not report the relationship (Di Stefano et al., 2021).

Personal Factors

Patient Preferences

Patient preferences can be interpreted as a desire for a particular type of therapy or weighing potential outcomes in a fashion that reflects their personal choice. In total, seven articles discussed the role that patient preference has in establishing the associated decision threshold, of which two articles observed a statistically significant relationship (Brundage et al., 2001; Cotler et al., 2001). The remaining five articles explored the concept from a qualitative perspective (n=2), discussed the impacts in a review (n=2), or discussed the role of patient preferences relative to the decision threshold but did not measure it (n=1).

Time Pressures

Two articles discussed the effects that time pressure has on an individual's decision threshold. Of the two, only one article demonstrated this relationship to be statistically significant. Notably, Thompson and colleagues (2008) observed that when nurses experienced time pressure to make a decision, they were significantly less likely to intervene. It was observed that under time constraints nurses may seek to reduce false positives while allowing for more false negatives, which subsequently increased the associated decision threshold (Thompson et al., 2008). Coenen and colleagues (2000) qualitatively explore the relationship between decision thresholds and time, but from the perspective of the amount of time a patient might be absent from work in the absence of prescribing a medication. They observed that when prescribing intervention it might reduce the amount of time a patient might be absent from work, this may lower the physician's decision threshold (Coenen et al., 2000).

Perceptive Factors

Risk Attitude

Within the seven articles that discuss the relationship between an individual's risk attitude and their associated decision threshold, none sought to empirically validate this assumption. Instead, the articles broadly discuss the implications that one might expect an individual's risk attitude (e.g., risk aversion, ambiguity aversion, etc.) to have on the decision threshold. Of these articles, four articles provide mathematical proofs of how 'risk perception' could be incorporated into: dual processing theory (n=1) (B. Djulbegovic et al., 2012a) and hybrid theory (n=3) (Courbage & Peter, 2021; Felder & Mayrhofer, 2014a; Sevim & Felder, 2022). For example, Courbage and Peter (2021) who explore the effects of ambiguity aversion relative to an individual's decision threshold within the context of vaccination decisions illustrate how ambiguity aversion would be expected to impact the decision threshold. Felder and Mayrhofer (2014) narratively explore the effect that an individual's risk preference would have on their decision threshold. Based on Felder and Mayrhofer (2014), when the perceived benefit of a treatment is greater than the perceived loss of a treatment, then individuals who are risk-adverse will have a lower treatment threshold than those who are risk neutral. The remaining three articles discuss the impacts of risk attitude on decision thresholds through a review (n=2) (Lazarus & Ost, 2013; Ost & Gould, 2012) or a general conceptual discussion (n=1) (Connors & Siner, 2015).

Culture/ Religion and (dis)Incentives

Six articles discussed the effects that culture, organizational norms and/or various incentive structures may have on an individual's decision threshold. Within the context of medical decision-making it is often perceived that patients' opinions, beliefs and values have an important role (Nair et al., 2017). Nair and colleagues (2017) are the only article included in the review that sought to empirically measure the effects of culture relative to the decision threshold. They explored how "participants' judged requests for treatment based on religious versus non-religious reasons in the two contexts of prolonging futile treatment and refusing a blood transfusion" (Nair et al., 2017, p. 835). The results of this study suggest that the effects of religion are inconsistent on decision thresholds to the extent that people did not differ in their endorsement of prolonging futile treatment based on whether or not it was for religious reasons (or not). Alternatively, people were significantly less likely to agree with a request to refuse a blood transfusion for religious reasons compared with non-religious reasons. Relative to culture, Ebell and colleagues (2015), although they do not specifically measure cultural differences and their effect(s) on decision thresholds, postulate that, "differences in decision-making between US and Swiss physicians [could] possibly [be] due to a different medical context and culture" (Ebell et al., 2015, p. 47). A similar perspective was adopted by De Alencastro and colleagues (2020) to explain variation in treatment thresholds between US and Swiss physicians. Sonnenberg (2015) briefly mentions, but does not measure and does not elaborate on, the possibility that religious, cultural, socioeconomic, and other influences may inform a person's 'knowledge' that subsequently is used to inform their decision threshold. Minami and colleagues (2020) articulate that, "future studies should be designed to further define women's risk thresholds for certain treatments (or lack thereof), delve into the psychological factors that direct their decisions, and attempt to understand how patients' valuations of risk interact with society's" (Minami et al., 2020, p. 306). Minami and colleagues (2020) do not provide greater elaboration as to how patients' valuations of risk may interact with society.

Beyond religion and culture, Mohan and colleagues (2012) discuss the influence that organizational norms and incentive structures may have on decision thresholds to transfer patients. Notably, the authors identify that:

> "The finding of lower decision thresholds among physicians at hospitals with an established trauma centre affiliation suggests that organizational norms or incentives may play roles as well. For example, hospitals without these affiliations may encourage their physicians to avoid transferring patients out of network to prevent the loss of revenue" (Mohan et al., 2012, p. 8).

Mohan and colleagues (2012) do not measure organizational norms or incentive structures relative to decision thresholds, but their discussion of its possible impacts highlights the role that values may have relative to an individual's decision threshold.

Table 12- Subjective Factors that may Influence Decision Thresholds

Subjective Factors	Source	Result/ Study Type
Health Related Factors		
Health Status	(Cotler et al., 2001)	Measured; Statistically Significant
Perceived Severity/ Risk of Disease	(Lahaye et al., 2014)	Measured; Statistically Significant
	(Connors & Siner, 2015)	Discussed; Not Measured
	(Nair et al., 2017)	Discussed; Not Measured
	(Taylor et al., 2023a)	Measured; Statistically Significant
Perception of Adverse Events Associated with Treatment	(Hartz et al., 1986)	Discussed; Not Measured
	(McAlister et al., 2000)	Discussed; Not Measured
	(Cotler et al., 2001)	Measured; Statistically Significant
	(Greenfield et al., 2005)	Explored Qualitatively
	(Ost & Gould, 2012)	Review
	(Connors & Siner, 2015)	Discussed; Not Measured
	(Sonnenberg, 2015)	Discussed; Not Measured
	(Nair et al., 2017)	Measured; Statistically Significant
Familiarity with the Disease/ Previous Experience	(Coenen et al., 2000)	Explored Qualitatively
	(McAlister et al., 2000)	Discussed; Not Measured
	(Brundage et al., 2001)	Measured; Not Statistically Significant
	(Ng et al., 2004)	Measured; Statistically Significant
	(H. Douglas, 2012)	Measured; Not Statistically Significant
	(Donner-Banzhoff et al., 2020)	Explored Qualitatively
	(Billington et al., 2020)	Measured; Statistically Significant
	(Di Stefano et al., 2021)	Measured; Not Reported
Personal Factors		
Patient Preferences	(Verp & Heckerling, 1995)	Explored Qualitatively/ Case Study
	(Coenen et al., 2000)	Explored Qualitatively
	(McAlister et al., 2000)	Discussed; Not Measured
	(Brundage et al., 2001)	Measured; Statistically Significant
	(Cotler et al., 2001)	Measured; Statistically Significant
	(Man-Son-Hing et al., 2005)	Review
	(Minami et al., 2020)	Review
Time Pressures	(Coenen et al., 2000)	Explored Qualitatively
	(Thompson et al., 2008)	Measured; Statistically Significant
Perceptive Factors		
Risk Attitude	(Ost & Gould, 2012)	Review
	(Lazarus & Ost, 2013)	Review
	(Felder & Mayrhofer, 2014a)	Discussed; Not Measured
	(B. Djulbegovic et al., 2012a)	Discussed; Not Measured
	(Connors & Siner, 2015)	Discussed; Not Measured
	(Courbage & Peter, 2021)	Discussed; Not Measured
	(Sevim & Felder, 2022)	Discussed; Not Measured
Culture/ Religion & (dis)Incentives	(Mohan et al., 2012)	Discussed; Not Measured
	(Sonnenberg, 2015)	Discussed; Not Measured
	(Ebell et al., 2015)	Discussed; Not Measured
	(Nair et al., 2017)	Measured; Statistically Significant
	(Minami et al., 2020)	Review
	(De Alencastro et al., 2020)	Discussed; Not Measured

Discussion

Our scoping review provides several important contributions to the body of scientific knowledge as it pertains to decision thresholds within medical decision-making: 1) to the best knowledge of the authors, it is the first review of non-expected utility decision thresholds used within medical decision-making that adopts a systematic methodology, 2) it systematizes theoretical paradigms that have been employed to inform non-expected utility decision thresholds within medical decision-making, and 3) it identifies various contextual and subjective factors that may inform an individual's decision threshold relative to medical decision-making. These will be discussed, in turn, below.

First, our scoping review is a natural progression from the narrative review by Djulbegovic and colleagues (2015) to the extent that we adopted a JBI scoping review methodology and systematically searched and identified articles from multiple databases to ensure our review was comprehensive and exhaustive. We also preregistered our scoping review protocol to help ensure transparency and reproducibility; whereas, a narrative review does neither. We expanded the scope of our review to include medical/ health related decisions made by non-physicians (e.g., patients, nurses, guardians/ caregivers, etc.). Within the scoping review, we observe that a majority of the research on non-expected utility decision thresholds has been published since 2013. Moreover, it has been close to 10 years since Djulbegovic and colleagues (2015) published their narrative review on decision thresholds and we observe that the literature has matured and almost doubled in relative size since 2013. To this end, our scoping review is of value add to the literature of non-expected utility decision thresholds within medical decision-making as we systematically identify the various non-expected utility decision thresholds that are used to inform decision-making across a variety of stakeholders who are involved in medical decision-making (e.g., physicians, nurses, patients, guardians/ caregivers, etc.).

Second, our scoping review identifies the multiplicity of theoretical paradigms for non-expected utility decision thresholds that are used within the literature related to medical decision-making. This systematic categorization of the theoretical paradigms that are used to inform non-expected utility decision thresholds within medical decision-making is a novel contribution to the literature. In the narrative review by Djulbegovic and colleagues (2015), the authors reflect that the non-expected utility decision thresholds related to physician decision-making included: regret theory, hybrid theory, and dual processing theory (B. Djulbegovic, van den Ende, et al., 2015b). Our review finds that regret theory, hybrid theory, and dual processing theory are common theoretical paradigms, however, we also identified several other theoretical paradigms (e.g., info-gap theory, information theory, regression, etc.) that can also inform non-expected utility decision thresholds. Consequently, our review provides an important resource for scholars and practitioners alike who may seek to study or understand the theoretical paradigms associated with non-expected utility decision thresholds.

Third, our scoping review identifies a variety of contextual (e.g., years of practice, difference between subspecialities, etc.) and subjective factors (e.g., risk attitude, culture, etc.) that influence an individual's decision threshold. Across contextual and subjective factors, we observed that there was a greater number of studies that dealt contextual factors than those dealing with subjective factors. This may be because it is relatively difficult to capture/ measure various subjective factors without pre-emptively impacting/ priming an individual's decision threshold.

Moreover, we also observed inconsistency in the effects of various contextual and subjective factors relative to an individual's decision threshold. For example, where Young and colleagues (1987), Steel (2000), Brundage and colleagues (2001), De Alencastro and colleagues (2020) and van Overbeeke and colleagues (2021) report that an individual's age has a statistically significant effect on decision threshold, this finding is not confirmed by McAlister and colleagues (2000), Cahan and colleagues (2003), Douglas (2012) and Nair and colleagues (2017). Similar, seemingly, contradictory findings were found for other contextual and subjective factors that influence an individual's decision threshold. These apparent contradictions ask for broader and more comprehensive study of these factors alone.

The articles included in this review explore the influence of various subsets of contextual and subjective factors relative to an individual's decision threshold. As previously commented, the effects of these contextual and subjective factors relative to an individual's decision threshold are sometimes inconsistent. Instead of exploring the influence of specific factors relative to an individual's decision threshold, we postulate that it would be advantageous to consider the totality of these factors relative to an individual's decision threshold. To this end, we propose that a broader consideration of an individual's cultural worldview relative to an individual's decision threshold may be a better explanator of why decision threshold differ across individuals. Specifically, cultural cognition theory formulates a perspective where cultural worldviews permeate into risk judgements in a way that helps people to, "evaluate the social meaning of a particular activity against a background of cultural norms and to express the values that define their identities" (Finucane, 2012, p. 680). Within cultural cognition theory affect/ emotion is perceived to enable "a person to identify a stance that is 'expressly rational' for someone with commitment to particular worldviews" (Finucane, 2012, p. 680; Kahan, 2008). Cultural worldviews have been studied across various health related decisions (e.g., abortion (Kahan et al., 2005), vaccines (Kahan, Braman, Cohen, et al., 2010; Kahan, 2013a), public health threats (Kahan, Jamieson, et al., 2017), etc.) and have consistently demonstrated that cultural worldviews explained the variation in risk perception amongst individuals' better than other characteristics such as: education, gender, income, race, personality type and ideology (Kahan, 2012). To this end, relative to the contextual and subjective factors that have been identified (with some inconsistency) to effect decision thresholds, we postulate that cultural worldviews may be a consolidating variable that, like risk perception, can explain variations in individual's decision thresholds.

Relative to cultural worldview, we highlight that several articles discuss the potential impact of religion, intraorganizational cultural or incentives relative to an individual's decision threshold. However, these studies do not quantify culture, beyond qualitative appraisals/ characterizations, and illustratively discuss the potential impact that such a subjective factor might have on an individual's decision threshold. Moreover, none of the articles sought to explore the phenomena of intra-cultural variation/ cultural worldviews ((Kahan, Braman, Cohen, et al., 2010; Kahan, 2012) and its relationship to decision thresholds. To the extent that there are different cultural worldviews within society and this variation likely influences and individual's decision thresholds, we postulate that this heterogeneity within societies might explain why people, even within the same country, have different decision thresholds.

Finally, we reflect on the common use of regret theory and hybrid theory paradigms to inform decision thresholds within medical decision-making. As previously discussed in this chapter, hybrid theory paradigms for decision thresholds are often perceived as a modified expected utility theory approach that is, "based on their knowledge and/or perception of about the harm and benefit of a treatment" (Basinga, Moreira, Bisoffi, Bisig, & Van den Ende, 2007, p. 54). Relative to these theoretical paradigms for decision thresholds there are two important points to make. First, because of the relatively ambiguous formulation of the hybrid theory and its incorporation of weights to reflect individual preferences (Basinga, Moreira, Bisoffi, Bisig, & Van Den Ende, 2007), "the hybrid model may be considered a version of the dual processing model" (B. Djulbegovic, van den Ende, et al., 2015b, p. 488). Second, we highlight the work of Djulbegovic and colleagues (2014) who state that "physician decision-making seems more compatible with the dual processing model than with either expected utility theory or a simple regret model" (B. Djulbegovic et al., 2014a, p. 9). To this end, our choice of the dual processing theory for decision thresholds as our theoretical paradigm is well founded given its substantiation as a valid theoretical paradigm for non-expected utility decision thresholds as it incorporates regret theory and hybrid theory paradigms. Finally, across all theoretical paradigms for non-expected utility decision thresholds, we do not find an incorporation of cultural worldviews into the decision threshold model. To this end, we are confident that our approach of extending the DPM for decision thresholds with the incorporation of risk perception as informed by cultural worldviews is a novel contribution to the body of scientific knowledge on non-expected utility decision thresholds for medical decision-making.

Limitations

Our scoping review has the following limitations:

- It is limited to articles in English language, articles that were indexed on SCOPUS, MEDLINE (Ovid), ProQuest (Theses and Dissertations. Consequently, we could miss the articles that are relevant but not in English nor indexed on either of these databases.
- The theoretical paradigms related to signal detection theory (SDT) as well as logistic regression may have similarities to expected utility theory to the extent that SDT and logistic regression can be used to inform receiver operator characteristic curves (ROC). Within our review, we maintain that SDT and logistic regression are different than expected utility theory and thus are included as non-expected utility decision thresholds.
- Our review had a relatively narrow focus on medical decision making. However, decision thresholds are explored within other contexts (e.g., insurance, econometrics, etc.) that were

not considered in this review but could provide new insights into the methods used or factors considered.

Chapter 5: Incorporating Cultural Worldviews into DPM: An Extended Dual Processing Model (DPM+)

Chapter Summary

In this chapter we proposed the Extended DPM for decision thresholds (DPM+) relative to medical decision-making. Building on the Dual System Model/ Dual Processing Model (DPM) for decision thresholds in medical decision-making, we extend the DPM for decision thresholds by incorporating risk perception informed by cultural worldviews (i.e., as per cultural cognition theory) into the process of an individual's 'type I system' reasoning. Where the DPM for decision thresholds assumes that individuals weigh possible outcomes equally within their process of 'type I system' reasoning, DPM+ posits that an individual's risk perception of those outcomes (i.e., as informed by their cultural worldview) plays an important role in the calculation of an individual's decision threshold. Ultimately, by incorporating the influence of cultural worldviews on an individual's risk perception into DPM+, we provide a prescriptive mechanism for an individual's subjective judgments and values to inform their decision threshold. Moreover, DPM+ seeks to prescriptively explain the decision heterogeneity we observe in preventative medicine related decisions.

This chapter is organized as follows. First, we focus our discussion on the limitations of the DPM model for decision thresholds. After which, we propose DPM+ as a new prescriptive decision-making model to address the various limitations of DPM. We then discuss whether cultural worldviews ought to be included as a function of 'type I system' reasoning or 'type II system' reasoning and conclude that, within the context of decision thresholds, cultural worldviews are a function of 'type I system' reasoning. We then provide an interpretation of DPM+ and discuss its meaningful contribution as a prescriptive decision-making model that can explain how people make different preventative medicine decisions. Finally, we discuss the contribution of DPM+ as well as potential limitations of DPM+.

Theoretical Limitations of DPM for Decision Thresholds

To the extent that the DPM decision-threshold model has been demonstrated to be a better predictor of physician thresholds than thresholds derived from expected utility models and/or regret-based models (B. Djulbegovic et al., 2014), we focus our contribution to advancing DPM for decision-thresholds. However, we contend that the DPM for decision-thresholds is incomplete because it fails to incorporate the influence of an individual's perceived risk and cultural cognition (i.e., 'type I system' reasoning) relative to an individual's decision threshold.

The DPM for decision thresholds is a prescriptive model that has predominantly been used to prescribe decision thresholds for physicians (Boyles et al., 2020; B. Djulbegovic et al., 2012, 2014; B. Djulbegovic, Hamm, et al., 2015; B. Djulbegovic, van den Ende, et al., 2015b; B. Djulbegovic et al., 2017; Tsalatsanis et al., 2015a). From the perspective of a lay-individual (i.e., non-physician), the DPM decision-threshold model is infrequently used to describe individual patient decisions. In the few studies that explore the DPM decision-threshold model from the perspective of the lay-individual (patient), Djulbegovic and colleagues (2016) demonstrated that the DPM for decision-thresholds could be used to explain individual decisions related to end-of-life care decisions (i.e., deciding between palliative/ hospice care and life-prolonging treatment) and that patient decisions are consistent with the course of action that is determined by the DPM for decision thresholds (B. Djulbegovic et al., 2016). Within this study, the authors report that the individuals use of their 'type I system' reasoning dominated their 'type II system' reasoning (B. Djulbegovic et al., 2016). In another study, Djulbegovic and colleagues (2017) compared the thresholds recommend by physicians to the individualized patient threshold for the use of statins for primary prevention of cardiovascular disease (B. Djulbegovic et al., 2017). The study observed that, "the patients' preferences are almost invariably different from their physicians' as also evident by the fact that as many as 17% of patients discontinue statin therapy despite their doctors' recommendations" (B. Djulbegovic et al., 2017, p. 245). This finding is illustrative of the inconsistency between decision thresholds of physicians and decision thresholds of lay-individuals. As an explanation for the inconsistency, the authors offer the explanation that individuals have different preferences and values and it is not appropriate to maintain a fixed decision threshold (B. Djulbegovic et al., 2017).

‘Type II system’ reasoning within the DPM is consistent with explicit/ objective knowledge (i.e., knowledge that is “not specific or idiosyncratic to the person or firm possessing it” (Sobol & Lei, 1994, p. 170; Ambrosini & Bowman, 2001)), linear and consistent with the expected utility model of decision thresholds without risk distortion (B. Djulbegovic et al., 2012a; Mukherjee, 2010), the source of variation of an individual’s decision threshold cannot be a function of differential ‘type II system’ reasoning. Instead, the variation in decision thresholds, as a function of different preferences and values, must be attributable to the ‘type I system’ reasoning process, which may also be influenced by various bias and heuristics (e.g., availability bias, confirmation bias, etc.) that result in greater involvement of ‘type I system’ reasoning.

Arguably, the current research on the DPM for decision thresholds does not provide insights as to how variation in either of these mechanisms prescriptively result in individuals maintaining different decision thresholds. To the extent that the DPM decision-threshold model is a prescriptive model of decision-making, the model is incomplete without a reasonable mechanism to explain how an individual’s decision threshold is likely to vary between individuals. In the remainder of this section, we briefly explore each of these mechanisms and identify why these mechanisms render the DPM of decision thresholds incomplete as a prescriptive decision-making model.

Within the ‘type I system’ reasoning function of the DPM for decision thresholds, there are four potential mechanisms worthy of exploration relative to their sufficiency to explain why individuals maintain different decision thresholds. We will explore each of the four potential sources of variability relative to ‘type I system’ reasoning and identify that the most likely explanation for variability (i.e., attributing different weights to outcomes) cannot be explained by the DPM for decision thresholds.

1. Propensity for different levels of involvement of ‘type I system’ reasoning (Sunstein, 2003b, 2003a, 2005; Weber & Stern, 2011);
2. Different anticipated regret of perceived harms and/ or perceived benefits (B. Djulbegovic et al., 2017);
3. Different ‘risk attitudes’; and,
4. Attributing equal weight to outcomes (B. Djulbegovic et al., 2012a).

First, we explore the relative to the involvement of an individual's involvement of 'type I system' reasoning, as per Mukherjee's (2010) dual system model. As previously discussed, the DPM for decision thresholds generalizes that there are 4 major categories that define the process of 'type I system' reasoning (B. Djulbegovic et al., 2012a). Without objection, individuals, across different actions, are likely to have different levels of involvement of 'type I system' reasoning relative to their decisions. For example, it may be relatively automatic (i.e., dominating 'type I system' reasoning; very little need for deliberative 'type II system' reasoning) for an individual to put their seatbelt on upon getting into their car, whereas an individual driving through bumper-to-bumper traffic, inclement weather, or remembering the pickup and drop off schedule for their children's afterschool activities may require greater involvement of 'type II system' reasoning (i.e., requiring greater need for slow, analytical, deliberative 'type II system' reasoning). However, when we hold the action constant (e.g., putting on a seat belt, driving in inclement weather, etc.) there is little evidence to suggest that one type of person, regardless of their values and/or preferences, is more likely to engage their 'type I system' reasoning relative to another (Kahan, 2016a, 2016b; Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017).

Within the risk perception literature, the science comprehension thesis (SCT) (Kahan, Peters, et al., 2017) postulates the lay public's capacity to comprehend scientific evidence is the primary reason why the lay-public make decisions that are different than scientific experts. Effectively, the SCT suggests that individuals with lesser capacity to comprehend scientific evidence are thought to rely more heavily on their 'type I system' reasoning, and as a result make different decisions than scientific experts as a result of various heuristics (Kahan, Peters, et al., 2017; Sunstein, 2003a, 2003b, 2005; Weber & Stern, 2011). If the SCT were true, then we would expect those of similar education, numeracy levels and involvement of 'type II system' reasoning to make convergent decisions. However, research has shown that for culturally divisive topics (e.g., vaccines, gun control, nuclear energy/ waste disposal, climate change, economic stimulus programs, etc.) that when presented with the same evidence, lay-individuals with equal involvement of 'type II system' reasoning (i.e., as measured by the cognitive reflection test) hold opposing views and make different decisions (Kahan, 2016a, 2016b; Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017). To this end, it is insufficient to conclude that variation in involvement of 'type I system' reasoning is the source of disagreement between decision thresholds of different individuals.

Second, we explore the possibility that different anticipated regret of benefits and/or anticipated regret of harms may be the reason that people maintain different decision thresholds and subsequently make different decisions. As reflected by Dekay and colleagues (2002), decision thresholds are dynamic and subject to change based on an individual's subjective judgements and values (Dekay et al., 2002). Within the DPM for decision thresholds relative to medical decision-making, the 'type I system' reasoning incorporates anticipated (ex-ante) regret as an important function (B. Djulbegovic et al., 2012a). Regret is often identified as a driver of 'irrational' decision-making given its' tendency to influence people to make decisions that are inconsistent with expected utility theory (Sugden, 1985). Specifically, regret can be measured as, "the difference between the utility of the action taken and the utility of the action that in retrospect should have been taken" (Hozo et al., 2018a, p. 68); this is consistent with how anticipated regret is adjudicated within the DPM for decision thresholds. Relative to DPM for decision thresholds, Djulbegovic and colleagues (2016) call for additional research to evaluate if, "cultural background, religion, race, and ethnicity affect regret" (B. Djulbegovic et al., 2016, p. 35). The authors postulate that these factors will not have an effect because, "regret is a unique human emotion, which appears to be easily understood by people of all races and background" (B. Djulbegovic et al., 2016, p. 35). While there is some empirical evidence the individuals of different cultural orientation experience different anticipated regrets (Breugelmans et al., 2014; Komiya et al., 2011), the literature remains. inconclusive if the level of anticipated regret is unique to different individuals (Gilovich et al., 2003; Gilovich & Medvec, 1995). Regardless, within the DPM for decision thresholds, because anticipated regret of harms and benefits is measured as the differential between two counterfactuals (i.e., $H_1 = x_4^{m_1} - x_2^{m_1}$ and $B_1 = x_1^{m_1} - x_3^{m_1}$; see page 19 for explanation of parameters) (B. Djulbegovic et al., 2012a), the only mechanism in which individuals can experience differential anticipated regrets is by virtue of differential risk attitudes (i.e., parameter $m_1; 0 < m \leq 1$). Yet, in applications of DPM, the values for H_1 and B_1 are often specified regrets (e.g., "I would regret this outcome X much") and do not invoke an exponent m to differentiate the anticipated regret of harm and the anticipated regret of benefit from those anticipated harm and anticipated benefit as prescribed by 'type II system' reasoning (B. Djulbegovic et al., 2012a); in the toy examples of DPM in the literature m_1 is commonly set to 1 (i.e., 'risk seeking'; see following paragraph(s) for additional explanation). It may be possible that individuals of differing cultural worldviews have different anticipated regrets, however, within the existing DPM for decision thresholds this potential source of variation is not possible to consider.

Thirdly, we explore the potential effects of risk attitude on an individual's decision threshold. As per Mukherjee (2010), the m_1 parameter is reflective of an individual's risk attitude. Importantly, risk attitude and risk perception are distinct concepts, albeit they are interconnected (Pennings & Grossman, 2008; Weber & Milliman, 1997). Risk perception refers to an individual's subjective judgement about the likelihood of a negative outcome (Fischhoff et al., 1984, 2011; Slovic, 1993), whereas risk attitude is an individual's predisposition to a particular risk and is reflective of how an individual behaves in relation to said particular risk (Pennings & Grossman, 2008). We focus our attention here on risk attitude, and observe that within the DPM for decision thresholds an individual's risk attitude is bounded such that $0 < m \leq 1$ (B. Djulbegovic et al., 2012a; Mukherjee, 2010). An individual's risk attitude is reflective of one of three behaviours: 'risk neutral', 'risk seeking' and 'risk averse' (B. Djulbegovic et al., 2012a; Mukherjee, 2010). When an individual is 'risk neutral' they are not sensitive to risks but rather are indifferent to certain versus uncertain outcomes when the expected payoffs are equivalent. Alternatively, when an individual's risk attitude is 'risk seeking' the individual prefers uncertain outcomes, relative to certain outcomes, even when the expected payoffs are the same (Weber et al., 2002). Finally, when an individual has a 'risk averse' risk attitude the individual prefers certain outcomes, relative to uncertain outcomes, even when the payoffs are the same (Weber et al., 2002). Within the DPM for decision thresholds, risk attitudes are interpreted to be context specific. While the related literature on risk attitudes is emerging, there is insufficient empirical evidence to substantiate that certain individuals have greater (or lesser) propensity for risk seeking (risk aversion). We postulate that variation in risk attitude in the DPM for decision threshold is likely to be normally distributed across the population and is not the source of variation of decision thresholds. Consequently, if risk attitude were the source of variation of decision thresholds, and if it were to be randomly distributed across the population, differential in risk attitudes would fail to explain why there are culturally divisive topics (e.g., vaccines, gun control, nuclear energy/ waste disposal, climate change, economic stimulus programs, etc.) for which different groups hold opposing views and make different decisions (Kahan, 2016a, 2016b; Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017). We reflect that a detailed discussion of the interpretation of the 'risk attitude' parameter is generally absent from Djulbegovic and colleagues (2012) formulation of DPM for decision thresholds.

Finally, we explore the assumption that all outcomes are weighted equally within an individual's 'type I system' reasoning within the DPM for decision thresholds (B. Djulbegovic et al., 2012a). Within the DPM for decision thresholds, an individual's 'type I system' reasoning is believed to be insensitive to probabilities and, consequently, "every outcome with nonzero probability gets equal weight in this system" (Mukherjee, 2010, p. 245). This assumption is akin to suggesting that individuals are indifferent to the various outcomes and evaluate their possibility of occurrence no differently than they would a flip of the coin (i.e., 1:1 odds). To the extent that the DPM for decision thresholds models this assumption as a constant, it cannot be a source of variation for decision thresholds. Moreover, the assumption that people weigh possible outcomes equally within their 'type I system' reasoning (i.e., fast, intuitive) is inconsistent with the 'risk as feelings' hypothesis (Loewenstein et al., 2001) and larger body of literature that relates to the study of risk perception (Finucane, 2012; Finucane & Holup, 2006; Slovic, 1987; Slovic et al., 2004; Slovic & Peters, 2006). While it is well established that individuals are commonly insensitive to probability (e.g., they are indifferent to 1 in 100,000 and 1 in 10,000 chances of winning) (Loewenstein et al., 2001), we position that it is unlikely that individuals weigh outcomes equally. Given the considerable literature on various biases and heuristics that people leverage in decision-making (Tversky & Kahneman, 1974), we find it unlikely that people give equal weight to all possible outcomes under their 'type I system' reasoning. Instead, we postulate that insight could be drawn from the risk perception literature to inform this parameter.

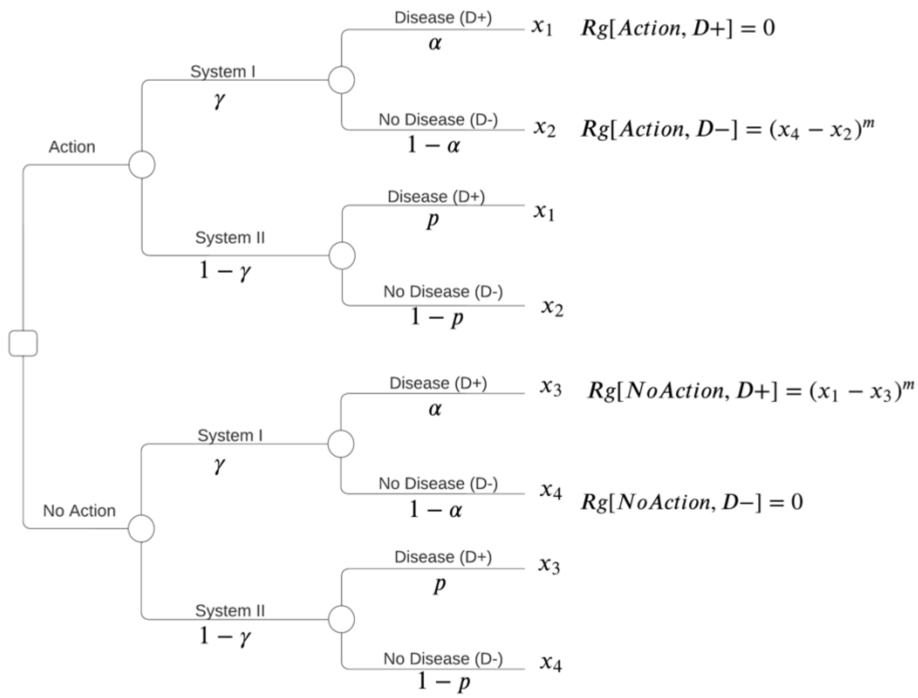
Theoretical Extension of the Dual Processing Model for Decision Thresholds

In this section, we propose an extended dual processing model for decision thresholds (DPM+) for preventative medical decision-making. As previously discussed, the DPM for decision thresholds has several theoretical challenges that limit its prescriptive explanatory power and generalizability to non-physicians at an individual level. Specifically, we challenge the assertion that lay-individuals weigh outcomes equally within their 'type I system' reasoning and contend that the inequal weighing of outcomes, informed by an individual's risk perception and cultural worldview, can prescriptively describe why different phenotypical groups of people make different decisions.

We recognize that within the management literature there are several interpretations of the term 'cultural worldview'(M. (Tew) Douglas & Wildavsky, 1982; Hofstede, 1983c, 1983d, 1983b, 1983a; Kahan, 2012; Koltko-Rivera, 2004). Throughout the rest of this thesis, we adopt an interpretation of cultural worldviews that is consistent with Kahan and colleagues (2012) proposed cultural cognition theory. Cultural cognition theory's interpretation of cultural worldviews seeks to combine a version of cultural theory with the psychometric paradigm as per Slovic and colleagues (1987) (Kahan, 2012). Specifically, cultural cognition theory uses two continuous attitudinal scales to denote an individual's cultural worldview: 1) "hierarchy-egalitarianism", and 2) "individualism-communitarianism" (see Figure 2) (Kahan, 2012). The scale related to "hierarchy-egalitarianism", seeks to measure, "a person's relative orientation toward high or low 'grid' ways of life" (Kahan, 2012, p. 730), whereas the scales related to "individualism-communitarianism" includes, "items that determine a person's relative orientation toward weak or strong 'group' ways of life" (Kahan, 2012, p. 730). We perceive the adoption of Kahan and colleagues (2012) interpretation of cultural worldviews to be appropriate for DPM+ to the extent that this interpretation has already been adopted within the risk perception literature.

The DPM for decision thresholds assumes that 'type I system' reasoning, "recognizes only whether an outcome is possible and is entirely insensitive to probabilities. Hence, every outcome with nonzero probability gets equal weight in this system" (Mukherjee, 2010, p. 245). Within the DPM for decision thresholds, "in a two-alternative choice, each probability is equal to 0.5 under system I" (B. Djulbegovic et al., 2012a, p. 3). The DPM+ revises this assumption to the extent that, "people typically do not know the exact probabilities associated with the relevant outcomes, but they have some notion about their likelihood" (Tversky & Fox, 1995, p. 281). Moreover, within medical contexts because of the asymmetrical nature of the gambles between false positives and false negatives, "using equal weights for false-positive and false-negative decisions is 'not realistic in many medical applications" (Steyerberg et al., 2010, p. 9; Greenland, 2008). To this end, within the DPM+, we use risk perception informed by an individual's cultural worldview (i.e., parameter α, as depicted in Figure 6) as a proxy for perceived probability of the associated outcomes instead of assuming that people will weigh outcomes equally within 'type I system' reasoning. The decision tree model for DPM+ which calculates the associated decision threshold for the corresponding binary decision (i.e., action vs. no action) is shown in Figure 6.

Figure 6- Extended Dual Processing Model of Decision Thresholds (DPM+) for Medical Decision-Making



The parameter γ in Figure 6 is reflective of the level of involvement for an individual's 'type I system' reasoning and is bounded such that $0 \leq \gamma < 1$. Correspondingly, $1 - \gamma$ is reflective of the level of involvement of an individual's 'type II system' reasoning. The parameter p is reflective of the objective probability (i.e., 'type II system' reasoning) of disease, and the complement (i.e., $1 - p$) is reflective of the objective probability of no disease. The parameter α is reflective of the perceived probability of disease as informed by an individual's cultural worldview, and the complement (i.e., $1 - \alpha$) is the perceived probability of no disease. The variable x_i is indicative of the utility of each respective outcome. Rg[Action, D+] (read: regret of action when disease is present) and Rg[NoAction, D-] (read: regret of no action when there is no disease present) represent the amount of regret an individual would experience (i.e., either ex-ante or ex-post). For both Rg[Action, D+] and Rg[NoAction, D-] the amount of regret that an individual would experience for having made the correct decision is understood to be zero as they would rejoice having made the 'correct' decision (Landman, 1987a, 1987b). Alternatively, we anticipate the individual would experience regret in scenarios where they made the incorrect decision, which is represented by Rg[Action, D-] (read: regret of action when there is no disease present) and Rg[NoAction, D+] (read: regret of no action when the disease is present).

Similar to the DPM for decision thresholds, in the DPM+ we, "define regret (Rg) as the difference (loss) in the utilities of the outcome of the action taken and that of the action we should have taken, in retrospect" (B. Djulbegovic et al., 2012a, p. 4). DPM for decision thresholds and DPM+ differ when it pertains to the involvement of an individual's risk attitude (i.e., parameter m) within the 'type I system' reasoning. Within the DPM for decision thresholds, the net benefit and net harms for 'type I system' reasoning are defined, respectively, as followed: $B_I = x_1^m - x_3^m$, $and\ H_I = x_4^m - x_2^m$ (B. Djulbegovic et al., 2012a). Within the 'type I system' reasoning, the parameter m is bounded, such that $0 < m \leq 1$, and is intended to represent an individual's risk attitude (i.e., 'risk seeking', 'risk averse', 'risk neutral') through the use of a power value function (B. Djulbegovic et al., 2012a; Mukherjee, 2010). Within the DPM+, we maintain that the parameter m represents an individual's 'risk attitude', however we calculate the net benefit and net harm for 'type I system' reasoning in the following way: $B_I = (x_1 - x_3)^m, and\ H_I = (x_4 - x_2)^m$. The DPM+ simplifies the power value function that represents the calculation of net benefits and net harms for 'type I system' reasoning for three reasons:

- First, to the extent that 'type I system' reasoning is perceived to be affectively driven, fast, and intuitive it is unlikely that individuals undertake a relatively complex form of mental arithmetic (i.e., raising individual outcomes to an exponent that is reflective of their risk attitude and then taking the difference). Instead, we postulate that their probability weighted anticipated regret (in its totality) is then subject to their value function (i.e., power value function) as determined by their risk attitude.
- Second, the DPM+, similar to the DPM for decision thresholds, assumes that valuation of outcomes within the 'type I system' reasoning is informed by the emotion of anticipated regret (B. Djulbegovic et al., 2012a). Conceptually, anticipated regret represents the difference in utilities between the action taken and the action that could have been taken had a different decision been made (Zeelenberg, 1999; Zeelenberg et al., 1996, 2002). However, when regret is measured empirically, researchers typically rely on participants Likert style response to questions similar to: "how much would a person regret his decision" (Zeelenberg et al., 2002), "how much would you regret that she did not get the HPV vaccine" (Ziarnowski et al., 2009, p. 412), etc.. To the extent that the common measurement of regret only identifies the anticipated regret (i.e., the perceived difference

in utility between two outcomes) it is appropriate that the difference of anticipated regrets provides the base of the power value function.

- Finally, by incorporating perceived risk (i.e., parameter α) into the calculation of anticipated regret of benefit and anticipated regret of harm, we can account for the notion that when people perceived greater risk of disease that they are likely to anticipate greater anticipated regret of benefit associated with treatment (i.e., αB_I^m). Alternatively, if an individual perceives little risk of disease, they are likely to anticipate greater anticipated harm associated with treatment (i.e., $(1-\alpha)H_I^m$).

Consequently, the decision threshold (P_t) equation for DPM+ is as follows:

$$P_t = \frac{1}{1+\frac{x_1-x_3}{x_4-x_2}}\left[1+\ \frac{\gamma}{(1-\gamma)}\ \left(\frac{(1-\alpha)(x_4-x_2)^m}{(x_4-x_2)}\right)\left(1-\frac{\alpha(x_1-x_3)^m}{(1-\alpha)(x_4-x_2)^m}\right)\right]$$

This equation can be simplified in the following way:

$$P_t = \frac{1}{1+\frac{B_{II}}{H_{II}}}\left[1+\ \frac{\gamma}{(1-\gamma)}\ \left(\frac{(1-\alpha)H_I}{H_{II}}\right)\left(1-\frac{\alpha B_I}{(1-\alpha)H_I}\right)\right]$$

The calculation of the decision threshold (P_t) based on the above equation estimates the point of relative indifference an individual/ decision-maker would be relative to the benefits and risks (i.e., action = no action) of the associated decision with consideration of the involvement of an individual's 'type I system' reasoning and 'type II system' reasoning. If the estimated probability of disease is greater than the threshold (i.e., P(disease) > Threshold) then action should be taken/ applied (Pauker & Kassirer, 1975b). Alternatively, if the estimated probability of disease is less than the threshold (i.e., P(disease) < Threshold) then action should be withheld (Pauker & Kassirer, 1975b). Similar to the threshold as calculated by the DPM for decision thresholds, the parameter γ represents the amount of involvement of an individual's 'type I system' reasoning relative to their involvement of 'type II system' reasoning (i.e., $1 - \gamma$ = involvement of 'type II system' reasoning) (B. Djulbegovic et al., 2012a). The parameter B_{II} represents the benefits as determined by 'type II system' reasoning and can be calculated as followed: $B_{II} = x_1 - x_3 =$

$U(True\ Positive) - U(False\ Negative)$. The parameter H_{II} represents the harms as determined by 'type II system' reasoning and can be calculated as followed: $H_{II} = x_4 - x_2 = U(True\ Negative) - U(False\ Positive)$.

Because DPM+ does not assume that individual's weigh outcomes equally within their 'type I system' reasoning, the estimation of B_I and H_I in DPM+ differs from DPM for decision thresholds. In DPM+ the parameter B_I represents the anticipated regret of benefits as determined by 'type I system' reasoning and is simplified to the following equation: $B_I = \alpha(x_1 - x_3)^m = \alpha(U(TP) - U(FN))^m$; where m reflects an individual's risk attitude such that $0 < m \leq 1$. The parameter H_I represents the anticipated regret of harms as determined by 'type I system' reasoning and can be calculated as followed: $H_I = (1 - \alpha)(x_4 - x_2)^m = (1 - \alpha)((U(TN) - U(FP))^m$.

Cultural Cognition and Cultural Worldviews: 'Type I System' Reasoning or 'Type II System' Reasoning?

DPM+ incorporates the effects of an individual's risk perception as informed by their cultural worldview and the effects that this has on an individual's decision threshold by way of their 'type I system' reasoning. We acknowledge that there are some researchers who have postulated that cultural cognition is a form of 'type II system' reasoning (Kahan, 2016a, 2016b; Kahan, Peters, et al., 2017). Specifically, these authors commonly cite that, "individuals scoring highest on standard measures of System 2 reasoning are the *most* polarized on the existence of climate change, the efficacy of control, and other contested risks" (Kahan, 2016b, p. 2; emphasis in original) and that, "it is perfectly rational, *from an individual welfare perspective*, for individuals to engage with decision-relevant science in a manner that promotes culturally or politically congenial beliefs" (Kahan, Peters, et al., 2017, p. 77; emphasis in original). Consequently, these authors position that, "ideologically motivated reasoning is expressively rational" (Kahan, Peters, et al., 2017, p. 77) and should therefore be considers an attribute of 'type II system' reasoning. Although cultural cognition and cultural worldviews are the central extension of DPM+, we do not agree with the proposition that cultural worldviews are an attribute of 'type II system' reasoning. Instead, we maintain that cultural worldviews are attributable to 'type I system' reasoning within DPM+. This assertion will be explained in greater detail in this section.

Both the DPM for decision thresholds and DPM+ maintain that the 'type II system' reasoning is consistent with expected utility theory, linear, and free from distortions (B. Djulbegovic et al., 2012a; Mukherjee, 2010). 'Type II system' reasoning can be interpreted as akin to what is known as 'objective knowledge' (Ambrosini & Bowman, 2001). Within the literature, objective knowledge can readily be explained, understood, encoded or written down (Ambrosini & Bowman, 2001; Sobol & Lei, 1994). Importantly, similar to 'type II system' reasoning and expected utility theory, objective knowledge is, "not specific or idiosyncratic to the person or firm possessing it" (Sobol & Lei, 1994, p. 170). To the extent that the literature has evidenced that people of different cultural worldviews have different appraisals of the perceived benefits and risks associated with the same hazard (Kahan, 2013b; Kahan, Braman, Cohen, et al., 2010; Kahan, Braman, Monahan, et al., 2010; Kahan et al., 2007), we postulate that cultural worldviews and cultural cognition theory are not attributable to 'type II system' reasoning (at least as it relates to decision thresholds).

Instead, we position that the effects of cultural cognition and cultural worldviews are attributable to 'type I system' reasoning as a form of tacit knowledge (Johnson, 2022; Kahan, Jamieson, et al., 2017). Illustratively, the knowledge of how to ride a bicycle, swimming, kneading bread, and how to use a word processor are common examples of tacit knowledge (Collins, 2007; Linde, 2001; Polanyi, 1966). Tacit knowledge, "consists of mental models that individuals follow in certain situations[…and are] so embedded within the individual that is seems entirely natural" (Ambrosini & Bowman, 2001, p. 813). Specifically, tacit knowledge is personal in nature and can be informed by an individual's personal experiences, is context specific, and is difficult to codify and/ or totally articulate the process through which an individual comes to an understanding on a given topic (Ambrosini & Bowman, 2001; Boiral, 2002; Leonard & Sensiper, 1998). Relative to the example of the tacit knowledge of riding a bicycle, it may not be possible for an individual to articulate how they manage to keep their balance (Polanyi, 1966). Moreover, it becomes increasingly difficult to explain social conventions for traffic management to ensure safe passage on a bicycle (Collins, 2007). For example:

> "[…] knowing how to make eye contact with drivers at busy junctions in just the way necessary to assure a safe passage and not to invite an unwanted response. And it involves understanding how differently these conventions will be executed in different

> locations. For example, bike-riding in Amsterdam is a different matter to bike-riding in London, or Rome, or New York, or Delhi, or Beijing."
>
> (Collins, 2007, p. 259)

Yet, if an individual cannot articulate this knowledge in a meaningful way, or even if they have an entirely wrong or grossly imperfect idea of it, it does not mean that they do not know how to ride a bike (Collins, 2007; Polanyi, 1966). To this end, cultural cognition and cultural worldviews, could likely be described as a form of collective/ group tacit knowledge (Collins, 2007; Erden et al., 2008; Hecker, 2012; Johnson, 2022; Kahan, Jamieson, et al., 2017). Specifically, collective tacit knowledge, "is the accumulated knowledge of the organization stored in its rules, procedures, routines and shared norms which guide problem-solving activities and patterns amongst its members" (Hecker, 2012, p. 424). Comparatively, "cultural cognition theory assumes that cultural worldview are latent predispositions of individuals (i.e., shared but unobservable orientations that one can measure, with varying degrees of precision, by observable indicators, primarily in the form of professed attitudes)" (Kahan, 2012, p. 736). It is the various psychological mechanisms that underpin an individual's cultural worldviews (i.e., as per by cultural cognition theory) that formulate collective/ group tacit knowledge; it would be exceptionally difficult (likely impossible) for an individual(s) to articulate how these mechanisms informed their beliefs. Ultimately, cultural worldviews create, "group values [that] invest objects (for example, guns) action (the termination of a pregnancy), or states of affairs (industrialization) with social meanings the valence of which determines whether group members' affective appraisals are positive or negative" (Kahan, Jamieson, et al., 2017, p. 3). Consequently, "beliefs on risks and related facts bear *social meanings*- that they are, in fact, generally understood (tacitly, at least) to convey that the individuals who espouse them are committed to one group *rather than* another" (Kahan, 2013b, p. 419).

We concede that there may be elements of cultural cognition theory and cultural worldviews that may be inherently 'rational' and that might be attributable to 'type II system' reasoning within the context of decision-making and an individual's chosen behaviour. For example, because of the effects that we postulate risk perception (i.e., as informed by cultural worldview) has on an individual's decision threshold, variability in an individual's decision-threshold may inherently explain how people of different cultural worldviews can make diametrically opposing decisions that are themselves expressively rational. With that said, we maintain our position, that relative to decision threshold analysis, cultural cognition theory and cultural worldviews are an expression of collective/ group tacit knowledge and are therefore attributable to 'type I system' reasoning.

Interpretation of DPM+

The DPM for decision thresholds and DPM+ are used to calculate a decision threshold, which is a continuous value that is interpretable between the values of 0 and 1; the former assumes that people evaluate outcomes equally as part of their 'type I system' reasoning, the later incorporates the effects of cultural worldview on perceived risk. As previously discussed, a decision threshold is reflective of a particular point of indifference between available actions. When the available evidence exceeds the decision threshold, then an individual should act in favour of the factual claim[12], otherwise they should defer to their presumptive claim[13].

A decision threshold that is less than or equal to 0 only occurs in a scenario where the quotient of perceived anticipated regret of benefits relative to perceived anticipated regret of harms is greater than 1 (i.e., $\frac{B_I}{H_I} > 1$)[14]. In this situation, if the decision threshold were to be less than or equal to 0, any evidence in favour of factual claim would be sufficient to warrant action consistent with the factual claim; any decision threshold that is less than 0 can be treated as a threshold of equal to 0 and has no additional interpretation (B. Djulbegovic et al., 2012a; Hozo et al., 2008a; Tsalatsanis et al., 2010a). Alternatively, if the decision threshold is greater than or equal to 1, then action in the direction of the factual claim is only warranted in the case of absolute certainty (i.e., treated as

[12] A **factual claim** expresses, "a belief about the way the world was, is, or will be" (Findlay, nd, p. 2). A factual claim may be true or false with, "the implication that the truth of the claim has been demonstrated – at least to the claimant's satisfaction" (Findlay, nd, p. 2). When making decisions under uncertainty a decision-makers make a factual claim that is informed by evidence about what they believe the true state of affairs to be. To this end we assume that any action/ decision/ hypothesis is consistent with the factual claim being made.

[13] "A **presumptive claim** is a claim that is presumed to be true either as a matter of procedure or in absence of a systematic consideration of the evidence. […] For example, in a criminal trial […] the presumption is that the defendant is innocent unless "proven" otherwise[…] Should the prosecution fail to do so, the presumption [of innocence] stands and the charges are dismissed" (Findlay, nd, p. 17)

[14] A quotient of perceived anticipated regret of benefits relative to perceived anticipated regret of harms that is > 1 does not guarantee that the decision threshold will be less than 0. Ultimately it will depend on the magnitude of the difference in addition to the involvement of an individual's type I system reasoning and the quotient of perceived anticipated regret of harms relative to the objective harms (i.e., as per the type II system). However, for a decision threshold to be less than 0, this condition (i.e., $\frac{B_I}{H_I} > 1$) must be met.

equivalent to a threshold of 1), which is a realistically unachievable goal (H. Douglas, 2000; Hozo et al., 2008a; Tsalatsanis et al., 2010a).

Contribution of DPM+

DPM+ can explain decision heterogeneity for individuals of different cultural worldviews by attributing different weights to anticipated outcomes as a product of perceived risk within their 'type I system' reasoning. Through employing DPM+, individuals of different cultural worldviews, can have the same involvement of their 'type I system' reasoning, have the same risk attitude, the same anticipated regret of benefits/ harms[15], and simultaneously maintain different decision thresholds. Consequently, decision heterogeneity amongst individuals, specifically as it pertains to preventative medicine decisions, may be able to be explained as a function of individuals of differing cultural worldviews having different decision thresholds.

In an example related to preventative medicine decisions, the DPM+ can be used to explain the heterogeneity in decisions that pertain to a parent's decision to vaccinate their child(ren) (e.g., the human papillomavirus (HPV) vaccine). The decision whether to vaccinate one's child(ren), despite scientifically demonstrated efficacy of the HPV vaccine (Lu et al., 2011), has proven to be a source of decision heterogeneity (i.e., some choosing to vaccinate their child(ren), and others not). Specifically, in Canada, it is estimated that the HPV vaccine uptake is roughly 56% of the eligible population (Bird et al., 2017), and in the United States it is estimated that roughly 59% of the eligible population are up to date with their HPV vaccination (Pingali et al., 2021). Notably, research has demonstrated that people of differing cultural worldviews have different perceptions of the harms associated with the HPV vaccine (Kahan, Braman, Cohen, et al., 2010), and likely have different perceptions of the probability of contracting HPV itself (Chen et al., 2020; Xue et al., 2014). The DPM+ can explain this decision heterogeneity regarding HPV vaccination though identifying that individuals of different cultural worldview maintain different decision thresholds.

[15] $B_I = \alpha(x_1 - x_3)^m$ and $H_I = (1-\alpha)(x_4 - x_2)^m$. Theoretically, because the values of x_i are derived from type II system reasoning, then all individuals, regardless of their cultural worldviews, ought to have the same value for: $x_1 - x_3$ and $x_4 - x_2$. As previously discussed, the value of alpha (α) is reflective of an individual's perceived risk of disease as informed by their cultural worldview, and m is reflective of their risk attitude.

Importantly, the DPM for decision thresholds fails to explain this heterogeneity between individuals in a convincing manner (i.e., as discussed in the limitations of DPM for decision thresholds). Contrastingly, the DPM+ incorporates an individual's cultural worldview, by way of their risk perception, to inform their decision threshold. The incorporation of cultural worldview and risk perception into the DPM+ is an important advancement to the extent that people of different cultural worldviews perceive risks differently. Consequently, decision heterogeneity may be explained as function of individuals of different cultural worldviews having different decision thresholds. For example, individuals who hold a cultural worldview that is more egalitarian (i.e., egalitarian-communitarian, and egalitarian-individualism) typically perceive greater risks of disease than those whose cultural worldview is more hierarchical (i.e., hierarchical-communitarian, hierarchical-individualism) (Chen et al., 2020). For example, we would expect those with a cultural worldview that is egalitarian orientated to have a greater perceived risk of HPV than those with a cultural worldview that is of hierarchical orientation. Contrastingly, those of with a cultural worldview that is hierarchically oriented perceive greater risk associated with the HPV vaccine itself (i.e., perceived risk of adverse event related to the vaccine) than those individuals with a cultural worldview that is oriented in the egalitarian direction (Kahan, Braman, Cohen, et al., 2010).

Consequently, we postulate that the DPM+ will reveal that individuals of different cultural worldviews have different decision thresholds. To the extent that individuals with a cultural worldview that is hierarchical in orientation often have greater perceived risks associated with adverse outcomes and smaller perceived risk of disease itself, in comparison to those individuals with a cultural worldview that is egalitarian in orientation, we expect individuals of different cultural worldviews to have different decision thresholds. Relative to decision thresholds, we expect that those of cultural worldview that are hierarchical in orientation will have higher decision thresholds than those of individuals with cultural worldviews that are oriented more towards egalitarianism because of their different perceived risks associated with various outcomes.

Applications of DPM+

DPM+ is conceptualized for preventative medical decisions and is specific to estimating the decision thresholds for a lay-individual (e.g., patient, caregiver, guardian). To this end, DPM+

could be used to estimate individual decision thresholds across a wide array of preventative medicine decisions (e.g., disease screening, prescription medication adherence, rehabilitation participation, vaccinations, etc.) and is not prescriptive to a specific preventative medicine decision. To apply DPM+ to different preventative medicine decisions would require the model inputs to be parameterized to the specified preventative medicine decisions with both the 'type I system' reasoning and 'type II system' reasoning arms of the model.

We specify that DPM+ is a prescriptive decision threshold model for lay-individuals as opposed to physicians. Specifically, DPM+'s contribution to the literature is based on the premise that lay-individuals are unlikely to weigh outcomes equally within their 'type I system' reasoning. However, theoretically, it is possible that physicians might be indifferent to potential outcomes and consequently attribute equal weighing to foreseeable outcomes within their 'type I system' reasoning (i.e., as prescribed by DPM). We challenge this assertion that physicians are impervious to the various heuristics and biases that may inform an individual's perceived risk of various outcomes, however this is beyond the scope of DPM+ and requires future exploration.

DPM+ can be used by lay-individuals and public policy makers alike. If DPM+ were adapted into a bed-side decision support tool, there is the potential that DPM+ could help patients identify their decision thresholds as informed by their perceived risk of various foreseeable outcomes. In turn, this would provide healthcare providers an opportunity to have an explicit informed discussion that is specific to various patient concerns that may be unduly informing their decision threshold (i.e., the patients decision threshold is either inappropriately high or low). From the perspective of a public policy maker, DPM+ can prescriptively explain why people of different cultural worldview may make different preventative medicine decisions. Consequently, by identifying the heterogeneity in decision thresholds this may provide an opportunity for decision-makers to tailor public health communication campaigns that are specific to the concerns of various groups of differing cultural worldviews (e.g., focusing educational messaging about the risk of a false negative or false positive to inform an individual's perceived risk).

Finally, although DPM+ is conceptualized for preventative medicine decisions, there is little reason to believe that DPM+ could not be applied to other decision-making contexts. For example, Robinson, Botzen and colleagues (2015; 2018, 2019, 2020) have explored decision thresholds within the context of an individual's decision to purchase flood insurance. It is possible that the DPM+ might be able to be applied to contexts other than preventative medicine decisions- these additional applications would require additional consideration and are beyond the scope of this thesis.

Limitations of DPM+

Many of the limitations for DPM+ are also shared for DPM for decision thresholds and include the following:

- The DPM and DPM+ implicitly assume an **independence between probability and utility estimates within the 'type 1 system' reasoning**. If DPM+ were a descriptive model, we highlight the potential for a dependency between probability and utility estimates that may be a consequence of other biases and heuristics (e.g., availability bias, etc.) that are known to influence people's decisions (Tversky & Kahneman, 1974). Because we position DPM+ as a prescriptive model, the concern of independence versus dependence of probabilities and utility estimates is mitigated.
- Similar to DPM for decision thresholds, **DPM+ does not provide a prescriptive explanation for why certain individuals may be more prone to have a greater involvement of their 'type I system' reasoning**. With that said, there is little evidence to suggest that one type of person, regardless of their values and/or preferences, is more likely to engage their 'type I system' reasoning relative to another (Kahan, 2016a, 2016b; Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017). However, we note that being prone to have a greater involvement of 'type I system' reasoning might represent a possible explanation for why individuals might have heterogeneity in relation to their decision thresholds.
- **DPM+ does not provide any prescriptive instruction relative to the risk attitude parameter (i.e., m)**. Instead, in explaining decision heterogeneity, we assume that 'risk attitude' is normally distributed across a population converging on a mean risk attitude that is reflective of being 'risk neutral'. We maintain that this assumption is valid as there is insufficient empirical evidence to substantiate that certain individuals have greater (or lesser) propensity for risk seeking/ risk aversion behaviours. Consequently, we maintain

that heterogeneity in decision thresholds is reflective of the differences in how groups weigh of outcomes within ‘type I system’ reasoning.

- Both DPM+ and DPM assume that an individual’s involvement of ‘type I system’ reasoning is limited such that $0 \leq \gamma < 1$. Effectively, **if a decision were ever to be solely motivated by an individual’s ‘type I system’ reasoning the calculations for DPM+ and DPM for decision thresholds become undefined**. In essence, this limitation stipulates that in all decisions there is always some involvement (no matter how small) of ‘type II system’ reasoning.
- In DPM+ and DPM calculations for **decision thresholds have the potential to estimate decision thresholds that are greater than 1, as well as less than 0**. In both situations, decision thresholds that exist beyond the limits of 0 and 1 have limited interpretability. As previously discussed, any decision threshold that is less than 0 has no meaningful interpretation and can be treated as a threshold of equal to 0 (B. Djulbegovic et al., 2012a; Hozo et al., 2008a; Tsalatsanis et al., 2010a). Alternatively, if the decision threshold is greater than or equal to 1, then action in the direction of the factual claim is only warranted in the case of absolute certainty, which is a realistically unachievable goal (H. Douglas, 2000; Hozo et al., 2008a; Tsalatsanis et al., 2010a). Prescriptively, we can accept these theoretical conclusions.
- From an applied perspective, **it is unlikely that an individual would ever maintain a decision threshold of 0 or 1**. Instead, there may be an asymptote that decision thresholds reach before they cross the limits of 0 and 1. The asymptote before the decision threshold crosses the lower theoretical limit of 0 may be thought of as a “minimally convincing threshold”, such that an individual may maintain a decision threshold that always requires some substantiation (i.e., to a varying level that is greater than 0) of the factual claim before taking action. Similarly, there may be an asymptote before an individual’s decision threshold crosses the upper theoretical limit 1, which could be identified as a “maximally convincing threshold”. An asymptote reflective of a ‘maximally convincing threshold’ embraces the understanding that condition of absolute certainty is a realistically unachievable goal, and while individuals may maintain decision thresholds for certain issues that requires the probability of an event to be “virtually certain” (Weiss, 2003b), it

does not condemn an individual to never acting regardless of the available evidence. The study of such asymptotes is beyond the scope of this research.

- As previously stated, **DPM+ is a prescriptive model** and not a descriptive model for decision thresholds. DPM+ is informative of how an individual should (or ought to) estimate their decision threshold, whereas a descriptive model would identify how people have previously estimated their decision threshold (i.e., in a 'real world' setting). It would be advantageous in future research to establish a descriptive version of DPM+.

Chapter 6: Proof of Concept

Chapter Summary

In this chapter we describe a proof of concept case study to demonstrate how DPM+ model generates decision thresholds that are informed by an individual's cultural worldview. Specifically, we explore the cultural worldviews of: hierarchical-communitarian, hierarchical-individualism, egalitarian-communitarian, and egalitarian-individualism. We constructed a case study related to the human papillomavirus (HPV) vaccine to illustrate how a difference in perceived risk of disease (i.e., as informed by an individual's cultural worldview) impacts decision thresholds by way of the 'type I system' reasoning (i.e., cognitive processes that are, "intuitive, automatic, fast, narrative, experiential and affect-based" (B. Djulbegovic et al., 2012a, p. 1)). We derived cultural worldview informed decision thresholds using a Monte Carlo simulation to incorporate uncertainty in the parameter estimates used in the DPM+.

This chapter is organized to demonstrate that the incorporation of risk perception as informed by cultural worldviews within DPM+ produce differences in an individual's decision threshold when controlled for 1) involvement of 'type I system' reasoning[16], and 2) an individual's 'risk attitude'. When controlled for each of these independent variables, we observed (across all scenarios) that individuals of differing cultural worldviews had differing decision thresholds as it pertains to preventative medicine decisions.

Methodology

Decision Problem

In this proof of concept evaluation we applied DPM+ to estimate cultural worldview informed decision thresholds in a case study involving the HPV vaccine.

A Preventative Medicine Decision Case Study: Human Papilloma Virus Vaccination

Cervical cancer is the second most common type of cancer, of which 70% of cervical cancers and precancerous cervical lesions are caused by the human papillomavirus (HPV) types 16 (HPV 16) and type 18 (HPV 18)(Bird et al., 2017; Crosbie et al., 2013). While it is observed that most HPV

[16] The complement of 'type I system' reasoning reflects the involvement of deliberate, effortful 'type II system' reasoning (i.e., 1- 'type I system' reasoning = 'type II system' reasoning). Together, an individual's decision threshold is equivalent to the weighted average of their 'type I system' reasoning and 'type II system' reasoning.

infections are relatively harmless and clear spontaneously, "persistent infection with high-risk human papillomavirus (especially type 16) can cause cancer of the cervix, vulva, vagina, anus, penis, and oropharynx" (Crosbie et al., 2013, p. 889). Because prophylactic vaccines have demonstrated impressive efficacy against persistent HPV type 16 and 18 infections (Lu et al., 2011) – a focus of this study - cervical cancer is viewed as a highly preventable disease by virtue of HPV vaccination (Bird et al., 2017). Yet, despite the efficacy of the HPV vaccine (Lu et al., 2011), HPV vaccination rates across Canada and the United States are consistently below public health goals (Bird et al., 2017; Pingali et al., 2021). In Canada, it is estimated that the HPV vaccine uptake is roughly 56% of the eligible population (i.e., below the 85% target set by the Canadian government) (Bird et al., 2017) and in the United States it is estimated that roughly 59% of the eligible population are up to date with their HPV vaccination (Pingali et al., 2021) (i.e., below the 80% target set by the United States government (Oh et al., 2021)). Moreover, the uptake of the HPV vaccine is considerably lower than for other childhood vaccines such as: measles, mumps, and rubella (MMR), hepatitis A, hepatitis b, and varicella (Pingali et al., 2021). Consequently, understanding how people make preventative health decisions, such as the decision as to whether to vaccinate their child against HPV, is important to understanding individual decision-making processes as well as informing future public health campaigns/ messaging to increase the uptake of the HPV vaccine. In the case study, we used a hypothetical guardian/ caregiver's decision whether to preventatively vaccinate their child with the HPV vaccine to demonstrate how differing cultural worldviews impact decision thresholds.

Experimental Design

Our case study involved running a Monte Carlo simulation (MCS) in order to estimate values of decisions thresholds for each of the scenarios. We used a MCS because, "it provides an unbiased estimate of outcomes in the presence of non-linear relationships between parameters and results" (Scarffe et al., 2022, p. 3). In simulations we adopted a quasi-experimental repeated measures/ within-group experimental design (Rogers & Revesz, 2020). We classified simulations as quasi-experimental design as the MCS does introduce/ emulate randomization into scenarios, however it is without random assignment as our groups are characterized by cultural worldviews (Rogers & Revesz, 2020; Trochim et al., 2015). Further, we drew comparisons across different groups (i.e., cultural worldviews), but did not maintain a 'control group', which is consistent with quasi-experimental designs (Rogers & Revesz, 2020; Trochim et al., 2015). Moreover, simulation is a repeated measures/ within-group design to the extent that effects of the each scenario (and the corresponding independent variables) are observed for every group (i.e., cultural worldviews) (Rogers & Revesz, 2020)

There were two independent variables that we consider: 1) involvement of 'type I system' reasoning, and 2) an individual's 'risk attitude'. Ultimately, the objective of each scenario was to examine an individual's average decision threshold under different conditions according to their cultural worldview. The resulting decision threshold curves are reflective of the mean (average) decision threshold for each cultural worldview.

Scenario 1: Involvement of 'Type I System' Reasoning

Within the decision-making and risk perception literatures there are two schools of thought that seek to explain, "persistent public controversy over risks and other policy-relevant facts" (Kahan, Peters, et al., 2017, p. 55). One school of thought is that this controversy exists because people are prone to different levels of involvement of their 'type I system' reasoning as a result of heuristics such as the availability bias (Kahan, Peters, et al., 2017; Sunstein, 2003b; Weber & Stern, 2011). The competing position is that this public controversy is a function of other factors (e.g., identity protective cognition) but that people have comparable involvement of their 'type I system' reasoning (Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017; Nurse & Grant, 2020). To this end, we seek to understand the effects that the involvement of 'type I system' reasoning has on an individual's decision threshold. When we refer to the involvement of 'type I system' reasoning we are reflecting that according to the DPM (Mukherjee, 2010), people have the capacity to concurrently use both their 'type I system' reasoning and 'type II system' reasoning. In effect, the estimated decision threshold by DPM is a weighted average of an individual's decision threshold as estimated by their combined 'type I system' reasoning and 'type II system' reasoning.

To explore the effects that the involvement of 'type I system' reasoning has on an individual's decision threshold, we designed three different scenarios where we hold the values of parameters for 'risk attitude' as a different constant for each scenario. In each scenario, we progressively increased an individual's involvement of their 'type I system' reasoning to observe its effect on their decision threshold. In each scenario we estimated the average decision threshold for increasing involvement of an individual's 'type I system' reasoning by running 10,000 simulations (for each cultural worldview) for every increment of 'type I system' reasoning between 0 and 0.99 in increasing increments of 0.01 (i.e., totalling 1,000,000 simulations for each scenario for each cultural worldview).

In the first set of scenarios (i.e., Scenarios 1A, 1B, & 1C), each iteration was reflective of a different 'risk attitude' (i.e., 'risk neutral', 'risk seeking', and 'risk adverse'), with an individual's 'risk attitude' represented by the 'm' parameter (i.e., see

Table 13). Mukherjee (2010) states that when the involvement of the 'type I system' reasoning is set to zero (i.e., $\gamma = 0$), 'risk neutrality' is implied; in the DPM+ we follow the same logic for the estimation risk neutrality. As Mukherjee (2010) articulates, 'risk neutrality' also can occur when $\gamma > 0$ for a particular value of m, namely $m*$ (i.e., 'risk neutral' when $m = m^*$). To inform the point of 'risk neutrality' in DPM+, we used the Mukherjee's (2010) approach for a simple two outcome gamble as a proxy estimate for the point of 'risk neutrality'. We recognized the limitations of this proxy estimate to the extent that, unlike Mukherjee's (2010) simple two outcome gamble (i.e., where one of the outcomes had a utility of zero), our two-outcome gamble has two non-zero outcomes. No less, we affirm this proxy estimate for 'risk neutrality' provides a point estimate that is reasonably comparable across different cultural worldviews. Relative to DPM+, the following equation is used to determine the value of 'risk neutrality' as per Mukherjee (2010):

Equation 1- Estimation of Risk Neutral Risk Attitude

$$m^* = \ln(\alpha) / \ln(p)$$

Our proxy estimate for 'risk neutrality' is informed, partially, by an individual's perceived risk of disease according to their cultural worldview (i.e., α); p is equal to the objective probability of disease (i.e., Probability of Persistent HPV ≥ 6 Months (when unvaccinated)). As a result, people of different cultural worldview have different points of 'risk neutrality'. When $m < m^*$ it implies 'risk adverse', and when $m > m^*$ it implies 'risk seeking' (Mukherjee, 2010).

Scenario 1A: Variable Involvement of 'Type I System' Reasoning- 'Risk Attitude' of 'Risk Neutral'

In this scenario we set the 'risk attitude' parameter m as a constant to reflect 'risk neutral' (i.e., $m = m^*$; see Equation 1) for the case of $\gamma > 0$ (i.e., the involvement of 'type I system' reasoning is > 0). We set the 'risk attitude' to be 'risk neutral' as it is, arguably, the most "neutral" point of comparison across cultural worldviews. As a result, because each cultural worldview has a different perceived risk of disease, the point at which an individual's risk attitude is equivalent to 'risk neutral' is different for each cultural worldview.

Scenario 1B: Variable Involvement of 'Type I System' Reasoning – Constant 'Risk Attitude' of 'Risk Seeking'

This scenario replicates scenario 1A but set the 'risk attitude' to be reflective of an individual who 'risk seeking'. Here we set value of the 'risk attitude' parameter m equal to 1 as it reflects a situation where an individual exhibits maximum 'risk seeking' behaviour (i.e., $0 < m \leq 1$) for the case of $\gamma > 0$.

Scenario 1C: Variable Involvement of 'Type I System' Reasoning – Constant 'Risk Attitude' of 'Risk Adverse'

This scenario 1C replicates scenario 1A and sets the 'risk attitude' to be reflective of an individual who 'risk adverse'. Here we set value of the 'risk attitude' parameter m equal to 0.01 for the case of $\gamma > 0$.

Scenario 2: Risk Attitude- Constant Partial Involvement of 'Type I System' Reasoning

To explore the effects that 'risk attitude' has on an individual's decision threshold, we explored the effects of holding the parameter for the involvement of 'type I system' reasoning as a constant (i.e., $\gamma = 0.20$). In this scenario, we progressively increased an individual's 'risk attitude' to observe the effects of an individual's 'risk attitude' on their decision threshold. We also estimated the average decision threshold for increasing 'risk attitude(s)'. To do so we ran 10,000 simulations (for each cultural worldview) for every increment of 'risk attitude' between 0.01 and 1 in increasing increments of 0.01. The objective of this scenarios was to demonstrate that individuals of different cultural worldviews have different decision thresholds associated with different risk attitudes, assuming constant involvement of 'type I system' reasoning (Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017; Nurse & Grant, 2020).

Parameters

The parameters and corresponding distributions that inform the MCS model are summarized in

Table 13. Parameters for the 'type II system' reasoning were derived from the literature that relates to the HPV vaccine and the persistent variant HPV-16. Parameters for the 'type I system' were derived from the risk perception literature that relates to the HPV vaccine, as well as literature for other diseases (e.g., prostate cancer, diabetes) when parameters related to HPV were unavailable (i.e., parameters related to risk perception coefficients related to cultural worldview) (Chen et al., 2020; Morison et al., 2010; Ziarnowski et al., 2009). The "base estimate" seen in

Table 13 is reflective of the parameter value that would be used in a deterministic analysis. All parameters were used in each scenario with their corresponding probability distribution. Selected parameters (i.e., “relative risk of serious adverse event from vaccine”, “relative risk of serious injection related event from vaccine”, “perceived risk of persistent HPV” and “anticipated regret of benefits/harms”) are explained in greater detail below.

Table 13- Model Parameters

Parameters	**Base Estimate**	**Distribution**	**Reference**
Type II System			
Probability of a Serious Adverse Event from Vaccine	0.07496	Constant	(Lu et al., 2011)
Relative Risk of Serious Adverse Event from Vaccine (Introducing Variability in Estimate)	1.11	Truncated log normal (1.11, 0.05612, 1)	Illustrative
Probability of a Serious Injection Related Event from Vaccine	0.0003646	Constant	(Lu et al., 2011)
Relative Risk Serious Injection Related Event from Vaccine (Introducing Variability in Estimate)	1.82	Truncated log normal (1.82, 1.2143, 1)	(Lu et al., 2011)
Probability of Vaccine Related Minor Discomfort	0.12	Constant	(Reiter et al., 2009)
Probability of Persistent HPV $\geq$ 6 Months (when unvaccinated)	0.06641	Constant	(Lu et al., 2011)
Relative Risk of Persistent HPV $\geq$ 6 Months with Vaccination	0.06	Log normal (-2.8449, 0.2511)	(Lu et al., 2011)
Type I System			
Perceived Risk of Persistent HPV (Baseline)	2.41	Truncated normal (2.41, 0.67, 1, 4)	(Ziarnowski et al., 2009)
Perceived Risk Coefficient for Hierarchical Orientation	-0.13	Truncated normal (-0.13, 0.06378, -1, 1)	(Chen et al., 2020)
Perceived Risk Coefficient for Individualism Orientation	0.12	Truncated normal (0.12, 0.06633, -1, 1)	(Chen et al., 2020)
Constant for Hierarchical Orientation	4	Constant	(Chen et al., 2020)
Constant for Egalitarian Orientation	1	Constant	(Chen et al., 2020)
Constant Individualism Orientation	4	Constant	(Chen et al., 2020)
Constant Communitarian Orientation	1	Constant	(Chen et al., 2020)
Perceived Risk of Persistent HPV Hierarchical-Communitarian	0.3295	Truncated normal (0.2085, 0.3051, 0.001, 0.99)	Inferred from (Chen et al., 2020)
Perceived Risk of Persistent HPV Egalitarian-Communitarian	0.5931	Truncated normal (0.5968, 0.1782, 0.001, 0.99)	Inferred from (Chen et al., 2020)
Perceived Risk of Persistent HPV Egalitarian- Individualism	0.7383	Truncated normal (0.9549, 0.3064, 0.001, 0.99)	Inferred from (Chen et al., 2020)
Perceived Risk of Persistent HPV Hierarchical-Individualism	0.5352	Truncated normal (0.5649, 0.3064, 0.001, 0.99	Inferred from (Chen et al., 2020)
Anticipated Regret of Harms	3.64	Truncated normal (3.64, 1.4, 1, 6)	(Morison et al., 2010)
Anticipated Regret of Benefits	5.42	Truncated normal (5.42, 0.98, 1, 6)	(Morison et al., 2010)
Scaling Constant (k)	1	Constant	
Type I System Involvement (γ)	Variable	$0 \leq \gamma < 1$	(B. Djulbegovic et al., 2012a)
Risk Attitude (m)	Variable	$0 < m \leq 1$	(B. Djulbegovic et al., 2012a)
Log normal distributions are defined by location and shape. Truncated normal are defined by mean, standard deviation, lower limit, upper limit. Truncated log normal are defined by mean, standard deviation, lower limit.			

Relative Risk of Serious Adverse Event from Vaccine and Relative Risk of Serious Injection Related Event

A meta-analysis conducted by Lu and colleagues (2011) observed that the relative risk of serious event from a vaccine[17] and the relative risk of a serious injection related event[18] both were not statistically significant (Lu et al., 2011). Relative risk, "tells us how much risk is increased or decreased from an initial level" (Davies et al., 1998, p. 990). For example, "a relative risk of 0.5 shows that the initial risk has been halved" (Davies et al., 1998, p. 990), whereas a relative risk of 2.0 shows that the initial risk has been doubled. To illustratively increase the relative risk of both events we use a truncated normal distribution with a lower limit of 1.0. According to the literature the 'relative risk of serious adverse event from vaccine' is equal to 1.0 (Lu et al., 2011). Within our analysis, we seek to, illustratively, impose some risk from the HPV vaccine and set the mean 'Relative Risk of Serious Adverse Event from Vaccine" to be 1.11; 1.11 was reflective of the upper limit of the corresponding confidence interval as reported within (Lu et al., 2011). We imposed a distribution with a fictious mean and lower limit using a truncated normal distribution so that there is variability in the risk of an adverse event associated with the vaccine. Because the 'relative risk of serious adverse event from vaccine' is isolated to the 'type II system' reasoning, it does not have meaningful impact on our analysis because it is on how risk perception as informed by cultural worldview have an effect on decision thresholds by way of involvement of 'type I system' reasoning. Consequently, assumptions that are isolated to the 'type II system' reasoning are isolated to the estimate of the decision threshold as calculated using expected utility theory.

Perceived Risk of Persistent HPV

To estimate the perceived risk of persistent HPV infection, we derived a baseline value of perceived risk of persistent HPV infection from a study on the perceived likelihood of cervical cancer by (Ziarnowski et al., 2009). The medical literature has documented that, "cervical cancer is caused by the human papillomavirus infection" (Crosbie et al., 2013, p. 889). HPV type 16

[17] **Serious adverse events from vaccine** might include: "abnormal pregnancy outcomes, blood and lymphatic system disorder, hepatobiliary disorder, immune system disorder, cardiac and vascular disorder, gastrointestinal disorder, musculoskeletal and connective tissue disorder, nervous system disorder, psychiatric disorder, renal and urinary disorder, reproductive system and breast disorder, respiratory, thoracic and mediastinal disorder, skin and subcutaneous tissue disorder, neoplasm, infection and infestation, injury, poisoning and procedural complications" (Lu et al., 2011, p. 12) .

[18] **Serious injection related events** might include: "bronchospasm, gastroenteritis, headache, hypertension, injection-site pain, decrease in joint movement at injection site, hypersensitivity to injection, chills, headache and fever" (Lu et al., 2011, pp. 12–13).

(HPV-16) is the most common cause of invasive cervical cancer and is detected in 55 percent of all cervical cancer cases (Lu et al., 2011). To this end, we interpreted the Ziarnowski and colleagues (2009) measure of perceived likelihood of cervical cancer to be a reasonable baseline estimate of the perceived risk of persistent HPV infection. Ziarnowski and colleagues (2009) measured the perceived likelihood of cervical cancer on a four-point scale ranging from "no chance" to "high chance". We incorporated uncertainty in this estimate by simulating 10,000 different values based on the mean and standard deviation in the estimate reported by Ziarnowski and colleagues (2009) using a truncated normal distribution. We used a truncated normal distribution because of bounding of the responses (i.e., limited to the ordinal scale as per Ziarnowski and colleagues (2009)). We then divided this estimate by four (i.e., reflective of the four-point scale) to create a continuous perceived probability of persistent HPV infection estimate between 0 and 1.

Findings from Chen and colleagues (2020) informed our estimate of perceived probability of persistent HPV that is specific to an individual's cultural worldview. Specifically, Chen and colleagues (2020) demonstrate that there is a statistically significant relationship between an individual's level of hierarchical worldview and their associated perceived susceptibility to diabetes. We used the findings of Chen and colleagues (2020) to estimate the perceived risk of persistent HPV, by drawing inference from the beta coefficients (and the associated confidence intervals) for level of: 1) Hierarchical-Egalitarianism, and 2) Individualism-Communitarianism as the relate to perceived susceptibility of diabetes[19].

To estimate the perceived risk of persistent HPV infection that are unique to each cultural worldview, we set the values for level of: 1) Hierarchical-Egalitarianism, and 2) Individualism-Communitarianism to be at their maximum values dependent on each cultural worldview. For example, in the case of "Hierarchical-Communitarian" we set the coefficients for: 1) Hierarchical-Egalitarianism, and 2) Individualism-Communitarianism, to be reflective of an individual who was, simultaneously, maximally hierarchical and maximally communitarian. We incorporated

[19] Chen and colleagues (2020) explore the effects of cultural worldview on the perception of susceptibility of diabetes and colorectal cancer. We chose to draw inference from the example of perceived susceptibility of diabetes, because the perceived risk variable for susceptibility of diabetes did not include additional covariates, whereas the perceived risk variable for susceptibility of colorectal cancer included a covariate for race/ ethnicity and did not have a statistically significant predictor of perceived risk (Chen et al., 2020).

uncertainty in the beta coefficients across a 95% confidence interval and derived a mean perceived risk of persistent HPV infection for each cultural worldview based on 10,000 simulations (see

Table 13).

Anticipated Regret of Harms and Benefits

The values for anticipated regret of harms and benefits were derived from literature on HPV vaccination (Morison et al., 2010). The anticipated regret of benefit (i.e., anticipated regret of omission (Gilovich & Medvec, 1995; Ritov & Baron, 1990)) was derived from Morison and colleagues (2010) who asked caregivers to identify how much regret they anticipated (i.e., on a six-point scale) based on the following question, “if my daughter does not have the HPV vaccine in the next year and she has an abnormal smear in the future I will feel…” (Morison et al., 2010, p. 155). The anticipated regret of harms (i.e., anticipated regret of commission (Gilovich & Medvec, 1995; Ritov & Baron, 1990)) was derived from Morison and colleagues (2010) who asked caregivers to identify how much regret they anticipated (i.e., on a six-point scale) based on the following question, “if my daughter has the HPV vaccine in the next year and experiences some distress/ pain due to the injections I will feel…” (Morison et al., 2010, p. 155). This approach is consistent with other studies that interpret regret as a cognitively based emotion that people are motivated to regulate, which distinct from other emotions such as anger, disappointment, guilt and shame (Zeelenberg & Pieters, 2007). It is also consistent with other measures of anticipated regret that have been solicited in relation to vaccination related decisions (Connolly & Reb, 2003; Ritov & Baron, 1990; Ziarnowski et al., 2009). We incorporated uncertainty in this estimate by simulating 10,000 different values based on the mean and standard deviation in the estimate reported by Morison and colleagues (2010) using a truncated normal distribution. We then divided this estimate by six (i.e., reflective of the six-point scale) to create a continuous anticipated regret of benefits and anticipate regret of harms estimates between 0 and 1 (see

Table 13).

Simulation Results

Risk Perception and Cultural Worldviews

The incorporation of risk perception as informed by cultural worldviews is central to the DPM+ model. To this end, prior to any analysis, we first explored differences in the proxy estimate for mean perceived risk of persistent HPV across cultural worldviews as informed by the theoretical distributions in

Table 13. We explored the differences in mean perceived risk across cultural worldviews because the estimates of mean perceived risk are derived by a function informed by Chen and colleagues (2020). As shown in Table 14 we report statistically significant differences in the mean perceived risk of persistent HPV (i.e., the proxy estimate) across each of the four cultural worldviews. To minimize the likelihood of a type I error, we apply the Bonferroni correction factor to a level of significant difference (Armstrong, 2014).

Table 14- Difference in Estimated (Proxy) Mean Risk Perception Between Cultural Worldviews

Variable	Estimated (Proxy)Mean Perceived Risk of Persistent HPV-16 (SD)	Difference
Hierarchical-Communitarian	0.3295 (0.2148)	$p<0.001$* $t = -96.059$ 95% CI= (-0.2690, -0.2582)
Egalitarian- Communitarian	0.5931 (0.1708)	
Hierarchical-Individualism	0.5352 (0.2370)	$p<0.001$* $t = -67.73$ 95% CI= (-0.2089, -0.1972)
Egalitarian- Individualism	0.7383 (0.1837)	
Hierarchical-Communitarian	0.3295 (0.2148)	$p<0.001$* $t = -144.65$ 95% CI= (-0.4143, -0.4032)
Egalitarian- Individualism	0.7383 (0.1837)	
Hierarchical-Individualism	0.5352 (0.2370)	$p<0.001$* $t = -19.83$ 95% CI= (-0.0637, -0.0522)
Egalitarian- Communitarian	0.5931 (0.1708)	
Hierarchical-Communitarian	0.3295 (0.2148)	$p<0.001$* $t = -64.31$ 95% CI= (-0.2120, -0.1994)
Hierarchical-Individualism	0.5352 (0.2370)	
Egalitarian- Communitarian	0.5931 (0.1708)	$p<0.001$* $t = -57.87$ 95% CI= (-0.1501, -0.1402)
Egalitarian- Individualism	0.7383 (0.1837)	
Applying the Bonferroni correction factor, we set a significant p-value to be $p<0.0083$ (i.e., 0.05/6 = 0.0083). *= Statistically significant; SD = Standard Deviation; t = t-score associated with the Welch two sample t-test. Estimated (Proxy) Mean Perceived Risk of Persistent HPV-16 was derived from a risk perception study on diabetes (Chen et al., 2020).		

Scenario 1A: Variable Involvement of 'Type I System' Reasoning- 'Risk Attitude' of 'Risk Neutral'

Across cultural worldviews we observed that there were statistically significant differences an individual's point of 'risk neutrality' (see Table 15).

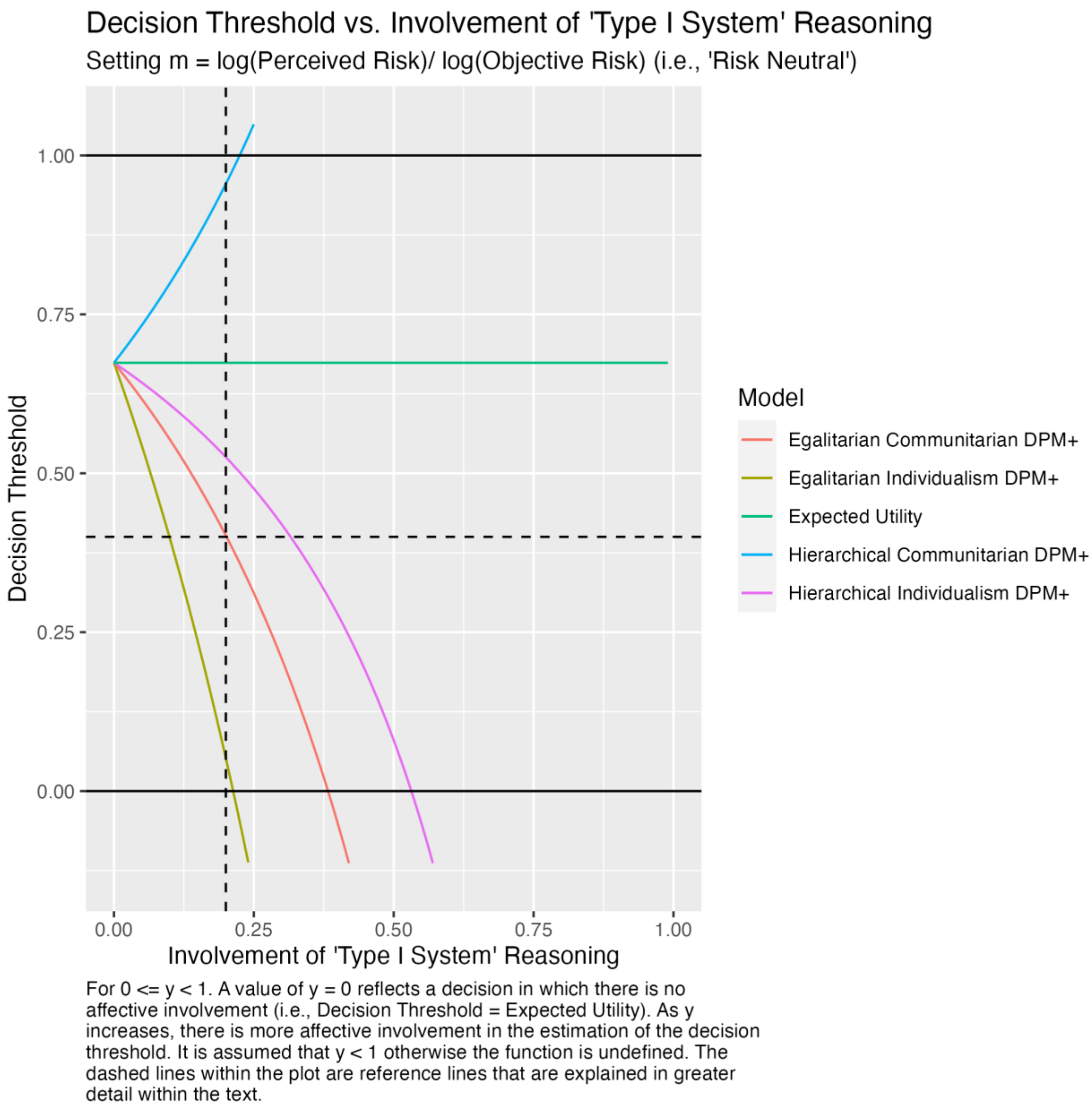
Table 15- Point of 'Risk Neutrality' for Parameter 'm'

Variable	Mean of Parameter 'm' at 'Risk Neutral' (SD)	Difference
Hierarchical-Communitarian	0.5247 (0.3553)	$p< 0.001$* $t= 82.80$ 95% CI= (0.3049, 0.3197)
Egalitarian- Communitarian	0.2123 (0.1266)	
Hierarchical-Individualism	0.2870 (0.2528)	$p<0.001$* $t=54.25$ 95% CI= (0.1491, 0.1603)
Egalitarian- Individualism	0.1323 (0.1318)	
Hierarchical-Communitarian	0.5247 (0.3553)	$p<0.001$* $t=103.52$ 95% CI= (0.3850, 0.3998)
Egalitarian- Individualism	0.1323 (0.1318)	
Hierarchical-Individualism	0.2870 (0.2528)	$p<0.001$* $t=26.40$ 95% CI= (0.0691, 0.0802)
Egalitarian- Communitarian	0.2123 (0.1266)	
Hierarchical-Communitarian	0.5247 (0.3553)	$p<0.001$* $t=54.51$ 95% CI= (0.2292, 0.2462)
Hierarchical-Individualism	0.2870 (0.2528)	
Egalitarian- Communitarian	0.2123 (0.1266)	$p<0.001$* $t=43.79$ 95% CI= (0.0764, 0.0836)
Egalitarian- Individualism	0.1323 (0.1318)	

Applying the Bonferroni correction factor, we set a significant p-value to be $p<0.0083$ (i.e., $0.05/6 = 0.0083$). *= Statistically significant; SD = Standard Deviation; t = t-score associated with the Welch two sample t-test. We estimate a proxy estimate of 'risk neutrality' using the equation provided by Mukherjee (2010) (i.e., as previously discussed).

In scenario 1A, we explore the impacts of increasing the involvement of an individual's 'type I system' reasoning (i.e., parameter γ) relative to their decision threshold, which is specific to cultural worldview (see Figure 7).

Figure 7- Decision Threshold vs. 'Type I System' Reasoning ('Risk Neutral')



The horizontal axis in Figure 7 represents the involvement of an individual's 'type I system' reasoning; as the value across the horizontal axis increases there is growing involvement of 'type I system' reasoning and proportionately less 'type II system' reasoning. The vertical axis represents the decision threshold. A decision threshold is theoretically bounded between 0 and 1. To this end, any decision threshold value that is greater than 1 has the same interpretation as a decision threshold of 1 (i.e., a threshold of absolute certainty). Similarly, any decision threshold value that is less than 0 has the same interpretation as a decision threshold of 0 (i.e., any weight of evidence would be sufficient to warrant action). The value in Figure 7 that is labelled “Expected Utility” represents the mean decision threshold that is calculated exclusively by ‘type II system’ reasoning (i.e., there is zero involvement of ‘type I system’ reasoning) and is representative of a decision threshold that is derived according to expected utility theory (B. Djulbegovic et al., 2012a; Mukherjee, 2010). When the involvement of ‘type I system’ reasoning is equal to zero (i.e., parameter $\gamma = 0$) we observe that all cultural worldviews converge on a decision threshold that is equivalent to the decision threshold as prescribed by expected utility theory.

With increased involvement of ‘type I system’ reasoning, we observe the decision threshold curves for each cultural worldview deviate away from the decision threshold prescribed by expected utility theory. Generally, there are observable differences in each respective decision threshold curve (i.e., unique to each cultural worldview) as the involvement of ‘type I system’ reasoning increases. We highlight a contrasting trend in the decision threshold curves between those who ascribe to a cultural worldview of hierarchical-communitarian (i.e., the blue decision threshold curve) and those individuals who ascribe to the cultural worldviews of: egalitarian-communitarian (i.e., the red decision threshold curve), egalitarian-individualism (i.e., the green decision threshold curve), and hierarchical-individualism (i.e., the purple decision threshold curve). Specifically, we observe that the decision threshold curve for those of hierarchical-communitarian becomes increasingly convex as the involvement of ‘type I system’ reasoning increases, whereas the other cultural-worldviews have an increasingly concave functions as the involvement of ‘type I system’ reasoning increases. When a decision threshold curve becomes increasingly convex with increasing involvement of ‘type I system’ reasoning, this is a signal that the quotient of perceived anticipated regret of benefits relative to the perceived anticipated regret of the harms is less than one but greater than zero. Effectively, when the term CP=$(1 - \frac{\alpha B_I^m}{(1-\alpha)H_I^m})$ has a value of $0 < (1 - \frac{\alpha B_I^m}{(1-\alpha)H_I^m}) < 1$, it subsequently shifts the decision threshold up relative to the expected utility threshold. Alternatively, when a decision threshold curve becomes increasingly concave with increasing involvement of ‘type I system’ reasoning, this is a signal that CP has a value of < 0 and subsequently shifts the decision threshold down.

As a general observation of Figure 7, we highlight that the decision threshold curves intersect with the theoretical limits for decision thresholds of zero and one (i.e., equivalent x-intercepts) at differing levels of involvement 'type I system' reasoning that are unique to each cultural worldview. Consequently, because each of the decision threshold curves represent the mean decision threshold that is estimated by 10,000 simulations for each increment of 0.01 of involvement of 'type I system' reasoning we can be confident that each decision threshold curve is different to a statistically significant level.

Results presented in Figure 7 can be interpreted in two different ways: 1) assuming fixed involvement of 'type I system' reasoning, and 2) assuming fixed decision threshold. Each of these interpretations will be discussed in turn.

Fixed Involvement of 'Type I System' Reasoning

The arbitrarily super imposed vertical dashed line at x-intercept = 0.20 is representative of an arbitrarily fixed involvement of 'type I system' reasoning (see Figure 7). The point at which each of the worldview decision threshold curves intersect with the vertical dashed line identifies the decision threshold for this fixed involvement of 'type I system' reasoning.

Figure 7 illustrates that for a fixed (or assumed) involvement of the 'type I system' reasoning, the cultural worldviews are associated with different decision thresholds. We observe that those of egalitarian cultural worldview orientation have lower decision thresholds than those of hierarchical cultural worldview. As previously discussed, because of the nature in how the decision threshold curves are derived (i.e., the mean of 10,000 simulations) and considering the simulation results, the differences between the decision threshold curves appear to be statistically significant. Consequently, the differences observed in the decision threshold are also statistically significant due to the nature of non-overlapping mean threshold curves that are informed by 10,000 simulations.

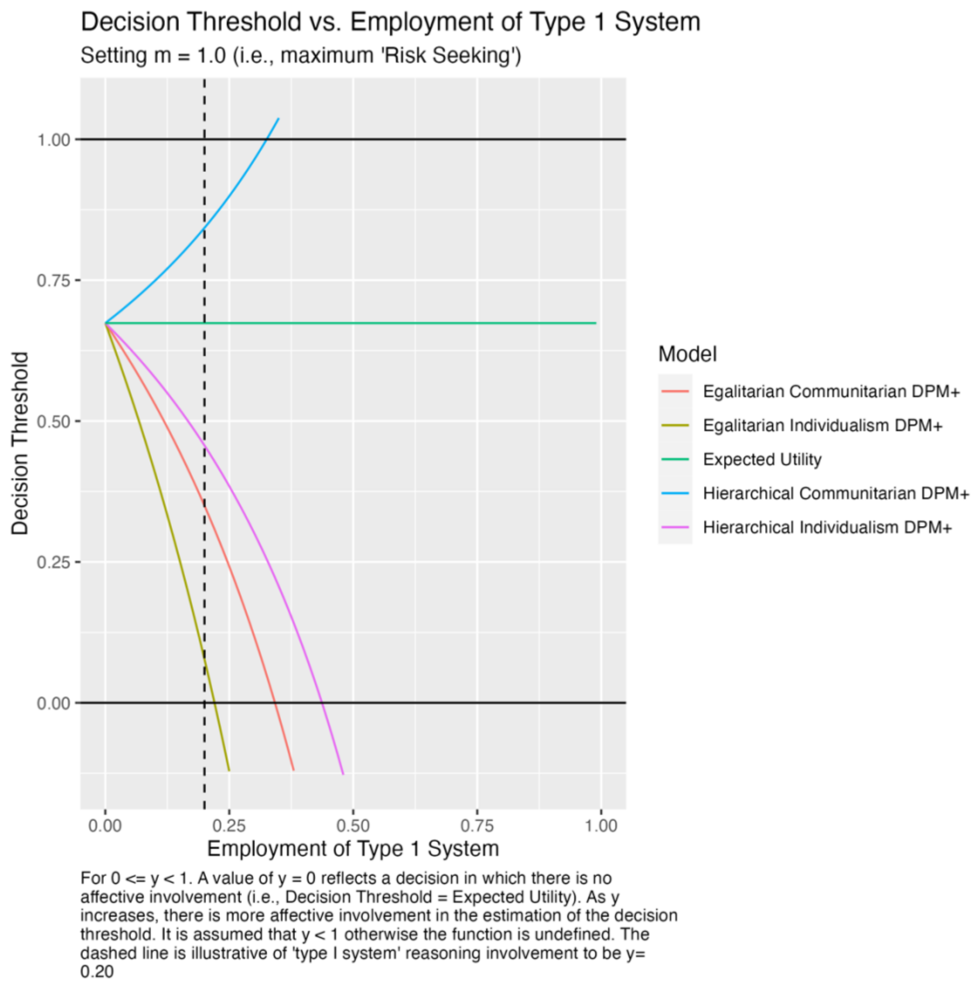
Fixed Decision Threshold

The arbitrarily super imposed horizontal dashed line at y-intercept = 0.40 in Figure 7, is illustrative of the scenario where there is a uniformly accepted decision threshold (see Figure 7). If we assume that decision thresholds are fixed across worldviews, we observe two important findings. First, we observe that those individuals with a cultural worldview that is hierarchical-communitarian, regardless of their involvement of ‘type I system’ reasoning, will never reach a decision threshold at that specific level. Second, for those with cultural worldviews that are: egalitarian-communitarian, egalitarian-individualism, or hierarchical-individualism, we observe that the different cultural worldviews require different levels of involvement of ‘type I system’ reasoning to reach the same decision threshold.

Scenario 1B: Variable Involvement of 'Type I System' Reasoning- Constant 'Risk Attitude' of 'Risk Seeking'

In Scenario 1B we set the 'risk attitude' (i.e., parameter *m*) as a constant to be reflective of a maximum 'risk seeking' position (i.e., $m = 1$) and gradually increase the involvement of 'type I system' reasoning. The results of Scenario 1B are presented in Figure 8.

Figure 8- Scenario 1B: Involvement of 'Type I System' Reasoning (Risk Attitude = 'Risk Seeking')



These results are similar the results in Scenario 1A. Both scenarios are focused on the gradual increase in the involvement of 'type I system' reasoning. Accordingly, we see a similar descriptive trend in decision thresholds with increasing involvement of 'type I system' reasoning to the extent that those of egalitarian cultural worldview have lower decision thresholds with increasing involvement of 'type I system' reasoning than those of hierarchical cultural worldview. Concurrently, we observe the same differentiation of convex versus concave decision threshold curves for the cultural worldviews of hierarchical-communitarian and hierarchical-individualism, respectively.

The difference between Scenario 1A and Scenario 1B is that in Scenario 1A we set the 'risk attitude' to be 'risk neutral', whereas in Scenario 1B we set the 'risk attitude' to be 'risk seeking'. When we set the 'risk attitude' to be 'risk seeking', the ratio of anticipated regret of benefits relative to anticipated regret of harms is maximized by virtue that both the anticipate regret of harms and anticipated regrets of benefits are raised to power of m =1. Because the ratio of anticipated regret of benefits relative to the anticipated regret of harms is maximized when m=1, the influence of risk perception as informed by cultural worldview (i.e., α and $(1-\alpha)$) is less pronounced on the decision threshold curves when m=1 than when m<1. With that said, risk perception as informed by cultural worldview is ultimately still the source of differentiation between decision threshold curves of differing cultural worldviews. Consequently, when $\alpha \gg (1-\alpha))$ and $B_I > H_I$ the decision threshold curve is likely to be concave. Alternatively, when $\alpha \ll (1-\alpha))$ and $B_I < H_I$ the decision threshold curve is likely to be convex. The decision threshold curves are less concave/ increasingly convex in Scenario 1B (i.e., relative to Scenario 1A) because the ratio of anticipated regret of benefits relative to anticipated regret of harms is greater than the same ratio when we set the 'risk attitude' as 'risk neutral'; we can identify this ratio as the source of differentiation between the decision threshold curves in Scenario 1A and 1B because risk perception as informed by cultural worldview is unaffected by 'risk attitude' in the model. This difference in anticipated regret ratios is influential in the decision threshold equation by virtue of the term $(1-\frac{\alpha B_I^m}{(1-\alpha)H_I^m})$ within 'type I system' reasoning. Consequently, when $B_I \gg H_I \; and \; \alpha \gg (1-\alpha))(i.e., (1-\frac{\alpha B_I^m}{(1-\alpha)H_I^m}) < 0)$ the decision threshold curves become less concave (i.e., as is the case for the cultural worldviews of: egalitarian-communitarian, egalitarian-individualism, and hierarchical-individualism; observing that because of a difference in perceived risk (i.e., α parameter) different cultural worldviews have different ratios of $(\frac{\alpha B_I^m}{(1-\alpha)H_I^m})$. Alternatively, when $B_I \ll H_I \; and \; \alpha \ll (1-\alpha))\left(i.e., 0 < (1-\frac{\alpha B_I^m}{(1-\alpha)H_I^m}) < 1\right)$ the decision threshold curves become increasingly convex as the term of $\left(1-\frac{\alpha B_I^m}{(1-\alpha)H_I^m}\right)$ approaches 0 (i.e., as is the case with the cultural worldview of hierarchical-communitarian).

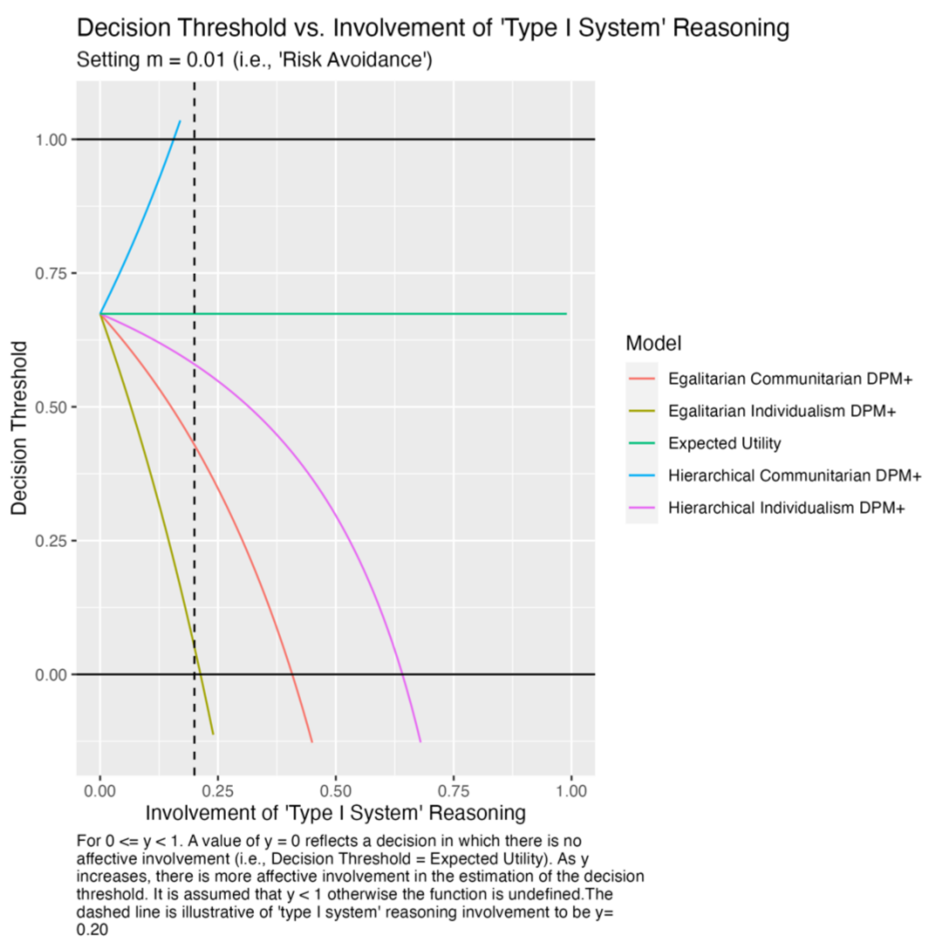
Scenario 1C: Variable Involvement of 'Type I System' Reasoning – Constant 'Risk Attitude' of 'Risk Adverse'

In Scenario 1C we set the 'risk attitude' (i.e., parameter m) as a constant to be reflective of a 'risk adverse' position (i.e., m = 0.01; recognizing that the bounds such that $0 < m \leq 1$) and gradually increase the involvement of 'type I system' reasoning. The results of this scenario are presented in Figure 9.

The findings in Scenario 1C are similar to those in Scenario 1A and 1B to the extent that we observe similar shapes of decision threshold curves (i.e., convex and converse) for each cultural worldview and also see a descriptively similar trend in decision thresholds with increasing involvement of 'type I system' reasoning. Specifically, those of egalitarian cultural worldview have lower decision thresholds with increasing involvement of 'type I system' reasoning than those of hierarchical cultural worldview. Similar to Scenario 1B, the difference between Scenario 1C and Scenario 1A is the 'risk attitude' parameter. When we set the 'risk attitude' to be 'risk adverse' we simulate a situation where the anticipated regret of harms and anticipated regret of benefits for the HPV vaccine are closest to parity as a result of the power function (i.e., m = 0.01; B_I^m, H_I^m); this minimizes the ratio of anticipated regret of benefits relative to anticipated regret of harms. Consequently, when ratio anticipated regret of benefits relative to the anticipated regret of harms is close to 1, this impacts the term $(1-\frac{\alpha B_I^m}{(1-\alpha)H_I^m})$within the threshold equation (see page 81); these effects are similar to the effects discussed in Scenario 1B. As a result, the decision threshold curves for each cultural worldview become increasing concave (i.e., when $\alpha B_I^m > (1-\alpha)H_I^m$) and less convex (i.e., $\alpha B_I^m < (1-\alpha)H_I^m$) relative to the same involvement of 'type I system' reasoning and the corresponding decision threshold curves presented in Scenario 1A and 1B. Consequently, because the ratio of anticipated regret of benefit relative to anticipated regret of harms is closest to 1 at m=0.01, when $\alpha \gg (1-\alpha)$ and the term $\left(1-\frac{\alpha B_I^m}{(1-\alpha)H_I^m}\right) << 0$ and the decision threshold curve becomes increasingly concave, alternatively, as $\alpha \ll (1-\alpha)$ and the term $0 <$

$\left(1 - \frac{\alpha B_I^m}{(1-\alpha)H_I^m}\right) < 1$ the decision threshold curve becomes less convex as it approaches 1. As a result, as the involvement of 'type I system' reasoning increases, the effects of this term cause the decision threshold curves to drop slowly/ rise quickly. If the anticipated regret of harm is greater than the anticipate regret of benefit (i.e., as is the case in hierarchical-communitarian worldviews) the 'risk attitude' of 'risk adverse' will rise the decision threshold quickly. Alternatively, if the anticipated regret of benefit is greater than anticipated regret of harm, the 'risk attitude' of 'risk adverse' will result in the decision threshold dropping more slowly with increasing involvement of 'type I system' reasoning.

Figure 9- Scenario 1C: Involvement of 'Type I System' Reasoning (Risk Attitude = 'Risk Adverse')



Scenario 2: Risk Attitude- Constant Partial Involvement of 'Type I System' Reasoning

This scenario sets the involvement of 'type I system' reasoning to be reflective of an individual who has constant partial involvement of their 'type I system' reasoning (i.e., $\gamma = 0.20$). In this scenario, we position that 'risk neutrality' is the most neutral point of comparison because to the best of our knowledge there is no reason to suspect that one cultural worldview would be more prone to ‘risk seeking’ or ‘risk neutral’ relative to their ‘risk attitudes’. Accordingly, we are interested in exploring how decision thresholds vary across cultural worldview at the point of ‘risk neutrality’ with partial involvement of ‘type I system’ reasoning (see Figure 10).

Figure 10- Scenario 2: Risk Attitude (Constant Partial Involvement of 'Type I System' Reasoning)

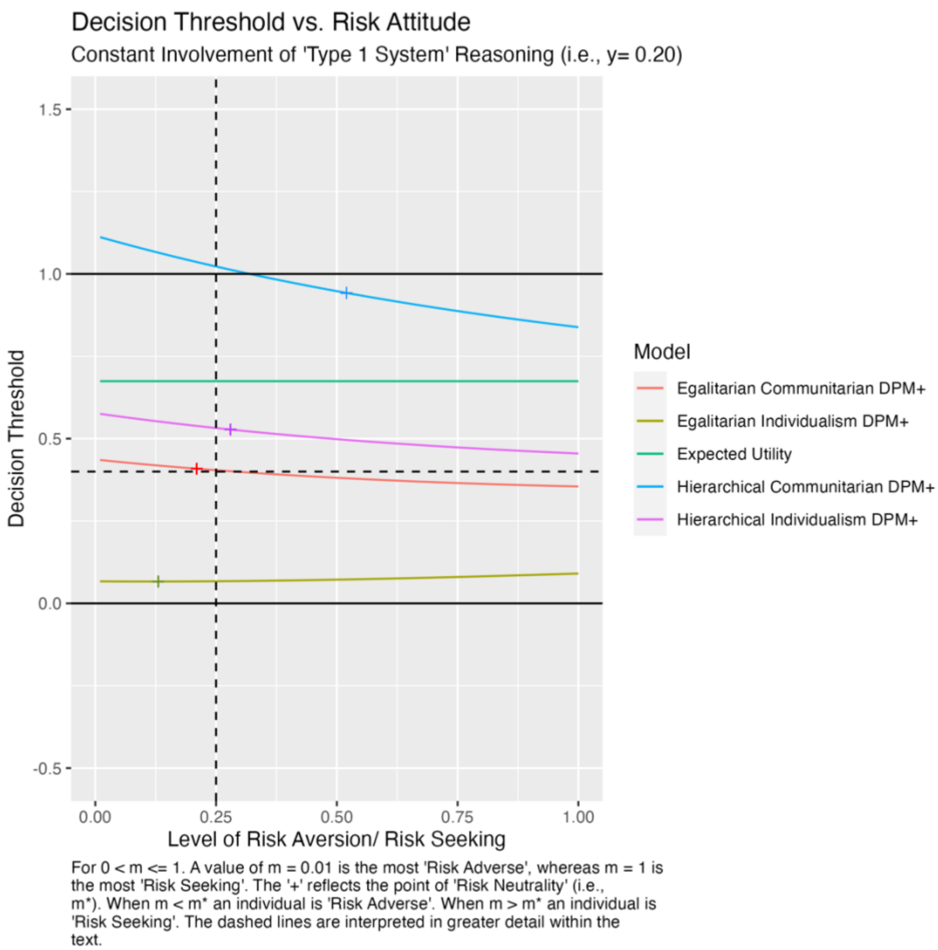


Figure 10 is representative of the mean decision threshold for each cultural worldview within increasing ‘risk attitude’ (i.e., parameter m) when we hold in the involvement of ‘type I system’ reasoning constant. The horizontal axis represents ‘risk attitude’ ($0 < m \leq 1$); where a value of m=1 is the most ‘risk seeking’ and a value of m=0.01 is the most ‘risk adverse’. The vertical axis represents the values of decision threshold. A decision threshold is theoretically bounded between 0 and 1 (B. Djulbegovic et al., 2012a; Mukherjee, 2010). The vertical axis can be interpreted in the same way as in Scenarios 1A, 1B, and 1C.

Examining Figure 10, we note that each cultural worldview has a different decision threshold associated with the point of 'risk neutrality' (i.e., as denoted by the + on the decision threshold curves) (see Table 15). Interpretatively, at the point of 'risk neutrality' individuals of hierarchical cultural worldview orientation have higher decision thresholds than those of egalitarian cultural worldview orientation. Specifically, we observe decision thresholds at the point of 'risk neutrality' to be greatest for those of hierarchical-communitarian cultural worldview and lowest for those of egalitarian-individualism cultural worldview. Considering design of the experiment, we feel confident to state that the differences between decision threshold curves are meaningful. We observe a similar tendency in the decision thresholds in Scenarios 1A, 1B, and 1C.

We also observe that the decision threshold of those of hierarchical-communitarian worldview extends beyond the theoretical upper limit of 1 for decision thresholds for a period of time where an individual of this cultural worldview would be considered 'risk adverse'; as their 'risk attitude' increases towards 'risk neutral' and ultimately towards 'risk seeking' we see the decision threshold emerge within the theoretical bounds of 0 and 1. As the parameter m approaches 1, the influence of α is tempered because the quotient of anticipated regret of benefits relative to anticipated regret of harms is less influenced by m parameter.

Fixed 'Risk Attitude'

We highlight the illustrative example in Figure 10, where we arbitrarily impose a fixed 'risk attitude' parameter (i.e., the vertical dashed line at x-intercept = 0.25). Consistent with the earlier findings, we observe that individuals of different cultural worldview continue to have different decision thresholds. However, if one were to arbitrarily set a fixed 'risk attitude' individuals would possess different categorial 'risk attitudes'. For example, individuals with cultural worldviews of egalitarian-communitarian and egalitarian-individualism would be perceived to be 'risk seeking' (i.e., $m > m^{*}$), whereas those with cultural worldviews of hierarchical-individualism and hierarchical-communitarian would be perceived to be 'risk adverse' (i.e., $m < m^{*}$). To this end, we maintain that the most neutral measure of risk attitude to estimate an individual's decision threshold is at the point of 'risk neutrality'.

Fixed Decision Threshold

Similar to Scenario 1A, we continue our analysis of Scenario 2 by exploring the possibility that all cultural worldviews have the same decision threshold (see Figure 10). In Figure 10 we arbitrarily imposed a decision threshold (i.e., horizontal dashed line at y-intercept = 0.40). We have two observations for this scenario. First, we observe that those individuals with a cultural worldview that is hierarchical-communitarian, hierarchical-individualism, and egalitarian-individualism will never reach this decision threshold, regardless of the ‘risk attitude’, when we assume a constant involvement of ‘type I system’ reasoning. Second, for those who are egalitarian-communitarian in their cultural worldview, they would only assume this decision threshold if they were in a ‘risk seeking’ state as per their ‘risk attitude’.

Discussion

Interpretation of Mean Risk Perception(s) as Informed by Cultural Worldview

The mean perceived risks of persistent HPV are directionally consistent with what is reported in other studies of cultural worldviews and perceived risks. In our analysis, people with a hierarchical cultural worldview orientation have lower perceived risks of HPV than those of egalitarian cultural worldview orientation; we infer the perceived risk of HPV based on the findings of perceived risk informed by Chen and colleagues (2020). This is consistent with other studies that have explored the effects of cultural worldview on the perceived risk of health risks (Chen et al., 2020; Kahan et al., 2005). Generally, those with a hierarchical cultural worldview orientation tend to perceive health risks to be less threatening (Chen et al., 2020; Kahan et al., 2005; Kahan & Braman, 2006; Xue et al., 2014). This tendency is believed to be partially explained by the notion that, “people with a hierarchical worldview prioritise the maintenance of social categories which, from their perspective, perpetuates as sense of protection for their own position and interests [… they may] have lower risk perceptions because they credit the social order, and the protection it extends to them” (Chen et al., 2020, p. 338). Directionally, our findings are consistent with Kahan and colleagues (2010) who observe that those of egalitarian-communitarian and egalitarian-individualism cultural worldviews have lower perceived risks of HPV than those of hierarchical-individualism and hierarchical-communitarian cultural worldviews (Kahan, Braman, Cohen, et al., 2010). Moreover, when considering the perceived risks associated with vaccination, our results are also consistent with those reported in the literature. The perceived risk associated with an adverse event from the vaccine in DPM+ is reflective of the event where an individual received the vaccine and experienced an adverse event. Within our analysis those of hierarchical orientation exhibit the greatest perceived risk of an adverse event associated with vaccination and lesser perceived risk of contracting a persistent HPV infection. This is consistent with Kahan and colleagues (2010), who found that, "subjects perceived greater risk as they became more hierarchical and less risk as they became more egalitarian" (Kahan, Braman, Cohen, et al., 2010, p. 508) relative to the risks associated with the HPV vaccine.

General Interpretations of Figure(s) in Scenario 1

Interpretively, relative to our case study, worldviews associated with a convex decision threshold curve will require greater levels of evidence to accept the HPV vaccine (i.e., higher decision thresholds) as they increasingly involve their 'type I system' reasoning until they, inevitably, reach a decision threshold equal to 1 and at this point the individual will never chose to receive the HPV vaccine as 'certainty' is a theoretically unattainable standard for evidence (H. Douglas, 2000). Alternatively, those worldviews associated with a concave decision threshold curve will require lesser levels of evidence to accept the HPV vaccine (i.e., lower decision thresholds) as they increasingly involve 'type I system' reasoning until they inevitably reach a decision threshold of less than or equal 0 and at this point any evidence in support of the vaccine would be sufficient to justify vaccination.

Interpretation of Scenario 1 Relative to an Understanding of Cultural Worldviews

Scenario 1 is about measuring the effects of increasing involvement of 'type I system' reasoning on decision thresholds for different cultural worldviews when we assume a constant 'risk attitude'. Across the various analyses for Scenario 1 we observe consistent face validity with the results of our simulation relative to the wider literature on cultural worldviews.

First, we reflect on the decision threshold curves for those of hierarchical-communitarian and hierarchical-individualism cultural worldviews. Across all levels of increasing involvement of 'type I system' reasoning, we observe that these cultural worldviews maintain greater decision thresholds than those of egalitarian cultural worldview orientation. This is consistent with what one would expect given the literature on cultural worldviews. For example, Kahan and colleagues (2010) observed that those of hierarchical-communitarian and hierarchical-individualism cultural worldviews had greater perceived risk of an adverse event from the HPV vaccine than those of egalitarian-communitarian and egalitarian-individualism cultural worldviews (Kahan, Braman, Cohen, et al., 2010). Accordingly, it is expected (perhaps intuitively) that those with greater perceived risk of an adverse event occurring because of the HPV vaccine would have greater decision thresholds relative to those with lesser perceived risk of an adverse event from the HPV vaccine.

Those who have hierarchical cultural worldviews have a tendency to discount health and technological risks (Kahan, 2012; Xue et al., 2014). This tendency to discount health and technological risks is believed potentially be an, "implicit indictment of competence and authority of social elites" (Kahan, 2012, p. 728). Commonly, those of hierarchical-individualism and hierarchical-communitarian cultural worldviews, "think that hierarchies and power differences are natural and healthy parts of society" (Hornsey et al., 2018, pp. 308–309). Zanocco and Jones (2018) put forward the 'American frontiersman of the Old West' and a participant within 'rigid rules-based religious structure' as the archetypal individual for those of hierarchical-individualism and hierarchical-communitarian cultural worldviews (respectively). Those of hierarchical-individualism cultural worldview value high degrees of prescriptive constraints but less collective social organization, whereas those of hierarchical-communitarian cultural worldview prefer high levels of collective organization and are more likely to subscribe to the notion that, "everyone has a specific and rank-ordered role to play within the group" (Zanocco & Jones, 2018, p. 3). Consequently, it is consistent that those of hierarchical cultural worldview would typically associate higher risk perceptions associated with the HPV vaccine and simultaneously lower vaccine support (Hornsey et al., 2018; Kahan, Braman, Cohen, et al., 2010; Lewandowsky et al., 2013).

While Scenario 1A showed that those of hierarchical-individualism and hierarchical-communitarian cultural worldviews maintained greater decision thresholds with increasing involvement of 'type I system' thinking relative to those of egalitarian cultural worldviews, the shape of the decision threshold curves for each cultural worldview are comparatively distinctive. Notably, the decision threshold curve for those of hierarchical-communitarian cultural worldview was convex (i.e., increasing from the threshold as prescribed by expected utility theory and approaching a decision threshold of 1), whereas the decision threshold curve for those of hierarchical-individualism cultural worldview was concave (i.e., decreasing from the threshold as prescribed by expected utility theory approaching a decision threshold of 0). This may be explained as those hierarchical individuals with an individualism orientation often perceive that they are self-reliant and have the responsibility for assessing health risks for themselves through access to information (Langford et al., 2000). Accordingly, individuals of hierarchical-individualism cultural worldview may be sufficiently convinced of the risk of HPV to receive the vaccine as they value the freedom to do as they please. Conversely, those of hierarchical-communitarian cultural worldview are more likely to be, "believers subject to timeless laws and God's greater plan" (Uecker & Froese, 2019, p. 286). Accordingly, individuals of hierarchical-communitarian cultural worldviews may be of the belief that the HPV vaccine may encourage their child to participate in behaviours that are inconsistent with the values and beliefs of their group (e.g., pre-marital sex). Consequently, individuals of hierarchical-communitarian cultural worldview may appraise the perceived risk of HPV to be lower and the anticipated risks to outweigh the foreseeable benefits and with increasing involvement of 'type I system' reasoning reach a decision threshold that is prescriptive of never having sufficient evidence to receive the HPV vaccine (i.e., a decision threshold greater than or equal to 1).

Zanocco and Joes (2018) propose the archetypal character of those of egalitarian-individualism cultural worldview to be that of the capitalist entrepreneur. Those of egalitarian-individualism cultural worldview, "value low levels of collective organization and few constraints" (Zanocco & Jones, 2018, p. 3). Relative to vaccination, those of egalitarian-individualism cultural worldview are likely to be supportive of HPV vaccination as, "they do not want non-vaccinated individuals to impose disease on others against their will; contracting a contagious disease due to negligence or choice of others violates individualists' preferences for individual autonomy" (Song et al., 2014, p. 532). Alternatively, those of egalitarian-communitarian cultural worldview, the archetypal character value equality within the group and, "shun social, racial, and gender rank orderings" (Zanocco & Jones, 2018, p. 3). Typically, individuals of egalitarian-communitarian cultural worldview characteristically would be supportive of government-mandated vaccination policies, however it is expected that these individuals would have some skepticism as they typically display aversion to, "concentrated authority based on expert (rather than community) consensus" (Song et al., 2014, p. 532).

Our findings are also consistent with the archetypes of individuals of egalitarian-individualism and egalitarian-communitarian. In our simulation, those of egalitarian-individualism had the lowest decision threshold with increasing involvement of ‘type I system’ reasoning. This is consistent with a belief that there should be few constraints on an individual’s decision and that they would not want to impose disease on others against their will. Similarly, individuals of egalitarian-communitarian cultural worldview had the second lowest decision threshold with increasing involvement of ‘type I system’ reasoning. This is consistent with the notion that individuals of egalitarian-communitarian cultural worldview may be increasingly skeptical of HPV vaccine due to prior external factors. As a result, although individuals of egalitarian-communitarian cultural worldview have a tendency to favour the HPV vaccine, due to their concern with expert consensus, it is expected that their decision threshold might be slightly higher than those of egalitarian-individualism cultural worldview with increasing involvement of ‘type I system’ reasoning.

In our analysis of a fixed decision threshold across all cultural worldviews (i.e., Scenario 1A and Scenario 2) we explore the possibility that the decision threshold is fixed (i.e., uniform across all cultural worldviews) and that the variation in decision thresholds is a product of different levels of involvement of ‘type I system’ reasoning. Generally speaking, this assumption of a constant decision threshold is not supported within the larger body of literature on ‘type I system’ reasoning and ‘type II system’ reasoning. Instead, the literature identifies that individuals, regardless of their cultural worldview, are perceived to have comparable involvement of ‘type I system’ reasoning (see for example, Kahan, Jamieson, et al., 2017; Kahan, Peters, et al., 2017; Nurse & Grant, 2020). Hence, we posit that it is unlikely that people of differing cultural worldviews have the same decision threshold. Instead, it is more likely that people of differing cultural world views have similar involvement of ‘type I system’ reasoning and consequently maintain differing decision-thresholds.

Interpretation of Scenario 2 Relative to Cultural Worldviews

We note face validity with the results of our simulation for Scenario 2 relative to the literature on cultural worldviews. We contend that the best point of comparison across cultural worldviews is to assume ‘risk neutrality’.

Consistent with the results of Scenario 1, the decision thresholds are lowest for those of egalitarian cultural worldview orientation and highest for those of hierarchical cultural worldview orientation. Similarly, there is the same rank order of decision thresholds from smallest to highest based on an individual's cultural worldview. Considering that general decision threshold trends observed in Scenario 1 are generally observed in Scenario 2, explanations relative to cultural worldviews provided earlier apply for Scenario 2 as well.

Within Scenario 2 we explore how decision thresholds would be impacted if we set a constant value for 'risk attitude' across all cultural worldviews while maintaining a constant involvement of 'type I system' reasoning. We highlight that using our proxy estimates for a 'risk neutrality' 'risk attitude' yield different decision thresholds that is dependent on an individual's cultural worldview. We also explore how decision thresholds are affected if we selected an arbitrary value to represent 'risk attitude' ($0 < m \leq 1$). Importantly, across any parameterization of 'risk attitude', when we hold 'type I system' reasoning constant, differences in decision thresholds are still present across different cultural worldviews. Moreover, relative to 'risk attitude' we are not aware of any evidence supporting the notion that an individual's 'risk attitude' is dependent on their cultural worldview or that individuals of a certain cultural worldview are more prone to 'risk seeking' or 'risk adverse' 'risk attitudes'. While there is some evidence to suggest that there are different propensities for sensation seeking behaviours for different ages and genders (Byrnes et al., 1999; Hirschberger et al., 2002), these affinities would equally affect all cultural worldviews.

Limitations

Proof of concept evaluation study has a few limitations.

1. In a few instances we impose and/or elevate an individual's risk of an adverse event when receiving the HPV vaccine. Importantly, within the literature, there is limited evidence to support the position that an individual's relative risk of an adverse injection related event is higher than a control group for the HPV vaccine (Lu et al., 2011). However, considering that the DPM+ is about individual's risk perception as informed by their cultural worldview within their 'type I system' reasoning, this limitation has negligible impact on the simulation results as it effects all cultural worldviews equally.

2. We derive an individual's anticipated regret and perceived risk of the HPV vaccine from the HPV vaccine literature (Morison et al., 2010; Ziarnowski et al., 2009) and convert ordinal scales into continuous values of anticipated regret and perceived risk. Consequently, the levels of anticipated regret and perceived risk may be greater than they would be if they had been measured using a continuous scale. While this effects the 'type I system' reasoning, these base estimates effect all cultural worldviews equally and therefore do not skew general conclusions from the simulation.

3. We use the risk perception beta coefficients from Chen and colleagues (2020) to adjust an individual's perceived risk of HPV according to their cultural worldview; these beta coefficients were derived from perceived susceptibility to diabetes (Chen et al., 2020). It is possible that HPV would elicit different beta coefficients for perceived risk than diabetes. Although this is a limitation, when we apply the beta coefficients to the case study on HPV, the corresponding perceived risks for each cultural worldview are directionally similar to Kahan and colleagues (2010) study on the perceived risk and benefits of the HPV vaccine (Kahan, Braman, Cohen, et al., 2010). It is also interesting to observe that for diabetes (i.e., a seemingly non-polarizing disease) that the perceived risk of diabetes is significantly influenced by an individual's cultural worldview. To this end, given HPV is often a culturally polarizing issue (Kahan, Braman, Cohen, et al., 2010), we suspect that similar (if not greater) effects of cultural worldview would inform the perceived risk of HPV as was observed with perceived risk of diabetes (Chen et al., 2020).

4. Finally, the case study assumes that each cultural worldview is reflective of strongest possible expression of each cultural worldview (i.e., the risk perception for each cultural worldview is reflective the strongest possible caricature of an individual who identifies with this cultural worldview). However, because cultural cognition theory measures an individual's cultural worldview on continuous axes, it is possible that individuals with cultural worldviews that are more moderate/ centrist may have more tempered perceived risk of HPV that are more convergent than they are divergent. As a result, individuals with a more centrist cultural worldview may have increasingly similar decision thresholds. To

the extent that DPM+ allows for this tempering of perceived risk as informed by cultural worldview, DPM+ is well positioned to account for this potential variability.

Chapter 7: Conclusion

Chapter Summary

In this chapter we present the conclusions of this thesis research. We highlight that the relevant discussions and limitations for each of the stated objectives are discussed in the associated chapters. We do not repeat these discussions/ limitations, but instead provide a summary of how the stated objectives of this thesis were achieved. We emphasize the main contribution of this thesis is that of DPM+ to the medical decision-making literature. Specifically, DPM+'s incorporation of risk perception as informed by cultural worldview prescriptively explains why people of different cultural worldviews may make different preventative medicine decisions. We explain this heterogeneity in preventative medicine decisions by incorporating the insight from cultural cognition theory, which demonstrates that individuals of different cultural worldviews have differing risk perceptions for the same hazard. By incorporating risk perception as informed by an individual's cultural worldview in to DPM+, we prescriptively explain how people of different cultural worldviews may make divergent, yet simultaneously 'rational', decisions because they maintain different decision thresholds.

Conclusion

In Chapter 1 (page 1), we identified the following general objectives for this thesis:

1. To complete a scoping review of non-expected utility decision thresholds;
2. To propose an extended dual progressing model (DPM+) for decision thresholds in medical decision-making that incorporates perceived risk as informed by cultural worldview; and
3. To provide a proof of concept of DPM+ that demonstrates how DPM+ can prescriptively explain heterogeneity in decision thresholds according to cultural worldview.

We describe how each of these objectives were achieved below.

Chapter 4 presented a scoping review of non-expected utility decision thresholds within the context of medical decision-making. The scoping review makes the following contributions to the scientific body of literature:

a. We identified and categorized what theoretical paradigms have been used to understand non-expected utility decision thresholds within the medical decision-making literature.
    i. To the best of our knowledge, this is the first review that has systematically reviewed the relevant literature on non-expected utility decision thresholds within the medical decision-making literature.
b. We, systematically, reviewed contextual and subjective factors identified within the literature that have an effect on an individual's decision threshold.
    i. We conclude that cultural worldviews as per cultural cognition theory have not been previously incorporated into decision thresholds within the field of medical decision-making. This is a gap within the literature related to medical decision-making and decision thresholds.

In Chapter 5 we proposed the extended dual processing model (DPM+) for decision thresholds relative to preventative medicine decisions. DPM+ addresses the identified gap within the body of academic literature that pertains to absence of consideration of cultural worldviews relative to decision thresholds and medical decision-making. Specifically, DPM+ theorizes that lay-individuals do not weigh outcomes equally within their 'type I system' reasoning and that risk perception as informed by an individual's cultural worldview informs their weighing of foreseeable outcomes. DPM+ makes an important contribution to the body of literature on decision thresholds within medical decision-making to the extent that it incorporates perceived risk as informed by an individual's cultural worldview into the decision threshold equation. Through incorporating risk perception as informed by cultural worldviews, we can prescriptively explain why, when presented with the same evidence, people of the same cultural worldviews make similar health related decisions (e.g., choose to vaccinate their child against HPV) and why people of different cultural worldviews make different decisions (e.g., choose not to vaccinate their child against HPV). We explain this divergence of decisions as a product of that people of different cultural worldviews have different decision thresholds; this variation relative to decision thresholds is explained by DPM+. DPM+ advances the corpus of literature related to medical decision-making and decision thresholds in the following way:

a. To our best knowledge, this is the first time that risk perception as informed by cultural worldviews has been incorporated into a non-expected utility decision threshold model for medical decision-making.
b. We theorized an extended dual processing model (DPM+) for decision thresholds that incorporates an individual's risk perception as informed by the cultural worldview. Consequently, DPM+ can prescriptively explain how people of differing cultural worldviews may have different decision thresholds while having the same level of 'type I system' reasoning involved in their decision.

In Chapter 6 we presented a proof of concept case study that demonstrated how the DPM+ can be applied to a preventative medicine decision. As theorized in Chapter 5, the proof of concept case study demonstrated how DPM+ results in decision threshold curves that are unique to each cultural worldview. The corresponding decision threshold curves that are informed by DPM+ are consistent with the larger risk perception and decision-making literatures. Consequently, we demonstrate that DPM+ can prescriptively explain how individuals of different cultural worldviews may have differing decision thresholds.

In conclusion, DPM+ offers an important contribution to the corpus of the academic literatures that relate to decision thresholds and medical decision-making. While we have demonstrated a proof of concept case study for DPM+ relative to a preventative medicine decision, DPM+ was theorized beyond a singular application and was informed by the decision threshold literature as well as the larger corpus of risk perception and decision-making literatures. To this end, it is possible that DPM+ could inform decision thresholds relative to decisions beyond a preventative medicine application. Specifically, the DPM+ extends the dual processing theory for decision thresholds by incorporating risk perception as informed by cultural worldview as per cultural cognition theory. To the best of our knowledge, this is the first-time cultural worldview has been incorporated in a decision threshold model. DPM+ provides a prescriptive explanation of how individuals of different cultural worldviews may have different decision thresholds without suggesting that a certain group of people (i.e., partitioned by cultural worldview) is more inclined to rely on their ‘type I system’ reasoning. Instead, DPM+ offers that individuals of differing cultural worldviews can have the same level of involvement of their ‘type I system’ reasoning and, simultaneously, maintain different decision thresholds as a product of different risk perceptions associated with anticipated outcomes. Hence, individuals of different cultural worldviews might arrive at distinct preventative healthcare decisions, all of which could be considered ‘rational’, ‘justifiable’ and/or ‘reasonable’ from their own perspectives. This divergence in decisions, as evidenced by DPM+, can be attributed to the heterogeneity in their associated decision thresholds when faced with identical evidence.

Appendix

Appendix 1.1- Characterization of IS Artifacts

Within IS research and design science methodologies, the artifact should be a focal point (Baskerville et al., 2018). Within the DPM+ the artifact of cultural worldview view is the focal point of the proposed research. The DPM as proposed by Djulbegovic and colleages (2012) and Tsalatsanis and colleagues (2015) appropriately reflects that people engage type 1 and type 2 thinking in their establishment of an implicit decision-threshold. However, we extend the DPM to include the artifact of cultural worldview. Within IS research and the design science methodology, an artifact can be categorized as a construct, model, method or instantiation (see Table 16)(Baskerville et al., 2018; Gregor & Hevner, 2013). We contend that the DPM+ is a model artifact within the context of IS research.

Table 16- Artifact Characterization

Artifact Characterization	**Interpretation**
Construct	"*Constructs* or concepts form the vocabulary of a domain. They constitute a conceptualization used to describe problems within the domain and to specify their solutions" (March & Smith, 1995, p. 256, emphasis in original).
Model	"A *model* is a set of propositions or statements expressing relationships amongst constructs. In design activities, models represent situations as problem and solution statements […] A model can be viewed simply as a description, that is, as a representation of how things are" (March & Smith, 1995, p. 256, emphasis in original).
Method	"A *method* is a set of steps (an algorithm or guideline) used to perform a task. Methods are based on a set of underlying constructs (language) and a representation (model) of the solution space" (March & Smith, 1995, p. 257, emphasis in original).
Instantiation	"An *instantiation* is the realization of an artifact in its environment[…] Instantiations operationalize constructs, models, and methods[…] Instantiations demonstrate the feasibility and effectiveness of the models and methods they contain" (March & Smith, 1995, p. 258, emphasis in original).

Appendix 1.2- Scoping Review Pre-Registered Protocol

Approaches to decision threshold models in medical decision-making: A scoping review protocol

Authors

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Keywords

Decision thresholds; medical decision-making; decision-making; thresholds; treatment threshold; standard of proof.

Introduction

People are often faced with medical decisions that have uncertain outcomes. For example, people may face questions like: Should they wear a facemask inside a public place? Should they become vaccinated or vaccinate their children against known illnesses (e.g., HPV, measles)? Should they engage in safe sex practices (e.g., use condoms)? Should they proactively engage in cancer screening? The list goes on. Interestingly, people frequently make different decisions (e.g., they decide to become, or not become, vaccinated; they choose to participate, or not participate, in cancer screening; they wash, or do not wash, their hands; they wear, or do not wear, a facemask in a public place; they engage, or do not engage, in safe sex practices, etc.). Generally, it is believed that these differing decisions can be attributed to individual differences in subjective judgements that result in different decision thresholds (B. Djulbegovic et al., 2012a). Understanding decision thresholds may have the potential to reduce variation within medical decision-making by understanding the cognitive mechanisms that inform our decisions (B. Djulbegovic et al., 1999a). Such variation may be explained by individual differences in assessments about the benefits and harms of particular decisions, or subjective risk-assessment judgements (B. Djulbegovic, van den Ende, et al., 2015b). As a product of its influence in decision-making, the, "development of [the] threshold model is considered as one of the most important advances in medical decision-making" (B. Djulbegovic, Hozo, Mayrhofer, Ende, et al., 2019, p. 186).

The threshold model of decision-making (the threshold model) suggests that an individual should act when the perceived benefits of acting outweigh the consequences of not acting (B. Djulbegovic et al., 1999a; B. Djulbegovic, Hamm, et al., 2015a; Pauker & Kassirer, 1980, 1975b)[20]. This notion of a decision threshold would be familiar to those acquainted with a courtroom setting, where phrases such as "beyond a reasonable doubt" (typical of a criminal proceeding) or "preponderance of proof" (typical of a civil setting) articulate different cut-offs for how compelling the evidence

[20] The threshold model of decision-making is different from the threshold hypothesis which postulates that when the probability of loss is below a certain threshold, people will treat those probabilities as if they were zero (Slovic et al., 1977).

ought to be to warrant action (Brand & Finkel, 2019; Dekay, 1996; Weiss, 2003b, 2003a). In a legal setting, a decision threshold is also commonly called a standard of proof (Weiss, 2003a). For the purposes of this study, we will refer to the concept as a decision threshold. A decision threshold is normally quantified as a continuous numerical value between 0 and 1. Effectively, a decision threshold is a, "judgment regarding the desired balance between false positives and false negatives (e.g., convicting the innocent and letting the guilty go free, respectively)"(Weiss, 2003a, p. 29). In simpler language: a decision threshold reflects a point where an individual is equally inclined to take action or not take action (i.e., they are indifferent to the outcomes) (B. Djulbegovic, van den Ende, et al., 2015b).

Within the literature on decision thresholds, several different models have been described to estimate an individual's decision threshold (B. Djulbegovic, Hamm, et al., 2015a). A previous narrative review by Djulbegovic and colleagues (2015b) summarized the various threshold theories: some rely on expected utility models (Pauker & Kassirer, 1980, 1975b), others estimate decision thresholds by way of acceptable regret (B. Djulbegovic et al., 1999a; Hozo et al., 2018a; Hozo & Djulbegovic, 2008), others use regret-informed decision models (B. Djulbegovic et al., 2016; M. Djulbegovic, Beckstead, et al., 2015c; Hozo et al., 2018a; Tsalatsanis et al., 2010a), others use a dual processing model/ dual system model approach to estimating decision thresholds (B. Djulbegovic et al., 2012a; Tsalatsanis et al., 2015a), in addition to other models (B. Djulbegovic, van den Ende, et al., 2015b). One of the findings of this important review was to note that "little empirical work has been published on the threshold models, or using the threshold concept as a theoretical platform to investigate clinical decision-making" (B. Djulbegovic, van den Ende, et al., 2015b, p. 491). This observation provides a natural starting point for our scoping review.

Herein, we explore the current literature related to decision threshold theory. As expected utility threshold models are generally already well established within the medical decision-making literature (B. Djulbegovic, van den Ende, et al., 2015b; Pauker & Kassirer, 1980, 1975b), we focus specifically on decision threshold concepts, models, or theories that are not related to expected utility theory. Our scoping review adds to the literature, not only by providing an update to the corpus of scholarship on decision thresholds within medical decision-making, but also extending the review to include literature on how non-physicians (i.e., allied health professionals, lay-persons, etc.) use decision thresholds in approaching medically related decisions. Our scoping review adopts a JBI methodology to ensure transparent and replicable results (Peters et al., 2021; Peters, Godfrey, et al., 2020). The structured search strategy of the scoping review has been designed to comprehensively identify the literature on a topic, unconstrained by field and topic boundaries. This approach may allow us to identify applications of decision thresholds that lie outside of the traditional field, or to identify similar concepts that intersect or converge with our current understanding of decision thresholds.

Review Objective

This scoping review will focus on how decision thresholds have been previously conceptualized relative to medical/ health related decisions.

The proposed scoping review seeks to address the following primary research objective:

> **Objective 1**: to identify and categorize what theories have been developed to inform or estimate decision threshold(s) within medical decision-making.

In addition to the objective listed above, within the included articles, we will seek to explore the following secondary objective:

> **Objective 2**: to identify what consideration(s) an individual's subjective judgment(s) (e.g., attitudes, emotions, preferences, risk perceptions, values) have been given relative to decision thresholds within the medical decision-making literature.

Eligibility Criteria

Participants, concept, and context

This study focuses on decision threshold models relative to decisions made by individuals (e.g., physicians, allied health professionals, lay individuals, etc.), within the field of medical decision-making. We exclude decision threshold models related to decisions made at the policy level.

Types of sources

The scoping review will include a search for relevant articles on the databases of: MEDLINE (Ovid), SCOPUS, and ProQuest (Dissertations & Theses).

This scoping review will consider all study designs, including quantitative, qualitative, mixed-method study designs, as well as those papers that contribute to the theoretical understanding and advancement of decision thresholds. Reviews meeting eligibility criteria will be included, as well as theses and opinion papers. News and social media sources will not be searched.

Methods

This scoping review is guided by the JBI methodology for scoping reviews (Peters et al., 2021; Peters, Godfrey, et al., 2020). Upon completion, a PRISMA flow diagram will be produced to map the selection process in accordance with the PRISMA-ScR guidance on reporting for scoping reviews (Page et al., 2021; Tricco et al., 2018).

Search Strategy

The search strategy was designed to identify literature published in academic sources. The comprehensive search strategy was developed around the concept of decision thresholds within the context of medical decision-making. An initial unstructured search of MEDLINE (Ovid) was undertaken to identify seed articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index (MeSH) terms used to describe the articles were used to develop a full search strategy for the MEDLINE (Ovid) database. Because SCOPUS does not include MeSH terms or related index terms and uses different search syntax, the MEDLINE search strategy was translated to search the SCOPUS database. Theses were retrieved from the ProQuest database and used a simple search strategy of "decision threshold" in either the title or abstract.

Broadly, our search strategy sought to identify articles where the term "decision thresholds", and other like terms (e.g., therapeutic thresholds, diagnostic thresholds, treatment thresholds, probability thresholds, standard of proof, etc.), appeared within the title or abstract of an article within the context of "medical decisions" or other like terms (e.g., clinical decisions, health decision, clinical reasoning, etc.). To increase the flexibility of our search strategy, we incorporated proximity indicators such that the terms "decision" and "threshold" (and other similar combinations) only needed to appear within 3 words of each other. For example, if an author wrote the following in the title or abstract, "the threshold for the decision…", it would be included within the search. Within the search strategy, we also used 'wildcard' operators to capture singularities and pluralities of the same word (e.g., probabilit* would return results for the terms: "probability" and "probabilities"; judg* would return results for the terms: "judge", "judges", "judged", "judgements", "judging", "judgingly"). Full search strategies used can be found in Appendix 1.3: Search Strategies. The reference lists of all included sources of evidence (i.e., after the full-text screen) will be screened for additional records based on the article title.

Source of Evidence Selection

Articles will be included if they are published in English, are accessible online through the University of Ottawa library or the library at Clarkson University or available for download (i.e., free of charge) on the internet.

All records identified during the search will be exported as a .ris file and imported into Zotero, a free, open source, citation management system. Duplicates will be removed using the Zotero Duplicates Merger plug-in (Frangoudes, 2021/2022). Once the duplicates have been identified, a singular file of records from MEDLINE and SCOPUS will be imported into COVIDENCE (Veritas Health Innovation, 2022) where additional duplicates may be detected and removed by that software and/or by the reviewers. COVIDENCE is a, "web-based systematic review program that aims to make evidence synthesis a more proficient process" (Babineau, 2014, p. 68). Access to COVIDENCE is provided under license from the University of Ottawa.

The titles and abstracts of the records identified in our search will be reviewed by two independent reviewers using the Title and Abstract Screening criteria described below. Any disagreements will be discussed and resolved through consensus. Full text files for all the records included through this initial screening stage will be reviewed by the same two independent reviewers using the Full Text Screening criteria described below. Disagreements will be flagged and resolved through a consensus discussion. Both sets of screening criteria will be piloted in a subset of the records as described in Appendix 1.3: Screening Guidelines.

Screening Criteria

Since our scoping review broadly seeks to understand the different types of models that have been conceptualized or theorized to estimate decision thresholds, our screening criteria are similarly broad. Given that the literature on our topic transcends disciplinary boundaries, we keep our title and abstract screening criteria purposefully conceptual rather than concrete in order to be inclusive of fields using different terms to capture the same or similar ideas. Because our inclusion and exclusion criteria are broad, we provide screening implementation guides to help the reviewer determine which records are relevant to our stated objectives (Table 17 provides a summary of the inclusion/ exclusion; see Appendix 1.3: Screening Guidelines for additional information).

At the full-text review stage, our screening criteria remain somewhat broad and flexible; however, these inclusion and exclusion criteria are more directly aligned with the identified objectives of this scoping review. The inclusion and exclusion criteria for the full-text screening stage can be found in Table 17 (full-text screening guidelines can be found in Appendix 1.3: Screening Guidelines).

Identifying Additional Literature

The reference lists or bibliographies of all articles that meet the full-text inclusion criteria will be scanned according to the title and abstract inclusion and exclusion criteria for consideration of inclusion in the scoping review on the basis of titles alone. All of the potentially suitable articles will be deduplicated against the already-screened articles and loaded into the full-text review stage in COVIDENCE where they will be reviewed according to the same process described previously.

Table 17- Inclusion/ Exclusion Criteria

Screening Phase	**Inclusion**	**Exclusion**
Abstract and Title	• Refers to, or implies, the cognitive process of using or establishing decision thresholds. AND • Involves health-related decision-making processes by humans about humans.	• Not in English. OR • Decisions do not involve humans. OR • Article tests the performance or quality of clinical parameters or tests without a human subjective element. OR • Article refers to purely to economic evaluation.
Full-Text	• The **focus** of the article is about understanding/ explaining/ informing how individuals make health related decisions when faced with uncertainty. AND • The **process/ theory/ calculation** in which the decision threshold is estimated is **explicitly stated and/or referenced** relative to the decision. OR	• Not available online through the University of Ottawa library, the Clarkson University library, or available for download on the internet. OR • The article is not in English. OR • The article is solely about a **standard of practice** or **clinical guideline** for which the concept of a decision threshold(s) is mentioned by not thoroughly discussed and/or is arbitrarily chosen. OR • The article is solely about a **clinical outcome assessment/ clinical test/ prediction model** and/or the decision threshold(s) is arbitrarily chosen. OR

<table>
<tr>
<td></td>
<td>The article discusses the influence that individual subjective judgments (e.g., attitudes/ emotions/ preferences/ risk perceptions) has/have on an individual’s decision threshold relative to the decision.</td>
<td>The article is solely about the development/ evaluation of a software/ tool/ decision aid for a specific disease.
OR
The article is solely about economic evaluation and establishing a decision threshold based on a willingness-to-pay for an intervention at a population level that is not specific to an individual and/or does not explore how the willingness to pay threshold ought to be established.
OR
The article discusses decision thresholds within the context of an individual experiencing impaired cognition impacting the individual’s ability to make decisions (e.g., concussion, anxiety, etc.).
OR
The article calculates/ explores the concept of decision threshold(s) solely based on expected utility threshold models.
OR
The article calculates/ explores the concept of decision threshold(s) solely based on linear programming.</td>
</tr>
</table>

Data Extraction

A preliminary data extraction template was developed in Google Forms to extract the necessary data to address the objectives of the scoping review. However, it is expected that, as the authors become more familiar with the characteristics of the literature, the data extraction tool will be modified capture the information reported in the literature that is relevant to the scoping review (Peters, Godfrey, et al., 2020).

Information will be extracted according to two categories: *information about the article*, and *information from the article.*

Information about the article:

- Name(s) of author(s);
- Journal of publication; and,
- Year of publication.

Information from the article:

- What is the objective of the article?
- Is the article proposing/ developing/ revising a new theory for decision threshold analysis OR leveraging an existing theory (without revision)?
- Is there an equation to calculate the decision threshold?
- Does the article consider subjective factors that may inform an individual's decision threshold?
- Who is the decision-maker (e.g., physicians, allied health professionals, lay-persons)?
- What type of medical decision is the study exploring (i.e., context/ application)
- What are the main conclusions of the study?
- Country of origin
- List of relevant references for screening

See Appendix 1.5: Data Extraction for additional information on the data extraction process.

Data Analysis and Presentation

Data Analysis

Information will be aggregated from the various studies included within the scoping review and will be organized in format that is conducive to answering the research objectives. Although data analysis and structure may undergo iterative changes based on team member input and the identified literature, it is envisioned that the information gleaned from this scoping review will be analyzed, and organized, based on the objectives of the scoping review. Specifically,

1. We seek to identify what theories (and corresponding equations), outside of expected utility theory, are used to inform decision thresholds within medical decision-making; and
2. We seek to identify what consideration subjective judgements (e.g., attitudes, emotions, preferences, risk perceptions) have been given relative to an individual's decision threshold.

Consequently, our analysis will be focused on addressing the objectives of the scoping review. Ultimately the data analysis will be an iterative and reflexive process. As the author(s) become more familiar with the articles included in the final analysis, they will complete a thematic analysis to identify recurring patterns, concepts, and themes across the literature. The synthesis may include both qualitative and quantitative approaches, such as content analysis and descriptive statistics. Ultimately, we seek to provide a comprehensive overview of the existing research landscape while identifying gaps and areas for further investigation.

Graphical Displays and Presentation

Upon completion of the text identification and screening process, a PRISMA flow diagram will be produced to map the selection process in accordance with the PRISMA-ScR guidance on reporting for scoping reviews (Tricco et al., 2018).

The analysis (i.e., as described above) will produce tabular results based on the categories of the scoping review objectives (Peters, Godfrey, et al., 2020). A descriptive summary of each tabular result will accompany each of the tables to describe the results (Peters, Godfrey, et al., 2020). Bibliographic information (e.g., year of study publication) will be charted in a histogram (and other various plots as appropriate) to visually communicate various study findings (Peters, Godfrey, et al., 2020). For illustrative examples of tabular results please see Appendix 1.5.

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Conflicts of Interest
The authors have no conflicts of interest to declare.

Appendix 1.3- Scoping Review: Search Strategy

Comparative Search Strategy – MEDLINE (OVID) vs. SCOPUS

Search #	MEDLINE (OVID)	Search #	SCOPUS
1	((treatment* or diagnos* or probabilit* or approach* or analys* or model* or action or therapeutic or utility) adj3 threshold*).ti,ab.	1	TITLE-ABS((treatment* OR diagnos* OR probabilit* OR approach* OR analys* OR model* OR action OR therapeutic OR utility) W/3 threshold*)
2	(standard* adj3 proof).ti,ab.	2	TITLE-ABS(standard* W/3 proof)
3	(decision* adj3 threshold*).ti,ab.	3	TITLE-ABS(decision* W/3 threshold*)
4	(threshold* adj3 hypothes*).ti,ab.	4	TITLE-ABS(threshold* W/3 hypothes*)
5	1 or 2 or 3 or 4	5	1 OR 2 OR 3 OR 4
6	Decision support techniques/	6	N/A
7	Thinking/ or Decision making/ or Uncertainty/ or Judgment/ or Problem Solving/ or Heuristics/	7	N/A
8	anticipation, psychological/	8	N/A
9	6 or 7 or 8	9	N/A
10	(medical* or clinical* or treatment* or therap* or health).ti,ab.	10	N/A
11	10 and 9	11	N/A
12	((medical* or clinical* or treatment* or therap* or health) adj3 (decision* or reason* or judg* or solv* or cognition or decide* or deciding)).ti,ab.	12	TITLE-ABS((medical* OR clinical* OR treatment* OR therap* OR health) W/3 (decision* OR reason* OR judg* OR solv* OR cognition OR decide* OR deciding))
13	Clinical Decision-Making/ or Clinical Reasoning/	13	N/A
14	11 or 12 or 13	14	N/A
15	14 and 5	15	12 and 5

MEDLINE (OVID) Search Results

Search #	Search Structure	Count
1	((treatment* or diagnos* or probabilit* or approach* or analys* or model* or action or therapeutic or utility) adj3 threshold*).ti,ab.	19,529
2	(standard* adj3 proof).ti,ab.	219
3	(decision* adj3 threshold*).ti,ab.	1,397
4	(threshold* adj3 hypothes*).ti,ab.	581
5	1 or 2 or 3 or 4	21,433
6	Decision support techniques/	22,494
7	Thinking/ or Decision making/ or Uncertainty/ or Judgment/ or Problem Solving/ or Heuristics/	180,250
8	anticipation, psychological/	2,693
9	6 or 7 or 8	202,320
10	(medical* or clinical* or treatment* or therap* or health).ti,ab.	12,197,241
11	10 and 9	83,967
12	((medical* or clinical* or treatment* or therap* or health) adj3 (decision* or reason* or judg* or solv* or cognition or decide* or deciding)).ti,ab.	180,175
13	Clinical Decision-Making/ or Clinical Reasoning/	15,504
14	11 or 12 or 13	2,252,132
15	14 and 5	1,104

As of July 10, 2023

SCOPUS Search Results

Search #	SCOPUS	Count
1	TITLE-ABS((treatment* OR diagnos* OR probabilit* OR approach* OR analys* OR model* OR action OR therapeutic OR utility) W/3 threshold*)	64,234
2	TITLE-ABS(standard* W/3 proof)	2,188
3	TITLE-ABS(decision* W/3 threshold*)	6,069
4	TITLE-ABS(threshold* W/3 hypothes*)	1,495
5	1 OR 2 OR 3 OR 4	72,917
6	TITLE-ABS((medical* OR clinical* OR treatment* OR therap* OR health) W/3 (decision* OR reason* OR judg* OR solv* OR cognition OR decide* OR deciding))	277,671
7	6 and 5	1,115

As of July 10, 2023

ProQuest (Dissertations & Theses) Search Results

Search #	SCOPUS	Count
1	publication("decision threshold") OR abstract("decision threshold"); Additional limits- Source type: Dissertations & theses	114

As of August 23rd, 2023

Appendix 1.4- Scoping Review: Screening Guidelines

Title and Abstract Screening Guidelines

Scoping Review Objective:
The scoping review will focus on the applications in which decision threshold analysis have been previously conceptualized relative to medical/ health related decisions.

The proposed scoping review seeks to address the following primary research objective:

> **Objective 1**: to identify and categorize what theories have been developed to inform or estimate decision threshold(s) within medical decision-making.

In addition to the objective listed above, within the included articles, we will seek to explore the following secondary objective:

> **Objective 2**: to identify what consideration(s) an individual's subjective judgment(s) (e.g., attitudes, emotions, preferences, risk perceptions, values) have been given relative to decision thresholds within the medical decision-making literature.

The topic of decision thresholds has a wide, and varied, interpretation within the medical decision-making literature. To the extent that our scoping review broadly seeks to understand the different types of models that have been conceptualized/ theorized to estimate decision thresholds, we have broad inclusion/ exclusion criteria for our title/ abstract screen. The general inclusion/ exclusion criteria for our title/ abstract screen are the following:

Inclusion Criteria:

- Refers to/ implies the cognitive process of using or establishing decision thresholds;
- Involves health-related decision-making processes by humans about humans.

Exclusion:

- Not in English;
- Decisions do not involve humans;
- Article tests the performance or quality of clinical parameters or tests without a human subjective element;
- Article refers to purely to economic evaluation.

Because our inclusion/ exclusion criteria are so broad, we provide title/ abstract screening implementation guidelines to help the reviewer determine which titles/ abstract are relevant to our stated objectives.

Pilot Testing

Prior to commencing the title and abstract screen, the screeners (AS and AC) will conduct a pilot test of the title and abstract inclusion/exclusion criteria to ensure inter-rater agreement. To conduct this pilot test, the 25 “most relevant” articles (i.e., as identified by COVIDENCE) will be independently reviewed by the screeners; this pilot test will be informed by inclusion/ exclusion criteria and screening guidelines. To ensure inter-rater agreement in the inclusion/ exclusion criteria, we seek to achieve an inter-rater agreement that is reflective of “substantial agreement” (i.e., Cohen’s Kappa value ≥ 0.61) (Cohen, 1960; McHugh, 2012). After the initial pilot screening test of 25 titles and abstracts, if we do not achieve a Cohen’s Kappa value that is reflective of “substantial agreement” (or better), the screening team will meet to discuss screening criteria requiring clarification or refinement. Subsequent pilot tests will continue the same way until the desired inter-rater agreement (i.e., Cohen’s Kappa value) is achieved.

Title/ Abstracting Screening Implementation Guidelines

Reviewer Instructions:

If the article is missing an abstract, evaluate according to the inclusion criteria based on title alone.

<table>
<tr><td colspan="3">Scan the Title and Abstract</td></tr>
<tr><td colspan="2">Title/ Abstract is not in English</td><td rowspan="2">EXCLUDE</td></tr>
<tr><td colspan="2">The title/ abstract is not related to a health decision for humans (e.g., agriculture, manufacturing, veterinary, etc.)</td></tr>
<tr><td colspan="3">Deeper Read of Title and Abstract</td></tr>
<tr><td colspan="3">We seek to include articles that explore the notion of decision thresholds (i.e., the point of indifference between net-benefit and net-harms that dichotomizes an individual’s behaviour into acting, or not) within medical decision-making. In screening the titles/ abstracts, the screener should consider the following questions (and key terms):</td></tr>
<tr><td>Does the title/abstract relate to a health-related decision that involves human judgement?
AND</td><td>May Include Key Terms (or Concepts) Such As:
• Health care provider/ Allied health professional
• Physician
• Caregiver/ Guardian
• Patient</td><td>IF NO, EXCLUDE</td></tr>
<tr><td>Does the title/abstract refer to a decision threshold(s) that helps to dichotomize a decision (e.g., treatment/ no treatment; action/ no action)?

Does the title/abstract

OR</td><td>May Include Key Terms (or Concepts) Such As:
• Prescriptive
• Descriptive
• Normative
• Expected Utility/ Expected Utility Theory
• Risk/ Benefit Analysis (Net-Risk/ Net-Benefit)
• Bayesian
• Rational Decision-Making/ Rational Choice
• Irrational Decision-Making/ Irrational Choice
• Intuitive threshold
• Variation in thresholds
• Treat/ Not treat
• Probability of X relative to a specified threshold.
Example text of inclusion:
E.g.,: “To help the physician decide whether or not to treat a patient who may or may not have a disease, a method has been developed for calculating a therapeutic threshold. If the probability of disease in a given patient exceeds the threshold, the preferable course of action is to treat; if the probability is below the threshold, the preferable course of action is to withhold treatment”.

Consider the following for not an automatic inclusion:
• The title/ abstract is focused on evaluating the performance and/or quality of a specific test/ medical procedure.</td><td>INCLUDE</td></tr>
</table>

	• The title/ abstract appears to interpret decision thresholds strictly in a clinical sense (e.g., X/parts per million, mmHg, etc.)	
Does the title/ abstract refer to the concept of regret? **OR**	**May Include Key Terms (or Concepts) Such As:** • Regret • Regret Theory • Anticipated Regret • Ex-ante or ex-post regret • Acceptable regret • Decision regret • Omission • Commission Example text of inclusion: E.g.,: "We explain these differences in practice by differences in disease probability thresholds at which physicians decide to act: contextual social and clinical factors and emotions such as regret affect the threshold by influencing the way doctors integrate objective data related to treatment and testing."	
Does the title/ abstract refer to any concepts related to dual processing theory? **OR**	**May Include Key Terms (or Concepts) Such As:** • Dual Processing Theory • Dual Processing Model • Dual System Model • Hybrid model • Type I/ Type 1/ thinking/ reasoning • System I/ System 1 thinking/ reasoning • Type II/ Type 2 thinking/ reasoning • System II/ System 2 thinking/ reasoning	
Does the title/ abstract refer to any concepts related to risk perception and/or cultural theory/ cultural cognition theory?	**May Include Key Terms (or Concepts) Such As:** • Perceived Risk/ Benefit • Prospect Theory • Cultural Theory • Cultural Cognition Theory • Cultural cognition • Worldviews • Cultural worldviews	
The inclusion/ exclusion of some articles, given their title/abstract, may require greater consideration. Below is a list of questions (non-exhaustive) that may assist the screening process.		
Is the article missing an abstract?	**Consider the following:** • Read the conclusion of the article and evaluate according to the inclusion criteria based on the conclusion alone. • In the absence of a conclusion, read the last paragraph of the main text and evaluate according to the inclusion criteria based on last paragraph alone.	**THOUGHTFUL CONSIDERATION**

Does the title/abstract refer to graphical representations of decision thresholds (e.g., Nomograms, ROC curves, etc.)?	**Consider the following:** • Does the title/ abstract appear to be evaluation of the performance and/or quality of a specific test/ medical procedure/ prediction? If yes, exclude. • Are they inferring a weighing of net-benefits vs. net-harms and/or the potential for different decision thresholds? If yes, include.	
Does the title/abstract refer to prediction models, algorithms, machine learning, or artificial intelligence?	**Consider the following:** • Does the title/ abstract appear to be focused on predicting a health-related outcome given a set of inputs? If yes, exclude. • Does the title/ abstract appear to be focused on a machine learning or artificial intelligence application? Do they reference decision thresholds for the perspective of a clinical threshold and/or evaluation of the performance/ quality of a test/ procedure? If yes, exclude. • Does the title/ abstract appear to be focused on a machine learning or artificial intelligence application and speak to the potential for threshold differentiation based on perceived harms and perceived benefits? If yes, include.	
Does the title/abstract refer to thresholds that relate to the health economic evaluation (i.e., "willingness to pay" thresholds)?	**Consider the following:** • Is it evaluating net-benefit vs. net-harms to derive a threshold? If yes, include. • Is it a function of QALY vs. Cost and from the perspective of a non-individual (e.g., government, etc.). If yes, exclude.	

Full-Text Screening Guidelines

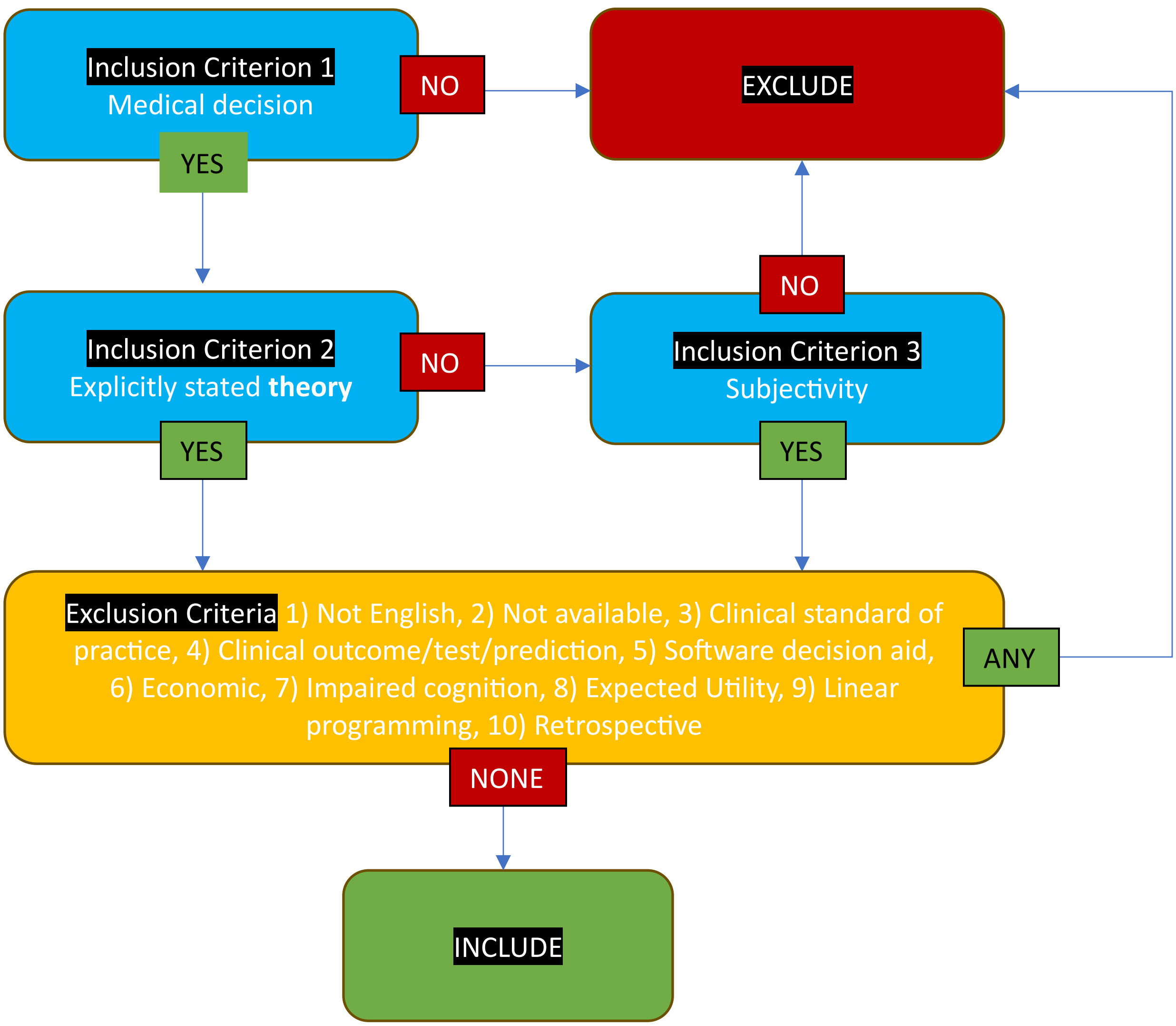
Interpretation

The literature included in this scoping review is quite diverse and will require the screener to read the full text to glean an understanding of how decision thresholds are being referenced within the main text. Ultimately, we seek to identify how individuals use decision thresholds in an ex-ante fashion (i.e., before the decision is made) to inform their decision. The full text screening guide can be interpreted in the following way.

For a text to be included in the review it must meeting the following:

- Consideration Criteria 1 AND Inclusion Criteria 1; Or,
- Consideration Criteria 1 AND Inclusion Criteria 2; Or,
- Consideration Criteria 1 AND Inclusion Criteria 1 AND Inclusion Criteria 2.

For a text to be excluded in the review it can meet any of the listed exclusion criteria (or combination thereof). The rational for exclusion of the article should be listed based on the rank order of the exclusion criteria (i.e., if excluding based on "Exclusion Criteria 2" AND "Exclusion Criteria 6", then select "Exclusion Criteria 2" as the rational for exclusion.



Pilot Testing

Prior to commencing the full-text screening, the screeners will conduct a pilot test of the full-text inclusion/exclusion criteria to ensure inter-rater agreement. To conduct this pilot test, the first 10 articles when sorted by alphabetically by authors last name (i.e., sorted A to Z) will be independently reviewed by the screeners; this pilot test will be informed by inclusion/ exclusion criteria and the screening guidelines relative to the full-text screening. To ensure inter-rater agreement in the full-text inclusion/ exclusion criteria, we seek to achieve an inter-rater agreement that is reflective of "substantial agreement" (i.e., Cohen's Kappa value ≥ 0.61) (Cohen, 1960; McHugh, 2012) relative to the inclusion/ exclusion decision. Relative to the "exclusion reason" we seek to achiever an inter-rater relative agreement of at least 60%. After the initial pilot screening test of 10 full-text articles, if we do not achieve a Cohen's Kappa value that is reflective of "substantial agreement" (or better) relative to the inclusion/ exclusion decision, and at least 60% inter-rater relative agreement relative to the exclusion rational, the screening team will meet to discuss screening criteria requiring clarification or refinement. Subsequent pilot tests will continue the same way until the desired inter-rater agreement (i.e., Cohen's Kappa value)/ relative inter-rater agreement is achieved.

Full-Text Screening Implementation Guidelines

<table>
<tr><th colspan="3">Inclusion Criteria</th></tr>
<tr><th>Criteria</th><th>Description</th><th>Decision</th></tr>
<tr><td>Inclusion Criteria 1: The focus of the article is about understanding/ explaining /informing how individuals make health related decisions when faced with uncertainty.
AND</td><td>Look at the article’s discussion/ conclusion:
• Does the discussion/ conclusion discuss a health/ medical related decision such as determining whether to: treat or not treat, test or not test, act or not act, etc.? OR
• Does the discussion/ conclusion discuss considering trade-offs between benefits and harms (costs) that ultimately inform and individual’s decision? OR
• Does the discussion/ conclusion discuss a decision threshold concept? OR
• Does the discussion/ conclusion propose a new/novel (as stated by the authors) framework that descriptively or prescriptively informs decision-making?

Hypothetical Examples That Meet the Above Criteria
E.g., 1: “The threshold concept represents a linchpin between evidence (which presents on the continuum of credibility) and decision-making, which is a categorical exercise (as choice options are either selected or not) […] the clinical action such as treat vs no treat [sic] is best explained by relating benefit and harms of proposed therapeutic interventions to the threshold probability: if the estimated probability of disease is greater than the threshold probability, then the decision-maker is inclined to give treatment; if the probability of disease is below the threshold, then the treatment is withheld” (B. Djulbegovic et al., 2012a, pp. 9–10).

E.g., 2: “When managing an individual patient, most physicians implicitly consider the trade-offs that influence the decision whether to withhold therapy, order another test, or administer therapy” (Pauker & Kassirer, 1980, p. 1114).

E.g., 3: “The relation between net benefit and cost of treatment and the minimal suspicion of disease (threshold probability) required to recommend therapy […is] defined by the equation, when the benefits and costs are known, the ratio between them defines how certain a physician should be of a diagnosis before recommending treatment. At one extreme, if the benefits of treatment is zero, the threshold (T) is one, and, since the probability of disease cannot exceed one, therapy would never be selected” (Pauker & Kassirer, 1975a, p. 232).

E.g., 4: “In this paper, we show how a simple threshold model can function as a foundational block as a link between SDT, FFTs and EAT” (Hozo et al., 2017b, p. 58).</td><td>INCLUDE</td></tr>
<tr><td colspan="2">After identifying that the focus of the article is about an individual’s decision relative to a health-related decision. Explore the main body of the text. Does the article address at least one of the following:</td><td></td></tr>
<tr><td>Inclusion Criteria 2: The process/ theory/ calculation in which a decision threshold</td><td>If an article refers to any of the following decision thresholds models as informing the calculation of the decision threshold, include to full text review. We believe there to be four general approaches to</td><td>INCLUDE</td></tr>
</table>

is estimated is **explicitly stated and/or referenced** relative to the decision. **OR**	calculating decision thresholds as per (B. Djulbegovic, van den Ende, et al., 2015b): • Regret Based Threshold Models. May include key terms such as: o Acceptable Regret o Anticipated Regret Typically articles using this type of decision threshold approach will cite (B. Djulbegovic et al., 1999a; Hozo et al., 2008a; Hozo & Djulbegovic, 2008) relative to approach taken to calculating the decision threshold. E.g., 1: "We introduce the concept of acceptable regret, a level of regret which the decision maker can comfortably tolerate, and show that it can be used to divide the range of disease probabilities into three zones: probabilities sufficiently low that the decision maker can comfortably withhold treatment, probabilities sufficiently high that the decision maker can comfortably initiate treatment and a 'gray zone' of probabilities between, in which no decision results in a comfortable level of expected regret" (B. Djulbegovic et al., 1999a, p. 259) • Hybrid Threshold Models Those who employ a hybrid threshold model, "retain the original EUT formulation but asks the decision-maker to weigh health outcomes (morbidities and mortalities) differently when the occur in patients with and without disease" (B. Djulbegovic, van den Ende, et al., 2015b, p. 488). In essence, within the hybrid model, individuals are believed to, "use a kind of intuitive threshold they cannot make explicit but that is based on their knowledge and/or perception of about the harm and benefit of a treatment" (Basinga, Moreira, Bisoffi, Bisig, & Van den Ende, 2007, p. 54). • Dual-Processing Threshold Models "The most important feature of the DPM model is interaction between type I and type 2 cognitive processes" (B. Djulbegovic, van den Ende, et al., 2015b, p. 488). • Type I processes are commonly affectively driven, fast, and intuitive. • Type 2 processes are commonly analytical, calculative, and deliberative. Typically, articles using this type of decision threshold approach will cite (B. Djulbegovic et al., 2012a). • Other Approaches If the article proposes a novel/ different threshold model than the ones above (exclude expected utility theory and linear programming- see exclusions). Then, include to full text review. E.g., 1: "The goal of the paper is to develop a novel decision-making approach that incorporates the decision maker's attitudes towards multiple treatment strategies. Our goal is addressed through three specific aims. First, we deviate from the traditional expected utility theory in an attempt to satisfy both formal criteria of rationality and human intuition about good decisions. We employ regret theory, since	

	regret is a cognitive emotion that combined both rationality and intuition, which are key elements for decision-making, to develop a novel methodology for eliciting decision makers' personal preferences. Consequently we reformulate decision curve analysis from the regret theory point of view to evaluate alternative treatment strategies and to integrate both evidence on prognosis and treatment with the decision maker's attitudes and preferences" (Tsalatsanis et al., 2010a, p. 2). E.g., 2: "We have presented her an Internet program and modified threshold formulas that can assist physicians in clinical decision making. We believe this modification will finally enable wider use of pioneering work of Pauker and Kassirer" (Hozo & Djulbegovic, 1999, p. 179). 2024-01-22 9:06:00 PM	
Inclusion Criteria 3: The article discusses the influence that individual **subjective judgments** (e.g., **attitudes/ emotions/ preferences/ risk perceptions**) has/have on an individual's **decision threshold** relative to the decision.	E.g., 1: "Variation in decision making can be explained using the threshold model as a descriptive theory: physicians act is if they refer to different thresholds, which in turn could be due to different ways of cognitively assessing disease probability or the consequences of treatments, or of integrating treatment benefits and harms. This directs attention to factors that may affect each of these processes, such as emotions, regret of omission versus commission, financial incentive, poor quality evidence, application of average data to individual patients and individual differences in subjective judgments of risk assessment and disease prevalence. Understanding the cognitive mechanisms that affect action thresholds may have important policy implications…" (B. Djulbegovic, Hamm, et al., 2015a, p. 1122). E.g., 2: "The approach presented in this paper relies on the concept of the threshold probability at which a decision maker is indifferent between strategies, to suggest the optimal decision. Unlike the approaches described in the classic threshold papers, our approach is based on the notion that the value of threshold probability is clearly subjective and depends on the personal preferences of the decision maker" (Tsalatsanis et al., 2010a, p. 11).2024-01-22 9:06:00 PM	
Exclusion Criteria		
Criteria	**Description**	**Decision**
Exclusion Criteria 1: The full text of the article is not accessible online. **OR**	Exclude if the full text is not available online through either the University of Ottawa library, the Clarkson University library or available for download on the internet.	**EXCLUDE**
Exclusion Criteria 2: The article is not in English. **OR**	Exclude if the main body of the text is not in English.	
Exclusion Criteria 3: The article is solely about a **standard of practice** or **clinical guideline** for which the concept of a decision threshold(s) is mentioned but not thoroughly discussed and/or is arbitrarily chosen.	E.g., 1: "since the release of these new guidelines, additional evidence has emerged that may suggest a rationale for extending statin consideration to an even larger proportion of asymptomatic adults. Some new evidence would support that a treatment threshold even below 7.5% risk of ASCVD [(atherosclerotic cardiovascular disease)] in 10 years could be justified. In this review, we discuss new findings since 2013, and propose strategies emanating from the current guidelines to help clinicians and patients make more informed decisions about long-term statin use" (Pender et al., 2016, p. 1691).	

OR	E.g., 2: "In this overview of SSc-ILD [(interstitial lung disease associated with systemic sclerosis)], our knowledge of epidemiology and pathogenesis is summarised. Larger sections follow in which key clinical uncertainties are explored and management dilemmas are discussed in detail" (Wells, 2014, p. 329) E.g., 3: "this study's thresholds were arbitrarily chosen and different thresholds result in a different number of patients categorized as low risk" (Geersing et al., 2010, p. 746). E.g., 4: "Aims: to optimise treatment and outcomes for older women with operable breast cancer by determining composite age, tumour and fitness thresholds for treatment selection and patient benefit"	
Exclusion Criteria 4: The article is solely about a **clinical outcome assessment /clinical test/ prediction model** and/or the decision threshold(s) is arbitrarily chosen. **OR**	E.g., 1: "The aim of the main study was to quantify the safety and accuracy of a diagnostic clinical decision rule to exclude DVT [(deep venous thrombosis)] when used by GPs" (Geersing et al., 2010, p. 743). E.g., 2: "The goal is compare the use of risk prediction Model 1 versus risk prediction Model 2 (with an additional marker) for making a decision of treatment versus no treatment when applied to a target population" (Baker et al., 2014, p. 3). E.g., 3: "Our aim in undertaking this comparison was to determine if any systematic differences could be detected between Scottish and Canadian dentists taking part in the two studies in terms of their stated restorative criteria and their ability to detect interproximal carries on bitewing radiographs" 2024-01-22 9:06:00 PM	
Exclusion Criteria 5: The article is solely about the development/ evaluation of a **software/ tool/ decision aid** for a specific disease. **OR**	E.g., 1: "the goal of the KASIMIR project is to provide tools for the management of decision knowledge in oncology" (Lieber et al., 2008, p. 262). E.g. 2: "In this study, we evaluated US physicians' current osteoporosis management. We also evaluated whether physicians who are presented with quantitative hip fracture estimates would use that information in decision making on postmenopausal osteoporosis prevention of treatment" (Neuner & Schapira, 2012, p. 371)	
Exclusion Criteria 6: The article is solely about economic evaluation and establishing a decision threshold based on a willingness to pay for an intervention at a population level that is not specific to an individual and/or does not explore how the willingness to pay threshold ought to be established. **OR**	E.g., 1: "Stochastic analysis showed that if the health service is willing to pay £10,000 per additional QALY [(Quality Adjusted Life Year)], the probability of this strategy being cost-effective was around 82% increasing to 95% at a threshold of £50,000 per QALY" (M. Robinson et al., 2005, p. 3).	

Exclusion Criteria 7: The article discusses decision thresholds within the context of an **individual experiencing impaired cognition** impacting an individual's ability to make decisions (e.g., concussion, depression, anxiety, etc.). **OR**	The article discusses decision thresholds within the context of an individual experiencing impaired cognition impacting an individual's ability to make decision (e.g., concussion, depression, anxiety, etc.). E.g., 1: "The purpose of this paper is to discuss three aspects relevant to decision-making in minimally-aware patients. These are: (a) the difficulties inherent in establishing a reliable means of communication with the patient; (b) the difficulty of exploring understanding and decision-making once a means of communication has been determined; (c) legal implications including problems that may arise with the 'balance of probabilities' legal standard of proof when determining capacity with specific reference to the right to die issue" (Coughlan et al., 2005, p. 249).	
Exclusion Criteria 8: The article calculates/ explores the concept of decision thresholds solely based on **expected utility threshold models**. **OR**	• Expected Utility Threshold (EUT) Models The equation for decision thresholds using this approach often look similar to: $Threshold = \frac{1}{1+\frac{Net\ Benefit}{Net\ Harms}}$ (Pauker & Kassirer, 1975a, 1980)OR $Threshold = \frac{Cost}{Cost+Benefit}$ (Cummings, 1996) Typically authors who are referencing this type of threshold analysis will cite (Pauker & Kassirer, 1975a, 1980) relative to approach taken to calculating the decision threshold. These papers will also likely list costs and utility benefits that are not specific or idiosyncratic to the individual evaluating the decision. E.g., 1: "To derive thresholds, we assigned a probability and utility to each terminal branch of the decision tree (Tables 1 and 2), calculated the expected value of the two main branches (for example, 'administer treatment' and 'perform diagnostic test'), set the expected value of the two main branches equal to each other, and then solved for the probability of disease" (Pauker & Kassirer, 1980, pp. 1110–1112). E.g., 2: "In quantitative terms, the treatment threshold is the probability of the outcome (hip fracture) at which the overall value of the treatment is equal to the overall value of not treating […] the 'treatment threshold' can be estimated quantitatively for any treatment to prevent any condition. Pauker (1) originally derived the concepts of treatment thresholds and thresholds for diagnostic testing" (Cummings, 1996, p. 101). 2024-01-22 9:06:00 PM	
Exclusion Criteria 9: The article calculates/ explores the concept of decision thresholds solely based on **linear programming**.	• Linear Programming Models Although linear programming and expected utility are similar to the extent that they both involve optimization and decision-making, linear programming is focused on finding optimal solutions in solutions with linear relationships, while expected utility theory is focused on decision-making under uncertainty in a fashion that maximizes their expected utility. E.g., 1: "The second aim of the present study was to demonstrate the applicability of linear programming to problems of threshold analysis" (Sonnenberg, 2000, p. 1415).	

For the purposes of Covidence, exclusion reasons will be selected based on the following order:

- Not Accessible
- Not in English
- Does not meet “Inclusion Criterion 1”: Not a medical decision.
- Does not meet “Inclusion Criterion 2” OR “Inclusion Criterion 3”: Does not refer to a decision theory OR subjective judgement.
- Standard of Practice/ Clinical Guideline
- Clinical Test/ Prediction Model
- Software/ Tool/ Decision Aid
- Willingness to Pay Threshold (WTP)
- Impaired Cognition
- Expected Utility
- Linear Programming

Appendix 1.5- Scoping Review: Data Extraction Tool

A custom Google Form was created to standardize data extraction from all included articles. All included articles were downloaded as PDF and imported into Zotero as part of the Data Extraction and Analysis process to allow for easy exportation of relevant annotations within the article. Data that was extracted from each article included: information about the article, and information from the article, as described below.

Information About the Article

Data Collection Field	Description	Answer Type	Answer Options
COVIDENCE ID	ID number assigned to the record in COVIDENCE. Found by looking the article up in COVIDENCE	Short answer	N/A
First Author Name	Last name and first initial of first name of first author in the publication header/ byline (e.g., Scarffe, A.)	Short answer	N/A
Year of Publication	Year of publication as listed in the citation (e.g., 2002)	Short Answer	N/A
Title of the Publication	Title of the publication in which the record appears (e.g., Journal of Organizational Behavior and Human Decision Processes)	Short Answer	N/A

Information From the Article

Data Collection Field	Description	Answer Type	Answer Options
Country of Study of the Participants	If the study is an empirical study, was is the country of origin of the participants in the study (e.g., USA, Canada, UK, etc.)	Short Answer	If not applicable, NA.
Objective/ Research Question	The objective or research question, if possible, in the authors words (use quotations and page numbers). In a case where the objective or question is vague or non-specific, use your own words.	Long Answer	N/A
Does the paper discuss decision thresholds in the context of:	Address the way manner in which decision thresholds are discussed in the paper.	Multiple Select (All that Apply)	• A specific theory/ theoretical understand of decision thresholds • Application of decision thresholds • Contextual/ Subjective factors that inform decision thresholds • Other: (text entry)
What are the contextual factors that are considered? (Place an * for factors that are statistically significant)	Identify any contextual factors for which were measured or discussed relative to the decision thresholds. Place an * if the article identifies a contextual factor as being statistically significant.	Short Answer	
What are the subjective factors that are considered? (Place an * for factors that are statistically significant)	Identify any subjective factors for which were measured or discussed relative to the decision thresholds. Place an * if the article identifies a subjective factor as being statistically significant.	Short Answer	

Data Collection Field	Description	Answer Type	Answer Options
Is the paper: (Pick One)	Identify what is the type of article that is included.	Single Select	• Empirical/ Primary Research • Conceptual/ Theoretical • Commentary • Conceptual with Research • Review • Other: (text entry)
If the paper is empirical/ primary research is the study:	Identify the type of study of the included article.	Single Select	• Qualitative • Quantitative • Mixed Methods • N/A
If the paper is empirical/ primary research is the study	Identify the nature of the decision thresholds that were used in the study.	Single Select	• Real world observations of real world medical decisions • Presents study participants with hypothetical vignetters of medical decisions • Simulation model • N/A
If the paper is a review, is it a:	Identify the type of review that is included in the included articles.	Single Select	• Narrative Review • Scoping Review • Systematic Review • Meta-Anlaysis • Literature Review • N/A
If the paper is theoretical/ conceptual/ review do they use hypothetical vignettes to illustrate important concepts the authors are trying to convey?	Do the authors of the article use a hypothetical vignette(s) of a medical decision to illustrate how decision thresholds can be used to inform the decision?	Single Select	• Yes • No • N/A

Data Collection Field	Description	Answer Type	• **Answer Options**
The paper explores decision thresholds from the following perspective:	Determining if the decision threshold was estimated ex-ante or ex-post	Multiple Select (Select All that Apply)	• Ex-Ante (before a decision/ before a hypothetical decision) • Ex-Post (After a decision has been made/ retrospectively)
Does the paper claim to propose a 'novel' decision threshold?	Identifying which articles (if any) state that they are proposing a novel decision threshold approach/ theory.	Single Select	• Yes • No
Theoretical Approach/ Contribution	Categorize the main theory that underpins the authors understanding of decision thresholds.	Single Select	• Regret/ Acceptable Regret/ Anticipated Regret • Hybrid (Expected Utility Formulation with Different Weighing) • Dual Processing • Info-Gap Theory • Information Theory • Signal Detection Theory • Social Judgement Theory • Expected Utility Theory • Regression • Unclear • Other: (Text Entry)
IF "Unclear/ Other" in "Theoretical Approach/ Contribution"	If the response of "Other" is selected in the question for "Theoretical Approach/ Contribution", then identify the approach	Long Answer	N/A
If there is a threshold equation, which page #?	Does the article provide an equation for how the decision threshold can be calculated? If yes, which page # is it on?	Short Answer	N/A
Type of Threshold Decision	What type of decision threshold does the article refer to?	Multiple Select (Select All that Apply)	• Diagnosis • Test/ No Test • Treatment/ No Treatment • Other: (Text Entry)

Data Collection Field	Description	Answer Type	Answer Options
Type of medical decision	What is the focus of the decision in the article? For example, is the decision about “vaccines”, “cancer screening”, “end of life decisions”, etc.	Short Answer	N/A
Who is the decision maker?	Who is the decision maker that the article explores the concept of decision thresholds about?	Checkbox (all that apply)	• Physician • Dentist • Nurses • Pharmacist • Other Allied Health Professional • Lay-Individuals/ Patients • Guardians/ Caregivers • Other: (Text Entry)
Main conclusions	What are the main conclusions of the study? If possible, use the authors words (use quotations and page numbers). In a case where the main conclusion(s) is (are) vague or non-specific, use your own words	Long Answer	N/A
Relevant References	Copy and paste relevant references from the appropriate reference lists for full-text review consideration.	Long Answer	N/A
Notes	Used for any relevant notes that the extractor may wish to articulate and does not fit in one of the above questions	Long Answer	N/A

Appendix 1.6- Scoping Review: Summary of Included Articles

Table 18- Summary of Included Articles in Scoping Review

Article	**Type of Paper**	**Decision-Maker**	**Decision Threshold Type**	**Health Condition/ Application**
(Christensen-Szalanski et al., 1982)	Empirical	Physician	Diagnosis; Test/ No Test	Pneumonia
(Eisenberg & Hershey, 1983)	Conceptual/ Theoretical	Physician	Diagnosis; Test/ No Test; Treatment/ No Treatment	Coronary Artery Disease
(Feinstein, 1985)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Angina
(Hartz et al., 1986)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Coronary Artery Disease
(M. J. Young et al., 1986)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Coronary Artery Disease
(M. Young et al., 1987)	Empirical	Physician	Treatment/ No Treatment	Coronary Artery Disease
(Asch et al., 1990)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	Streptococcal Pharyngitis; HIV
(Sainfort, 1991)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	Disease in General
(Plasencia et al., 1992)	Empirical	Physician	Diagnosis	Coronary Artery Disease
(Winkenwerder et al., 1993)	Empirical	Physician	Test/ No Test; Treatment/ No Treatment	Sexually Transmitted Infections
(B. Djulbegovic et al., 1995)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Myocardial Infection; Acute Appendicitis; Pulmonary Embolism
(Glasziou & Irwig, 1995)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Stroke
(Verp & Heckerling, 1995)	Empirical	Patient	Treatment/ No Treatment	Prenatal testing
(Hanson et al., 1996)	Empirical	Physician	Treatment/ No Treatment	Chronic Obstructive Pulmonary Disease; Heart Failure; Malignant Neoplasms; Hepatic Cirrhosis
(B. Djulbegovic et al., 1999b)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Cerebral Artery Ischemic Stroke

Article	Type of Paper	Decision-Maker	Decision Threshold Type	Health Condition/ Application
(Hozo & Djulbegovic, 1999)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Pulmonary Embolism; Acute Appendicitis
(Coenen et al., 2000)	Empirical	Physician	Diagnosis; Treatment/ No Treatment	Tracheitis; Bronchitis
(B. Djulbegovic et al., 2000)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	Deep Veinous Thrombosis; Breast Cancer; Atrial Fibrillation; Coronary Artery Disease
(McAlister et al., 2000)	Empirical	Physician; Patient	Treatment/ No Treatment	Hypertension
(Steel, 2000)	Empirical	Physician	Treatment/ No Treatment	Hypertension
(Van Hoe & Miserez, 2000b)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Acute Appendicitis
(Brundage et al., 2001)	Empirical	Caregiver/ Guardian	Treatment/ No Treatment	Advanced Non-Small Cell Lung Cancer
(Cotler et al., 2001)	Empirical	Physician; Patient	Treatment/ No Treatment	Hepatitis C
(Sinclair et al., 2001)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Atrial Fibrillation
(Cahan et al., 2003)	Empirical	Physician	Test/ No Test; Treatment/ No Treatment	Coronary Artery Disease; Dissecting Aortic Aneurism; Reflux Esophagitis; Bilary Colic; Anxiety Disorder
(Ng et al., 2004)	Empirical	Physician	Treatment/ No Treatment	Hodgkin’s Disease
(Sonnenberg, 2004a)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Gastroenterology
(Greenfield et al., 2005)	Empirical	Physician	Treatment/ No Treatment	Coronary Artery Disease
(Man-Son-Hing et al., 2005)	Review	Patient	Treatment/ No Treatment	Atrial Fibrillation

Article	Type of Paper	Decision-Maker	Decision Threshold Type	Health Condition/ Application
(Basinga, Moreira, Bisoffi, Bisig, & Van Den Ende, 2007)	Empirical	Physician	Treatment/ No Treatment	Tuberculosis
(Hozo & Djulbegovic, 2008)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	Pulmonary Embolism
(Hozo et al., 2008b)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Active Malignant Disease
(Thompson et al., 2008)	Empirical	Nurse	Treatment/ No Treatment	General Health – Not Disease Specific
(van Dijk et al., 2008)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Testicular Cancer
(Ben-Haim et al., 2009)	Conceptual/ Theoretical	Physician; Patient	Diagnosis	Diabetes
(Moreira et al., 2009)	Empirical	Physician	Treatment/ No Treatment	Tuberculosis
(Boland & Lehmann, 2010)	Empirical	Physician	Treatment/ No Treatment	Ocular Hypertension
(Malhi et al., 2010)	Empirical	Physician	Treatment/ No Treatment	Psychosis
(Tsalatsanis et al., 2010b)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Prostate Cancer
(Warner et al., 2010)	Commentary	Physician	Diagnosis Test/ No Test Treatment/ No Treatment	Bacterial Meningitis
(Tsalatsanis et al., 2011)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Palliative Care
(Cheyne et al., 2012)	Empirical	Physician; Midwife	Action/ No Action (Patient Transfer)	Childbirth
(B. Djulbegovic et al., 2012b)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Pulmonary Embolism; Acute Leukemia
(F. Douglas et al., 2012)	Empirical	Physician; Patient	Treatment/ No Treatment	Osteoporosis
(Mohan et al., 2012)	Empirical	Physician	Action/ No Action (Patient. Transfer)	Trauma Patients
(Ost & Gould, 2012)	Review	Physician	Test/ No Test; Treatment/ No Treatment	Pulmonary Nodules
(Pines et al., 2012)	Empirical	Physician	Treatment/ No Treatment	Pulmonary Embolism

Article	Type of Paper	Decision-Maker	Decision Threshold Type	Health Condition/ Application
(Lazarus & Ost, 2013)	Review	Physician	Test/ No Test; Treatment/ No Treatment	Pulmonary Nodule
(Vickers et al., 2013)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Diagnostic Tests
(B. Djulbegovic et al., 2014b)	Empirical	Physician	Treatment/ No Treatment	Acute Myeloid Leukaemia; Pulmonary Embolism
(Felder & Mayrhofer, 2014b)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	Brain Tumour
(Hernandez et al., 2014)	Empirical	Physician	Treatment/ No Treatment	Pancreatic Adenocarcinoma
(Lahaye et al., 2014)	Empirical	Patient	Treatment/ No Treatment	Atrial Fibrillation
(Sreeramareddy et al., 2014)	Empirical	Physician	Treatment/ No Treatment	Tuberculosis
(Tsalatsanis et al., 2015b)	Conceptual/ Theoretical	Physician	Test/ No Test	Prostate Cancer
(Connors & Siner, 2015)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	ICU Decisions
(Cucchetti et al., 2015)	Empirical	Physician; Patient	Treatment/ No Treatment	Intermediate Hepatocellular Carcinoma
(B. Djulbegovic, Hamm, et al., 2015b)	Commentary	Physician	Treatment/ No Treatment	N/A
(B. Djulbegovic, van den Ende, et al., 2015a)	Review	Physician	Test/ No Test; Treatment/ No Treatment	Tuberculosis
(Ebell et al., 2015)	Empirical	Physician	Test/ No Test; Treatment/ No Treatment	Influenza; Acute Coronary Syndrome; Deep Veinous Thrombosis; Urinary Tract Infection

Article	Type of Paper	Decision-Maker	Decision Threshold Type	Health Condition/ Application
(Sonnenberg, 2015)	Review	Physician	Treatment/ No Treatment	Gastroenterology
(Courbage & Rey, 2016)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Preventative Treatments
(deVos-Kerkhof et al., 2016)	Empirical	Physician	Treatment/ No Treatment	Bacterial Infection
(Sheldrick et al., 2016)	Empirical	Physician	Treatment/ No Treatment	Paediatric Mental Health
(Vickers et al., 2016)	Commentary	Physician	Test/ No Test; Treatment/ No Treatment	Prostate Cancer
(Genders et al., 2017)	Review	Physician	Test/ No Test; Treatment/ No Treatment	N/A
(Hozo et al., 2017a)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Cardiovascular Disease
(Nair et al., 2017)	Empirical	Patient	Treatment/ No Treatment	Premature Births
(Tsalatsanis et al., 2017)	Empirical	Patient	Treatment/ No Treatment	Palliative Care
(Ebell et al., 2018b)	Empirical	Physician	Test/ No Test; Treatment/ No Treatment	Community-Acquired Pneumonia
(Felder & Mayrhofer, 2018c)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	Acute Appendicitis
(Fujii & Osaki, 2018)	Conceptual/ Theoretical	Patient	Treatment/ No Treatment	Colds
(Hozo et al., 2018b)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Palliative Care
(de Bree et al., 2019)	Review	Physician; Patient	Treatment/ No Treatment	Oral Squamous Cell Carcinoma
(B. Djulbegovic, Hozo, Mayrhofer, van den Ende, et al., 2019)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Deep Venous Thrombosis; Pulmonary Embolism
(Donner-Banzhoff et al., 2020)	Empirical	Physician	Treatment/ No Treatment	Medical Errors
(Billington et al., 2020)	Empirical	Patient	Treatment/ No Treatment	Osteoporosis
(Boyles et al., 2020)	Review	Physician	Test/ No Test; Treatment/ No Treatment	Tuberculous Meningitis

Article	Type of Paper	Decision-Maker	Decision Threshold Type	Health Condition/ Application
(De Alencastro et al., 2020)	Empirical	Physician	Treatment/ No Treatment	Appendicitis; Pharyngitis
(M. Djulbegovic et al., 2020)	Review	Physician	Treatment/ No Treatment	Venous Thromboembolism
(Minami et al., 2020)	Review	Patient	Treatment/ No Treatment	Breast Cancer
(Courbage & Peter, 2021)	Conceptual/ Theoretical	Patient	Treatment/ No Treatment	Vaccines
(Di Stefano et al., 2021)	Empirical	Physician	Treatment/ No Treatment	Premature Birth
(Patel et al., 2021)	Empirical	Physician	Treatment/ No Treatment	Prescribing Statins
(van Overbeeke et al., 2021b)	Empirical	Patient	Treatment/ No Treatment	Gene Therapy
(Cai et al., 2022)	Empirical	Physician	Test/ No Test; Treatment/ No Treatment	Influenza
(Rugolo et al., 2022)	Empirical	Physician	Treatment/ No Treatment	Sepsis
(Sevim & Felder, 2022)	Conceptual/ Theoretical	Physician	Test/ No Test; Treatment/ No Treatment	N/A
(Stojan et al., 2022)	Empirical	Physician	Test/ No Test; Treatment/ No Treatment	Influenza
(van der Keylen et al., 2022)	Empirical	Physician; Patient	Treatment/ No Treatment	Osteoporosis
(Wen et al., 2022, p. 202)	Empirical	Caregiver/ Guardian	Treatment/ No Treatment	Palliative Care
(Cucchetti et al., 2023b)	Empirical	Physician	Treatment/ No Treatment	Pancreatic Adenocarcinoma
(de Rooij et al., 2023)	Review	Physician	Test/ No Test Treatment/ No Treatment	Tuberculosis
(B. Djulbegovic et al., 2023)	Conceptual/ Theoretical	Physician	Treatment/ No Treatment	Pulmonary Embolism
(Taylor et al., 2023b)	Empirical	Physician	Treatment/ No Treatment	Sepsis

Appendix 1.7- Scenario 2B: Risk Attitude- No Involvement of 'Type I System' Reasoning

In Scenario 2B we seek to explore the effects of 'risk attitude' on an individual's average decision threshold for different cultural worldviews. In this scenario, we set the involvement of 'type I system' reasoning to be set to zero (i.e., no involvement of 'type I system' reasoning) (see Figure 11).

Figure 11- Scenario 2B: Risk Attitude- No Involvement of 'Type I System' Reasoning

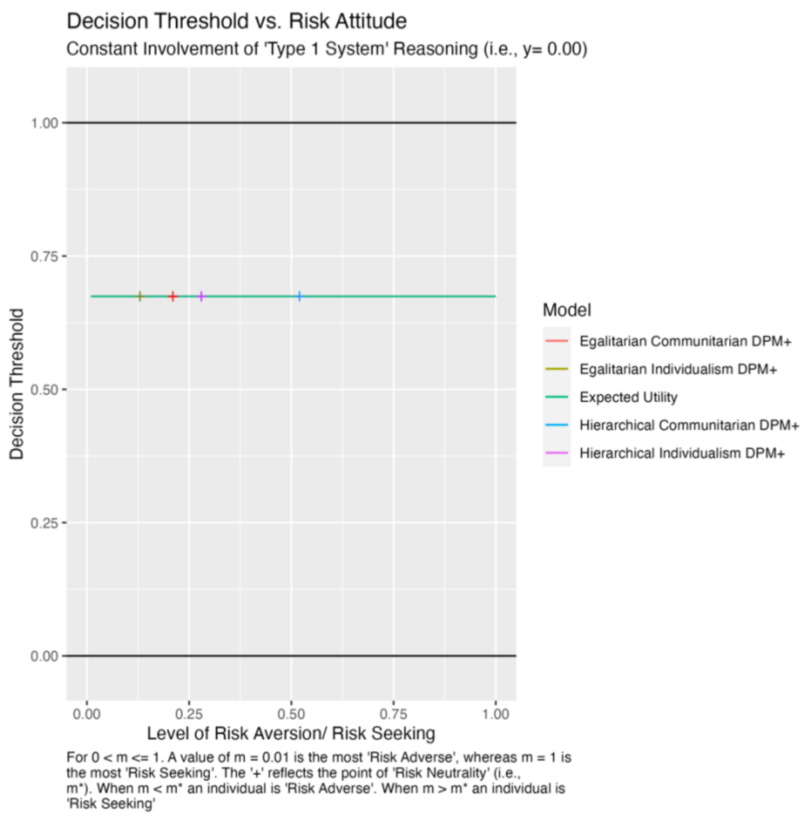


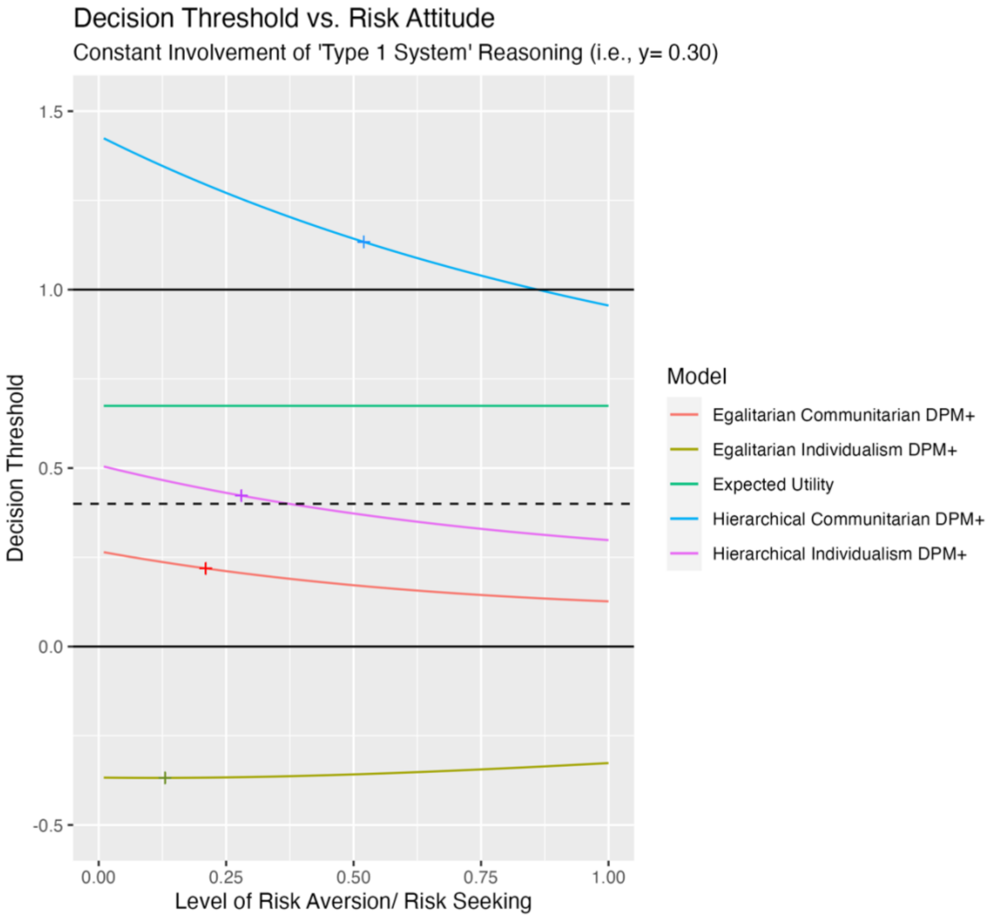
Figure 11 is reflective of the situation when there is no involvement of 'type I system' reasoning. We observe that all cultural worldviews converge on a decision threshold that is defined by expected utility theory. Of particular interest in this scenario are the points of 'risk neutrality' for each cultural worldview relative to the decision threshold. Although the points of 'risk neutrality' are different for 'risk attitude' (i.e., m) all worldviews have the same decision threshold when there is no involvement of 'type I system' reasoning. As is seen in Table 15, value of the 'risk attitude' at the point of 'risk neutrality' is different for each cultural worldview.

Appendix 1.8- Scenario 2C: Risk Attitude- Constant Involvement of 'Type I System' Reasoning

This scenario 2C replicates Scenario 2A but sets the involvement of 'type I system' reasoning to be reflective of an individual who has constant involvement of their 'type I system' reasoning (i.e., $\gamma = 0.30$). In this scenario, by maintain the involvement of 'type I system' reasoning we can explore the effect that 'risk attitude' has on an individual's decision threshold.

Figure 12 illustrates the results of Scenario 2C and can be interpreted in a similar fashion to respective figures for Scenarios 2A and 2B. What is observed in Scenario 2C is the effects of 'risk attitude' with constant involvement of 'type I system' reasoning relative to the decision threshold curves for each cultural worldview. In this scenario, regardless of 'risk attitude', the decision threshold for egalitarian-individualism exists beyond the lower limit for decision thresholds of 0. This can be interpreted as an individual of egalitarian-individualism worldview, regardless of their 'risk attitude', will always favour the vaccine in light of any evidence that supports receiving the vaccine. For those of hierarchical-communitarian worldview, we observe that the decision threshold exists beyond the theoretical upper limit for decision thresholds of 1 until the individual assumes a relatively strong 'risk seeking' risk attitude, upon which their decision threshold drops below 1. This can be interpreted that individuals of hierarchical-communitarian worldview for most risk seeking states would choose not to receive the vaccine (regardless of the available evidence) until they assumed a relatively 'risk seeking' 'risk attitude'.

Figure 12- Scenario 2C: Risk Attitude (Equal Involvement of 'Type I System' Reasoning)



For 0 < m <= 1. A value of m = 0.01 is the most 'Risk Adverse', whereas m = 1 is the most 'Risk Seeking'. The '+' reflects the point of 'Risk Neutrality' (i.e., m*). When m < m* an individual is 'Risk Adverse'. When m > m* an individual is 'Risk Seeking'

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