The Expected Utility of Vaccination:

Parental Choices From a Decision–Making Framework

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Abstract

Vaccine hesitancy amongst parents remains a concern for child welfare and for the wider community. Although vaccination is an archetypal scenario within the decision–making domain, there is currently no research that measures utility weightings of possible vaccination outcomes, and how these change under intervention. The aim of this study is to directly measure individual estimates of vaccination outcomes and attempt to influence vaccination choices through disease education, rather than mitigation of autism fears. Participants (n = 413) were recruited online, invited to review information from one of three conditions and answer a series of questions relating to vaccine choices. Results found information about diseases could significantly influence preferences between diseases, and affect estimates of how bad those diseases were. Disease information did not influence vaccination attitudes or intent beyond that of Control however, contrary to expectations, attitudes responded best to direct factual negation. *Expected Utility* measurements could predict vaccination intent to a significant degree. Findings suggest that information about diseases can decrease the utility of disease, but severity estimates are less reliable. Attitudes respond better to directly relevant information, which helps to decrease uncertainty around vaccination. Findings are discussed in terms of position within the broader vaccine literature.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and, to the best of my knowledge, this thesis contains no materials previously published except where due reference is made. I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

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1st October, 2017

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SECTION 1

Introduction

1.1 Vaccine Hesitancy

Vaccinations have become a modern medical paradox, in that their success has seen them become an uncertain risk (Salmon, Dudley, Glanz, & Omer, 2015). It is particularly evident in Western nations, where deadly diseases are rare, and diseases whose mortality occurs through complications can be dealt with more effectively (Boyd, Gazmararian, & Thompson, 2013). This situation has led to a decrease in the perceived threat of the disease, by both a reduction in perceived seriousness and susceptibility (Boyd et al., 2013; Carlsen & Glenton, 2016; Salmon et al., 2015; Sandhofer, Robak, Frank, & Kulnig, 2017). Side-effects following an immunisation have thus become more salient in the public's eye, more so than the diseases being combated; leading to an inevitable decline in vaccination rates and subsequent outbreaks (Figure 1; Edwards & Hackell, 2016).

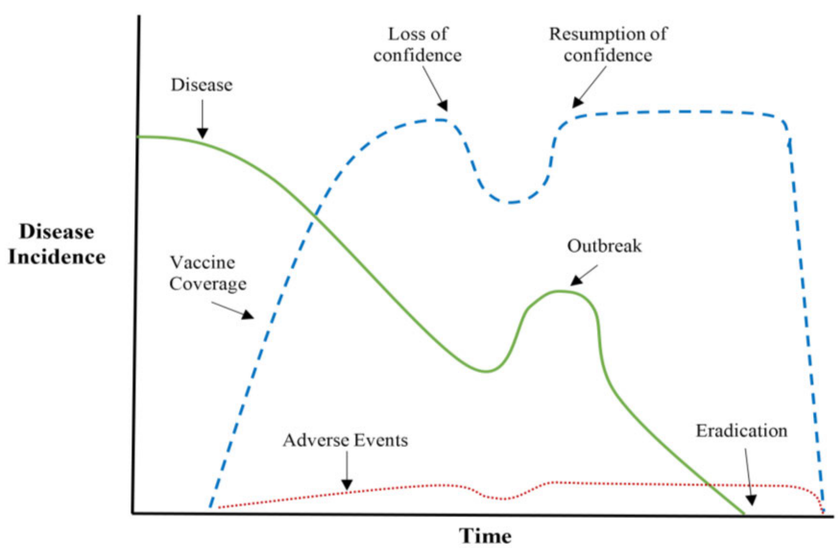

Figure 1.1. Evolution of a vaccine program. The success of vaccination causes a decrease in disease saliency, leading to a drop in confidence. Adapted from Edwards & Hackell (2016).

Vaccine hesitancy is described as the delay or refusal of a vaccination, despite services being available (Killian et al., 2016). While vaccination rates in Western countries are typically high, vaccine hesitancy and clustering of unvaccinated children has resulted in several recent disease outbreaks (Feemster, 2013; Haelle, 2015; Hussey, 2017; Kennedy, 2017). Globally, vaccine hesitancy has caused the World Health Organisation (WHO) to recommend the constant monitoring of the issue at the governmental level (World Health Organisation, 2016).

Leask and Chapman (1998) had summarised the arguments against vaccination prevalent in the media at the conclusion of the 20th Century, which included: Information cover-ups; profit–making; collusive totalitarian states; belief in "experts" who run counter to medical orthodoxy, and; hidden truths about safer "natural" methods. These categories can be further collated into three over–arching themes: Relationship to authority; safety, and; synthetic versus natural interventions. Vaccine hesitancy remains a complex topic in the 21st Century. Themes from the past era have been carried forward, but increased in specificity. Safety concerns now vary between vaccine types, for instance; the measles, mumps, and rubella (MMR) vaccine is cited as the most influential on parents' decision to deviate from the vaccine schedule, due to its' association with autism (Whyte, Whyte Iv, Cormier, & Eccles, 2011). The diphtheria, tetanus, and pertussis (DTP) vaccine has been associated with sudden infant death syndrome (SIDS), and the hepatitis B vaccine with multiple sclerosis (Macdonald & Dubé, 2015; Whyte et al., 2011).

The degree of access to information is surpassed only by its' sheer volume. However, on the internet anti-vaccination material is mixed with pro-vaccine material, and conflicting claims lead to a general distrust (Carlsen & Glenton, 2016; Clarke, Weberling Mckeever, Holton, & Dixon, 2015). The role of the media cannot be understated, and apart from content, the way information is conveyed is just as influential (Verger et al., 2016). It is the nature of the media to generate interest in its’ readership however, overly sensationalised issues can be taken less seriously (Boyd et al., 2013), and the amplification of controversy has even been shown to negatively influence physician attitudes as much as the lay person (Verger et al., 2016). Television tended to be a primary source of information for those that under–vaccinated (Sandhofer et al., 2017) which is understandable, as dialog with distressed parents of purportedly vaccine–injured children is more relatable, and carries more emotional influence, than blocks of dry text in an obscure medical journal (Leask & Chapman, 1998).

Physicians are generally a trusted authority, and this holds across cultures (Dubé, 2017; Gargano et al., 2013; Gilkey, Calo, Marciniak, & Brewer, 2016; Macdonald & Dubé, 2015; Sandhofer et al., 2017). Physicians could influence attitudes to the point where people who held negative attitudes towards vaccines, were more likely to vaccinate after physician recommendations than were people who already held positive attitudes towards vaccination (Bonville, Cibula, Domachowske, & Suryadevara, 2015). However, discrepancies have been shown in vaccine coverage between physicians’ families, and that of their patients (Dubé, 2017). While physicians’ children tended to be vaccinated above community averages for some vaccinations (Killian et al., 2016), survey results show physicians were not typically recommending the same for their patients (Dubé, 2017). Vaccine hesitant physicians reported they were more likely to practice “alternative medicine”, less likely to have treated patients with vaccine–preventable diseases, and more likely to have had experience with adverse events, possibly due to vaccination (Verger et al., 2016).

Society is now faced with misconceptions of vaccine safety, and a lack of perceived threat from disease. When this is combined with the situation that the most trusted source on vaccination is not necessarily the strongest advocate, concerns over vaccine–preventable diseases are increasingly dismissed. One thing to consider is that vaccination is essentially another decision–making problem. The decision to vaccinate or not must be assessed in terms of benefits and risks, then compared accordingly. While a substantial amount of research has been conducted into the factors of vaccine hesitancy (Dubé, Vivion, & Macdonald, 2014), there is currently no research on the weightings these factors are given, how they interact, and how they behave after exposure to various types of information.

1.2 Anti-Vaccine Attitudes and Beliefs

Beliefs. In the attempt to make sense of the environment or anticipate danger, the brain will search for new patterns and causal mechanisms, and focus less on familiar things (Goldstein, 2015). While this strategy is largely successful, one may see things that are not there, or make connections in place of mere coincidence (Liu et al., 2014; Nickerson, 1998). Information is dealt with in a similar manner to environmental stimuli. Processing information is often heuristically based and when information is already familiar, it is treated with less scrutiny, passes through unfiltered, or accepted at face value (Lord, Ross, & Lepper, 1979; Nickerson, 1998; Tversky & Kahneman, 1974). How well new information is learned and retained can also depend on how it fits with what is already known (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). The collection of knowledge and beliefs within an individual come to shape a particular view of the world. This world-view is extended to become part of the individual's social identity, and thus becomes resistant to change (Kahan, 2010; Lewandowsky et al., 2012). On the other hand, Information that challenges an individual's beliefs is subjected to *increased* scrutiny and scepticism, as the challenge is not only to a worldview, but to the individual's identity (Kahan, 2010; Lord et al., 1979). Thus, the tendency is to protect a belief by bringing alternate information to the fore and reject the inconsistent information, causing a *back-fire effect* and *belief polarisation* (Clarke et al., 2015; Lewandowsky et al., 2012; Lord et al., 1979). Ultimately, individuals become more steadfast in their beliefs, so the strategy of directly addressing concerns about vaccine safety often meet with limited success (Frew et al., 2016; Nyhan & Reifler, 2015; Nyhan, Reifler, Richey, & Freed, 2014). Other attempts have involved dispelling misconceptions by presenting a balanced view of the issue. However, in highly contentious issues presenting both sides of an argument can seem conflicting, as if both sides are well represented when in fact, only one side has a valid basis (Clarke et al., 2015; Dixon & Clarke, 2013; Lewandowsky et al., 2012). For example, when two groups were compared—one exposed to an autism–vaccine refutation, the second exposed to supporting *and* refuting arguments on the link between autism and vaccines; the second group were less certain about the issue and decreased their intention to vaccinate (Clarke et al., 2015). A recent example in the public sphere occurred in Queensland, Australia where; conflicting information about the safety of flu vaccinations saw a decline in vaccination rates (Bali, 2017). Moreover, the "fact versus myth" approach (cf. Department of Health and Aging, 2013) can highlight otherwise unknown issues, causing an increase in concern (Nyhan et al., 2014) and after a period, memory can conflate facts and myths, such that myths are remembered as facts (Lewandowsky et al., 2012).

Attitudes. While beliefs refer to some set of facts, attitudes are subjective and form as a product of experience within the environment (Sherif & Cantril, 1945). Attitudes predispose an individual to respond in a habitual or characteristic manner, towards some object or circumstance (Sherif & Cantril, 1945); in much the same way that "disgust" of a certain food would motivate an individual to avoid it. Attitudes are strongly linked with emotions, which play an important part in decision–making (Haidt, 2001; Kahneman, 2011). The role of emotion in attitudes is often overlooked in vaccine interventions (Nan & Madden, 2012), even to the point where the manipulation of emotion in research is regarded in the pejorative (cf. Betsch, Korn, & Holtmann, 2015). However, emotion is highly influential and can often trump reason (Lewandowsky et al., 2012). An example was seen during a whooping cough epidemic in Great Britain circa 1982: Emotive notifications and warnings to immunise children were saturating the media in an effort to change public attitudes towards vaccination (Baker, 2003). In an ironic twist, the anti-vaccinators who typically use emotion to dissuade (Nan & Madden, 2012), now decried such methods as a "campaign of terror" (Barrie, 1983, p. 922). More recent studies have started to explore the effect of emotionally affective material on vaccine intention, albeit with mixed results (Nyhan et al., 2014; Papachrisanthou, Lorenz, & Loman, 2016). In contrast, Horne, Powell, Hummel, and Holyoak (2015) found attitudes towards vaccination increased after exposure to disease–imagery and a narrative. The intervention performed better than a refutation of the concern between autism and vaccines. This is essentially the strategy of changing an attitude through bypassing a persistent belief, rather than attempting to address the issue directly (Lewandowsky et al., 2012). The relational attitude to vaccination had been improved by increasing the saliency of disease, as opposed to challenging existing beliefs. Most importantly, this indicates there is an alternate way to influence vaccine decisions.

1.3 Expected Utility Theory

Utility refers to some measure of value or preference (Von Neumann & Morgenstern, 1964). It most easily applies to money as this can be matched per unit of utility however, the notion of utility holds across various contexts and psychological domains (Kühberger, 1998). In non-mathematical contexts, utility is simply "the immediate sensation of preference" (Von

Neumann & Morgenstern, 1964, p. 16) for some object over another; which makes direct measurement difficult. Individuals will act in a way so as to obtain a preference thus, the tendency to choose value can be considered a maxim of human behaviour (Friedman & Savage, 1952). When a choice contains risk—some chance of occurring, or not—decisions are governed by their *expected* utility (Friedman & Savage, 1952). *Expected Utility* (*EU*) *Theory* holds that the value of an outcome is determined by the probability of it occurring, multiplied by its' utility (Von Neumann & Morgenstern, 1964). The choice between outcomes then, is that with the highest *EU* (Von Neumann & Morgenstern, 1964), and can be expressed as the following equation:

$$EU(\mathrm{A}) = \sum_{\mathrm{o} \in \mathrm{A}} P(\mathrm{o}) \cdot U(\mathrm{o}) \tag{1}$$

Where; $EU(\mathrm{A})$ is the expected utility of some decision *A*; $\mathrm{o} \in \mathrm{A}$ is a possible outcome *o* under *A*; $P(\mathrm{o})$ is the probability of *o* occurring, and $U(\mathrm{o})$ is the utility of *o*. The resulting *EU* for a decision, is the product of probability and utility values, summed for all outcomes under that decision. The highest *EU* is the preferred choice between decisions such that, for the choice *A* between *A* or *B*: $EU(A) > EU(B)$. For example, you have a choice to purchase one of two tickets in a lottery. Each ticket has a different set of possible outcomes:

Decision *A*:
A 10% chance of winning $100 and,
A 5% chance of winning $180

Decision *B*:
A 20% chance of winning $25 and,
A 10% chance of winning $50 and,
A 30% chance of winning $20

To determine the preferred decision, we simply calculate the *EU* of each outcome then add them together:

<u>Decision *A*:</u>

$EU(A) = (0.1 \times 100) + (0.05 \times 180)$
$= 10 + 9$
$= 19$

<u>Decision *B*:</u>

$EU(B) = (0.2 \times 25) + (0.1 \times 50) + (0.3 \times 20)$
$= 5 + 5 + 6$
$= 16$

Since Decision *A* has the highest *EU* (19 > 16), it is the preferred choice.

Vaccine–hesitant parents facing a decision on whether to vaccinate, choose between two possible outcomes—the chance of disease if they do not vaccinate, versus the risk of vaccine–injury. It becomes clear that the issue of vaccination can be understood in terms of *EU*. Probabilities reflect the likelihood of contracting a disease, or suffering a vaccine side-effect. Whereas utilities represent the desirability, or rather, the undesirability of a disease or vaccine side-effect. Consider the utility of catching a "cold" for the average adult. Perhaps a week or two of coughing and blocked sinus, possibly a number of days off work. While not the worst experience, it is typically undesirable. Now consider cancer; involving hospital visits, chemotherapy, months of suffering, and perhaps an early death. This condition would be *highly* undesirable, and given a choice between the two, there is an obvious preference for one over the other. While these are extreme examples, they serve to illustrate that different health states can vary in their desirability (utility), therefore preferences exist between them. Vaccinations can share a similar decision set: Imagine a parent deciding whether to give their child an influenza vaccination however, there is a concern over side-effects. The parent believes there is a 5% chance of fever from a vaccine, that it will be particularly severe, last for several days, and may result brain damage. Fever is regarded as having utility of −1,000 units (where a state of normal health is set to 0 units). Conversely, the parent believes there is a 10% chance of influenza that season, which will cause discomfort, a disruption to the weekly schedule, and bedrest for a week. Influenza is regarded as having a utility of −50 units. The prospect of vaccination becomes:

Vaccinate	Not Vaccinate
A 5% chance of fever (loosing 1000 units)	A 10% chance of flu (loosing 50 units)
A 95% chance of no change (no fever)	A 90% chance of no change (no flu)

To calculate the *EU* of each choice:

$$EU(\text{Vax}) = EU(\text{fever}) + EU(\text{no change}) = (0.05 \times (-1000)) + (0.95 \times 0) = -50 + 0 = -50$$

$$EU(\neg\text{Vax}) = EU(\text{flu}) + EU(\text{no change}) = (0.1 \times (-50)) + (0.9 \times 0) = -5 + 0 = -5$$

Since the *EU* of not vaccinating is higher (−50 < −5), the rational choice for this parent is to not vaccinate. Now if this parent were to visit a doctor, and when asked about vaccinating, the parent mentions their concern over fever from the vaccine. The doctor explains that the chances of a side-effect such as fever is actually one per thousand vaccinations (0.1%), is very mild, and typically lasts for a few hours. The parent considers this new information, decides that a fever would not be as bad as the flu, which is now regarded as having a utility of −30 units. The new prospect of vaccinating becomes:

Vaccinate	Not Vaccinate
A 0.1% chance of fever (loosing 30 units)	A 10% chance of flu (loosing 50 units)
A 0.99% chance of no change (no fever)	A 90% chance of no change (no flu)

With these new values, the *EU* of each choice changes accordingly:

$$EU(\text{Vax}) = EU(\text{fever}) + EU(\text{no change}) = (0.001 \times (-30)) + (0.95 \times 0) = -0.03 + 0 = -0.03$$

$$EU(\neg\text{Vax}) = EU(\text{flu}) + EU(\text{no change}) = (0.1 \times (-50)) + (0.9 \times 0) = -5 + 0 = -5$$

Since the *EU* of vaccinating is higher ($-0.03 > -5$), the preferred choice would be to vaccinate. Two important implications from *EU* Theory are that: Changing estimations of probability and utility can change decision preferences, and; that the *EU* of one choice can be manipulated *independently* of the other. For decisions on immunisation, choices can be changed by either increasing the *EU* of vaccinating, or decreasing the *EU* of not vaccinating. Typical interventions focus on the former, by trying to minimise possible negative vaccination consequences or dispelling specific myths. The problem with this approach, are the biases that can be enacted to protect a particular world-view. The present study attempts to influence the other route of changing preferences—decrease the *EU* of not vaccinating, by highlighting the severity of vaccine preventable diseases.

A Pilot study was conducted to explore whether measuring preferences could be fruitful. Known vaccination concerns such as fever and the potential for autism were included as potential risks (Edwards & Hackell, 2016; Whyte et al., 2011), as were perceptions about pertussis (whooping cough). The Pilot study found participants believed the chances of fever from a vaccination was 10%, and a good portion felt the chance of autism was 1% or greater. While whooping cough was rated as being ten times worse than fever, autism was rated as being 10,000 worse than whooping cough. Preliminary results showed the *EU* of perceived outcomes may be driving vaccine decisions. People may be overestimating the probability of some outcomes, and perhaps misevaluating their relative severity. This interesting finding prompted additional motivation for the present study.

1.4 Research Aims

At present, the impact of disease and vaccination risks on *EU* calculations remains unstudied. In line with the Pilot study and previous work by Horne et al. (2015), this paper seeks to examine what effect disease–information and vaccine–concerns have on subsequent *EU* estimations, and the intention to vaccinate a child in the future. The change in *EU,* is also expected to reflect a change in vaccination attitudes. Results from this paper may inform the content and format of disease– and vaccine–risk information, and help to re-calibrate the perceived susceptibility and severity of disease in the general community.

The first hypothesis is that *the Control group in this study will replicate results of the Pilot study.* The goal is to elicit probability and utility estimations about certain vaccine outcomes and, check the stability of those perceptions and preferences throughout the population. These values then serve as a baseline from which to measure the influence of the interventions used in this study.

The second hypothesis is that *information about certain diseases will significantly decrease their utility*. By exposing participants to the severity of a disease, including: symptoms, likelihood of death, images of the visual symptoms, and a statement on how that disease affected a family; the nature of the disease is made salient. Participants will likely have a stronger perception of the seriousness of that disease—in this case whooping cough—and this in turn will change the utility of whooping cough in relation to the utility of autism.

The third Hypothesis is that *information about certain diseases will significantly increase attitudes towards vaccination.* This follows from Hypothesis 2 and is an attempt to replicate findings from Horne et al. (2015). An increase in the perceived severity of a disease should increase the motivation to avoid it. Vaccination provides such a means, and will therefore be viewed more favourably by changing the relative severity between diseases and vaccine risks, without changing vaccine–risk perceptions directly.

The fourth hypothesis is that *expected utilities will be predictive of vaccination intent.* The choices individuals make reflect the best value between alternate outcomes. If whooping cough has a lower *EU* compared to autism, the predicted decision will be to vaccinate. If autism has the lower *EU,* participants are expected to not vaccinate—in keeping with rational decision–making under *EU* theory.

The fifth hypothesis is that *information about certain diseases will significantly increase the intention to vaccinate.* This follows from Hypothesis 2 and Hypothesis 4: Exposure to information about whooping cough will lower the utility of whooping cough, and if normative choices hold, cause a differential increase in those willing to vaccinate.

SECTION 2

Method

2.1 Participants

A total of 451 participants responded to the survey. Participants (*n* = 38) were excluded due to: Failed attention–check questions (*n* = 1); non-completion (*n* = 2); those who said developing a coma was better than a cold (*n* = 21); those outside a target country–of–origin (*n* = 13); and incorrect age entry (*n* = 1). The remaining participants (*n* = 413) used for analysis were aged from 19 to 98 years (*M* = 36.01, *SD* = 11.65). Table 2.1 provides a detailed demographic breakdown.

Table 2.1
Demographic characteristics of participants

	Group (*n* = 413)	
Demographic	*n*	Prevalence (%)
Gender		
Female	167	40.44
Male	244	59.08
Other	2	<0.01
Education level		
Highschool	138	33.41
Associate degree	73	17.68
Four–year college	167	40.44
Professional degree	31	7.51
PhD	3	0.01
Prefer not to say	1	<0.01

Table 2.1 (*continued*)

Demographic	*n*	Prevalence (%)
Political Affiliation		
Strongly Conservative	17	4.12
Conservative	40	9.69
Mildly Conservative	36	8.72
Centrist	78	18.89
Mildly Liberal	50	12.11
Liberal	121	29.30
Strongly Liberal	68	16.46
Prefer not to say	3	0.01
Annual income		
Less than $25,000	146	35.35
$25,000 to $50,000	150	36.32
$50,000 to $75,000	71	17.19
$75,000 to $100,000	24	5.81
More than $100,000	16	3.87
Prefer not to say	6	1.45
Country of Origin*		
America	409	99.03
Canada	3	0.01
Sweden	1	<0.01
Number of children		
Zero	271	65.62
One	47	11.38
Two	61	14.77
Three	20	4.82
Four to six	15	3.63

Note. * “Country of Origin” refers to the participants’ residence at the time the survey was taken.

2.2 Sampling Procedures

The participant sample was drawn from the Amazon Mechanical Turk™ platform (MTurk; www.mturk.com). This service hosts voluntary tasks or activities that can be completed by people registered on the website as “workers”. Some small financial compensation is offered based on time spent or complexity (approximately $10 per hour). Participation for this study was thus, on a voluntary basis by registered workers within the MTurk platform.

The intended sample size ($250 < n < 450$) was calculated using *G*Power statistical software*© (version 3.0.10), to obtain the desired statistical power (0.95) and a medium effect size ($f = 0.2$). Participant information was provided where participants had the option to decline further involvement. Informed consent was obtained prior to commencement of the survey. This study received ethics approval from the Subcommittee for Human Research in the School of Psychology, University of Adelaide, and funding from the Discovery ARC Project.

2.3 Design and Procedure

This study is a randomised controlled trial, using post-test comparison. This was chosen over a pretest-posttest design to mitigate memory effects from prior exposure. Testing was done entirely online by registered users on MTurk, who chose to participate in this study from a list of available tasks. Consent and participant information was presented, and if accepted, demographic data was requested, then the participant was randomly assigned to one of three groups: Control, Concerns, or Disease.

The participants were instructed to read through the materials and give an honest response to the questions. Participants were presented with four topics topics to read, one at a time, until the participant was ready to proceed to the next topic by clicking “next”. Once finished, attention–check questions were presented that required four out of five correct responses (80%) before proceeding. More than one incorrect answer directed the participant reread the topic materials until a score of 80% or higher was achieved. Next, participants answered probability and utility questions, as well as their intention to vaccinate a child in the future and whether other people should have children vaccinated. Attitude questions were presented last to avoid any unwanted influence on probability and utility questions. Once completed, participants were given a token code with which to obtain their financial compensation.

2.4 Measures

Probabilities. Probabilities represent a subjective estimation of the likelihood an event will occur, with a range between zero and one. The probability questions presented ask for the likelihood of some vaccine–related outcomes, and included a distractor question (Appendix A). Responses were chosen from a pre–determined list of percentages: Less than 0.00001; between 0.00001 and 0.1; between 0.1 and 1; between 1 and 5; between 5 and 10; between 10 and 25; between 25 and 75; between 75 and 90; between 90 and 95; between 95 and 99; between 99 and 99.9999, or; over 99.9999. Where, the higher percentage indicated a higher chance of occurring.

Utilities. The utility of an event refers to the subjective preference of one outcome over another, and the degree to which that outcome is desired (Von Neumann & Morgenstern, 1964). The utility questions presented, ask to choose the "worst" outcome between alternates, such as between autism or whooping cough and include distractor comparisons (Appendix B). Participants were also asked "how much worse" the outcome was they selected, with response options presented as a nine–point logarithmic scale: 2, 5, 10, 50, 100, 500, 1000, 5000, or 10000 (times worse). A logarithmic scale was used to capture extremes in opinion.

Intention. Two extra questions were included in the survey: The intention to vaccinate a child in the future, and; whether other parents should be required to have their children vaccinated. Both questions are answered by selecting a choice between alternate statements (Appendix C). Responses to the intention to vaccinate include: "Yes"; "yes, but slower than the suggested vaccine schedule"; "yes, but only some vaccines"; "I don't know", or; "no, I don't think vaccines are a good idea". Responses about others having to vaccinate include: "Yes, unless they are immunocompromised"; "No, but if they don't the children shouldn't be allowed in public schools"; "No, it's really only up to the individual and is not my business", or; "I have no opinion either way on this issue".

Attitudes. Attitudes are given as a person's disposition or feeling towards a statement or state of affairs (Sherif & Cantril, 1945). For this study, participants responded to how strongly they agree with a set of statements relating to vaccinations. These statements reflect common themes from previous research, including; validity–tested scales, and those developed through qualitative analysis (Gilkey, Reiter, et al., 2016; Horne et al., 2015; McRee, Brewer, Reiter, Gottlieb, & Smith, 2010; Shapiro, Holding, Perez, Amsel, & Rosberger, 2016). Five of the twelve attitude questions were combined into an attitude scale, to replicate findings from Horne et al. (2015; Appendix D). This scale was previously measured as having good internal reliability (α = 84; Horne et al., 2015). Answers were indicated on a seven–point Likert scale, shown as a continuous "bar", with a "position slider" (Figure 2.1). The participant positioned the slider to indicate their level of (dis)agreement. Scoring position is given as: 1 (full left position = disagree), 2, 3, 4 (centre), 5, 6, 7 (full right position = agree).

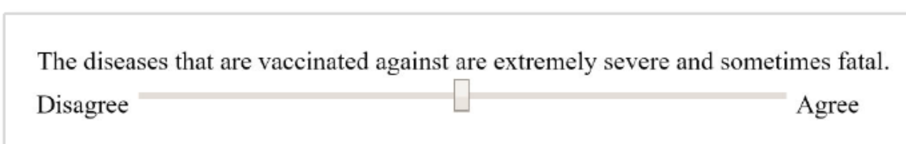

Figure 2.1. The bar and slider setup for measuring attitude questions. The more agreement, the higher the attitude score.

2.5 Stimulus Material

Stimulus materials were created for three conditions; Control, Concerns, and Disease. The material–sets consisted of four topics within a theme, matched to 400 words, and each with an accompanying image (Appendix E). Attention–check questions were presented after reading the material, to ensure adequate comprehension and engagement with the task (Appendix E).

Control group. The Control group was given a geological theme, unrelated to the other conditions. Topics included: Pumice, volcanoes, plate tectonics, and Pangea. The text describes the topic and gives some interesting facts, and an image is included for illustration (Figure 2.2). An example attention–check question is as follows: “Pumice can be used to make concrete, true or false?”.

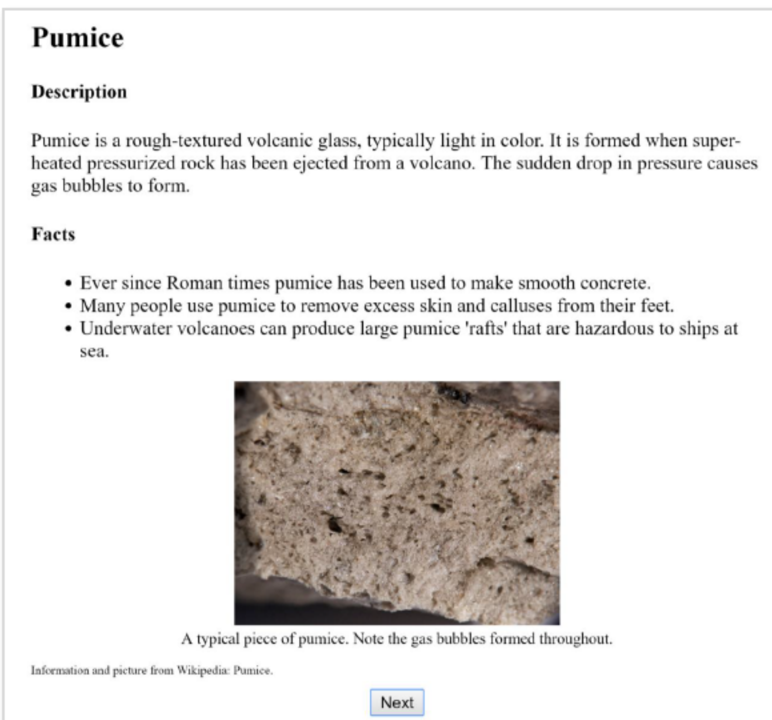

Figure 2.2. An example of the stimulus material used in the Control group.

Concerns group. The Concerns group was given information about frequent vaccine concerns drawn from the wider literature and government sources (Department of Health and Aging, 2013; Horne et al., 2015; Shapiro et al., 2016). Topics included: The vaccine schedule, trust in authority, negative side–effects, and the autism–vaccine link. The text describes a concern, offers factual information to address it, and an image is included to complement the text (Figure 2.3). An example attention–check question is as follows: “The study upon which the autism-vaccination link was originally based has been retracted, true or false?”.

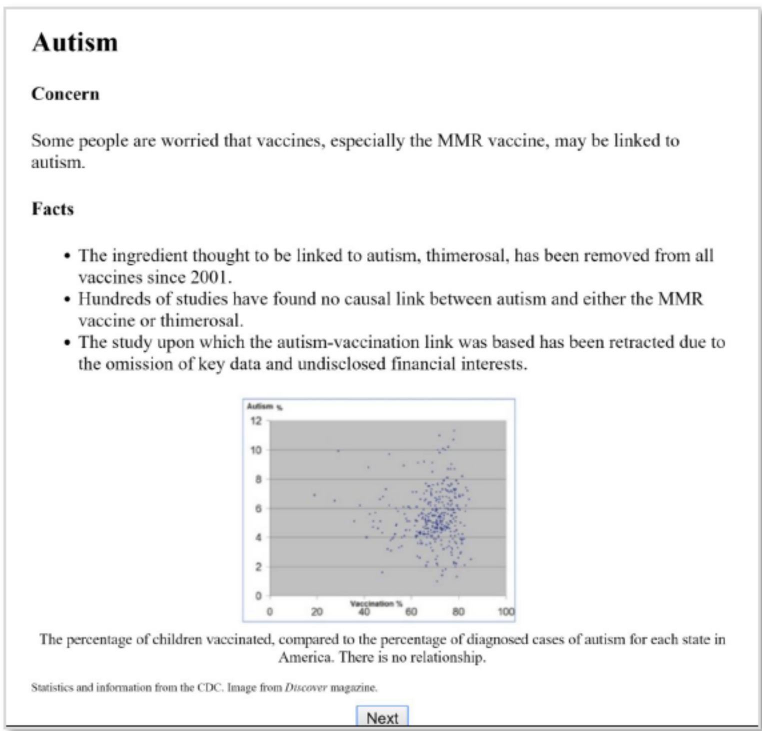

Figure 2.3. An example of the stimulus material used in the Concerns group.

Disease group. The Disease group was given information on four vaccine–preventable diseases: Whooping cough, tetanus, diphtheria, and measles. Data on the mortality rate and symptoms were included, as well as testimony from a victim’s parent and an image of a child with the illness (Figure 2.4). An example attention–check question is as follows: “Whooping cough is named that because the cough lasts a long time, but it's extremely mild, true or false?”.

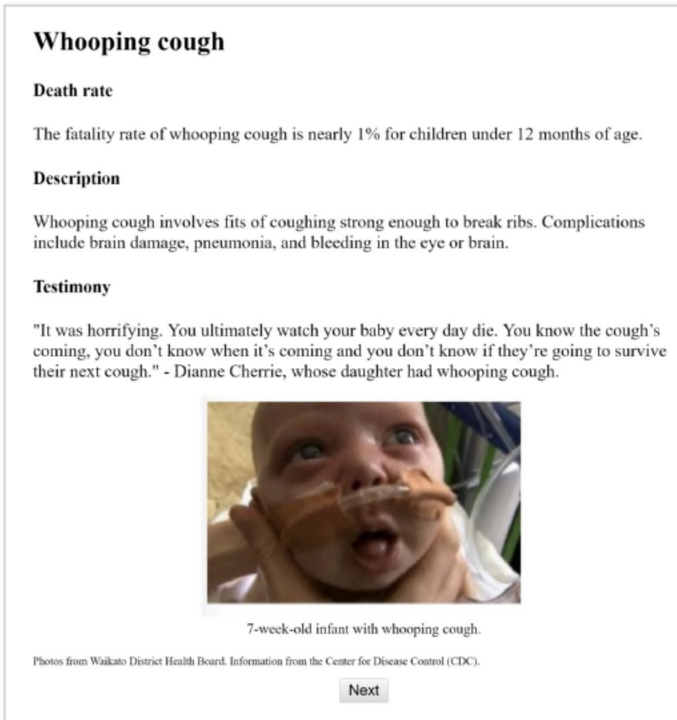

Figure 2.4. An example of the stimulus material used in the Disease group.

SECTION 3

Results

3.1 Hypothesis 1: The Control Group in This Study Will Replicate Results From the Pilot Study

The first hypothesis is that the Control group would replicate the probability and utility estimates of the Pilot study. Only the Control group is compared for the purposes of replicating perceptions in the population. The Concerns and Disease groups underwent manipulation, so are included in the remaining hypotheses. The questions examined relate to autism probabilities and the preference between autism or whooping cough. Because the response categories were nonlinear and contained extreme values, results were compared using modal scores and distribution shapes, rather than means.

What is the probability of a child developing autism? The modal response for both the Pilot study and Control group in this study was 5%, and a Fisher's exact test found no significant difference between the two distributions ($p = 0.25$; Figure 3.1).[1] Results indicate similar estimations across replications, and support the hypothesis.

[1] In all cases, Fisher's exact test was used when there was a violation of the *minimum expected frequency* (MEF) assumption for a Chi-square test of association.

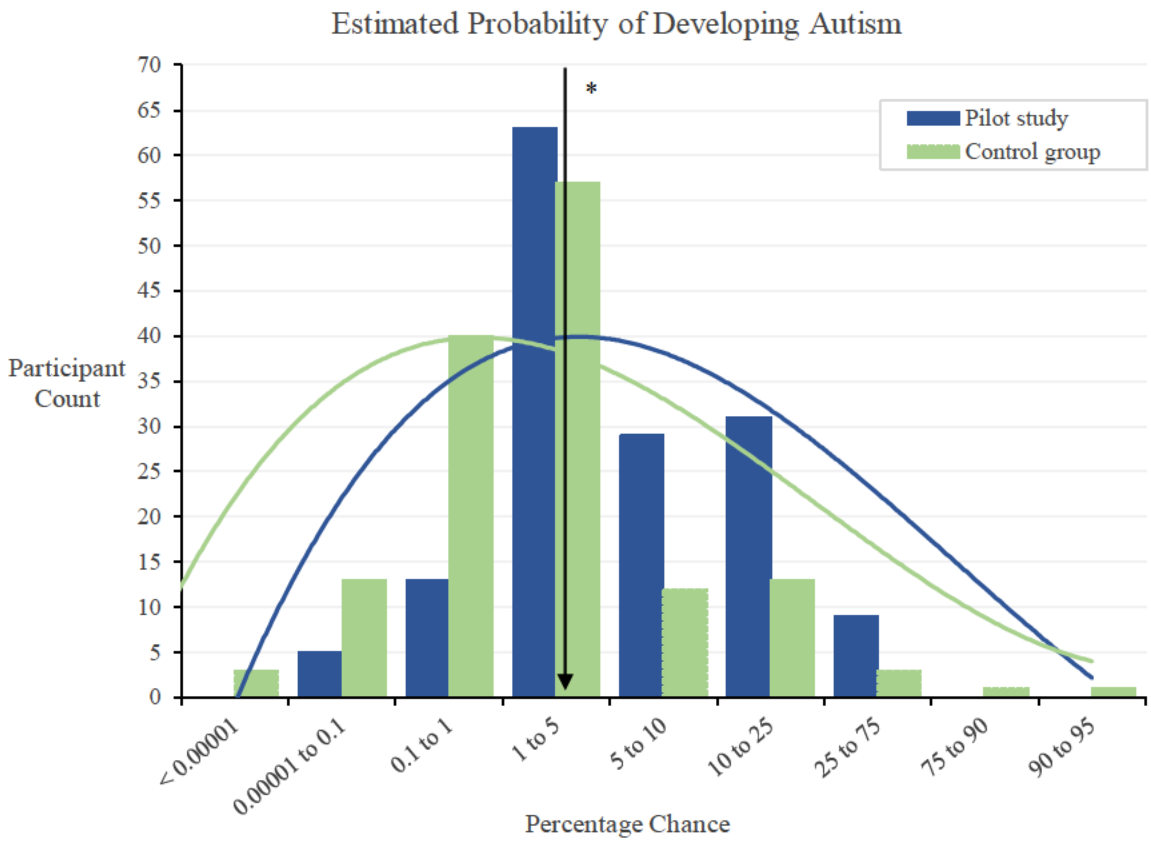

Figure 3.1. Responses to the chance of a child developing autism. Bins are the response options available to the participants. The Control group has replicated the result of the Pilot study. * = actual prevalence of autism in the community (1.5%; Center for Disease Control and Prevention, 2017).

What is probability of a child developing autism because of a vaccination? The Pilot study enabled participants to freely respond, and obtained a modal score of 0%. Responses for this study were pre-set options, and the Control group obtained a modal score of the lowest option "less than 0.00001%", which can be interpreted as "practically zero". A Fisher's exact found the two distributions are not significantly different ($p = 0.08$; Figure 3.2), indicating similar estimations across replications, which supports the hypothesis.

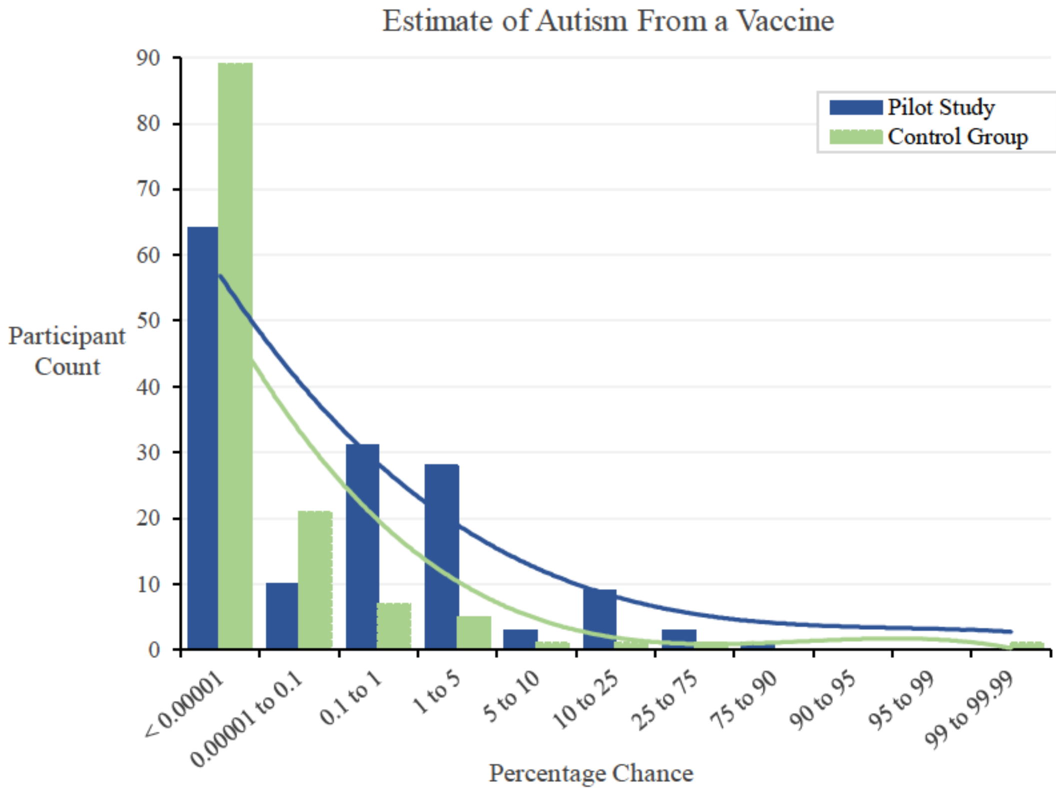

Figure 3.2. Responses to the chance of autism from a vaccination. Bins are the response options available to the participants. The Control group has replicated the result of the Pilot study.

Which is worse; developing autism or whooping cough? Participants in the Pilot study and in the Control group rated autism as being worse than whooping cough (84% and 78%, respectively). A Chi-square test of association found no significant difference between the two groups ($\chi^2(1, 293) = 1.55$, $p < 0.21$), indicating a similar preference for autism.[2]

How much worse? As shown in Figure 3.3, the modal score for both the Pilot study and Control group revealed autism as ten times worse than whooping cough. An association test found no significant difference between the Pilot study and Control group ($\chi^2(8, 238) = 12.62$, $p < 0.13$), indicating similar perceptions of the severity of autism, and support for the hypothesis.

[2] The Chi-square test for association will further be referred to as an “association test”.

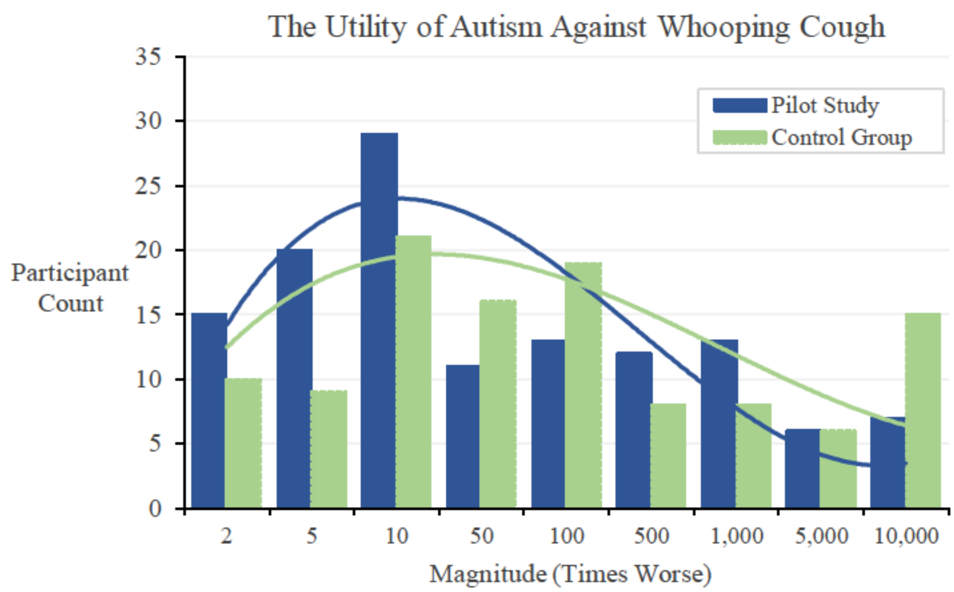

Figure 3.3. Responses to how many times worse autism is compared to whooping cough. Bins are the response options available to the participants. The Control group has replicated the result of the Pilot study.

3.2 Hypothesis 2: Information About Certain Diseases Will Significantly Decrease Their Utility

The second hypothesis states that giving participants information about the severity of certain diseases should decrease the rated utility of those diseases. Participants were asked: "*Which do you think is worse: Your child developing whooping cough or developing autism?*", and responses were analysed between the Control, Concerns, and Disease groups. An association test found a significant association between group and preference for whooping cough ($\chi^2(2, 410) = 21.21, p < 0.001$). A Cramer's V calculation gave a medium effect size ($V = 0.23$), and an examination of the standardised residuals shows the effect is being driven by the Disease group ($SR = 3.05$).[3] The Disease group was more likely to perceive whooping cough as worse than autism (Figure 3.4).

[3] The contribution to a model is significant when a standardised residual is greater than two: $|x| > 2$.

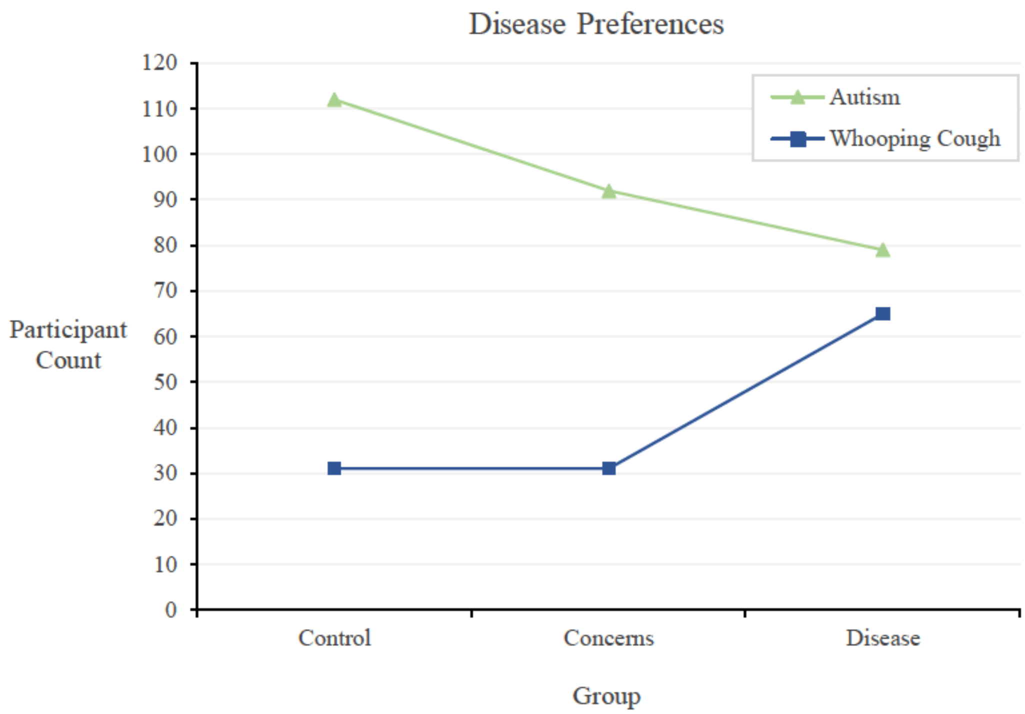

Figure 3.4. Responses to which condition is worse, by group. Significantly more participants rated whooping cough as being worse than autism in the Disease group.

Participants were then asked; "*How much worse is it?*", to obtain a magnitude of the less preferred outcome. For participants who perceived autism as being worse than whooping cough (Figure 3.5): A Kruskal-Wallis test for group differences in rated severity was significant ($\chi^2(2, 283) = 12.21$, $p = 0.002$), with a very small effect size ($\omega^2 = 0.04$).[4] Post hoc testing with Holm correction found the result was due to a significant difference between the Concerns and Disease group ($\chi^2(1, 161) = 11.61$, $p = 0.002$, $\omega^2 = 0.07$).[5] However, the Disease group was not significantly less than Control, which was the prediction under the hypothesis. For participants who perceived whooping cough as being worse than autism: A Kruskal-Wallis test for

[4] In all cases the Kruskal-Wallis test was used because the *normality* assumption for ANOVA testing had been violated.
[5] The Holm correction method is used on all further post hoc testing.

differences in rated severity was not significant ($\chi^2(2, 127) = 0.80$, $p = 0.67$), indicating perceptions of whooping cough were similar across groups (Figure 3.6). Overall, Hypothesis 2 was partially supported; information about diseases increased the likelihood of perceiving whooping cough as being worse than autism however, the magnitude of severity was not sufficiently different than Control.

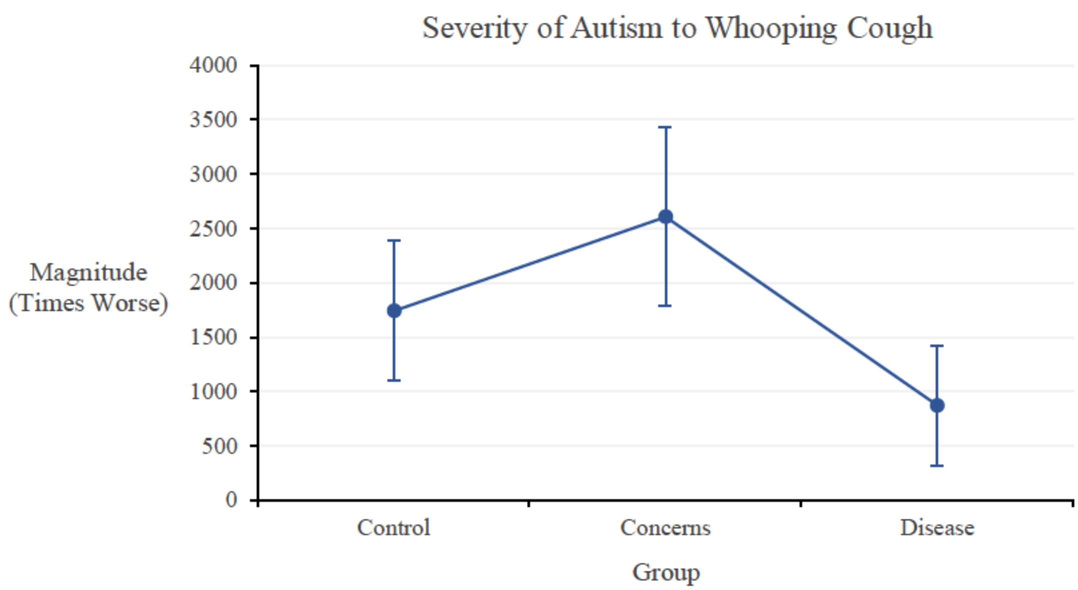

Figure 3.5. Magnitude of how many times worse autism is to whooping cough, by group. Concerns significantly different than Disease, other comparisons not significant. Error bars indicate 95% confidence intervals.

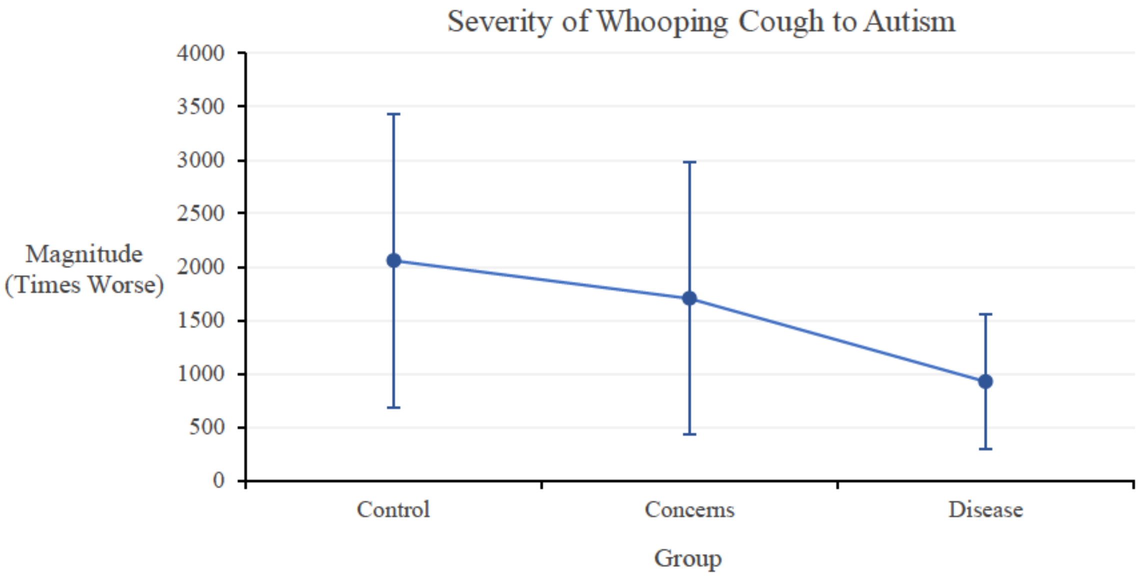

Figure 3.6. Magnitude of how many times worse whooping cough is to autism, by group. There are no significant differences between groups. Error bars indicate 95% confidence interval.

3.3 Hypothesis 3: Information About Certain Diseases Will Significantly Increase Attitude Towards Vaccination

The third hypothesis states that disease information should positively influence vaccination attitudes, and was an attempt to replicate findings published by Horne et al. (2015). The attitude scale developed by Horne et al. (2015) was tested for differences between groups using a Kruskal-Wallis test (Figure 3.7). A significant difference was found ($\chi^2(2, 413) = 11.32$, $p = 0.003$) with a very small effect size ($\omega^2 = 0.03$) however, post hoc testing showed the result was being driven by significantly higher attitudes in the Concerns group compared to Disease ($\chi^2(1, 270) = 11.65$, $p = 0.002$, $\omega^2 = 0.04$). This finding did not support the hypothesis, which expected higher attitudes in the Disease group.

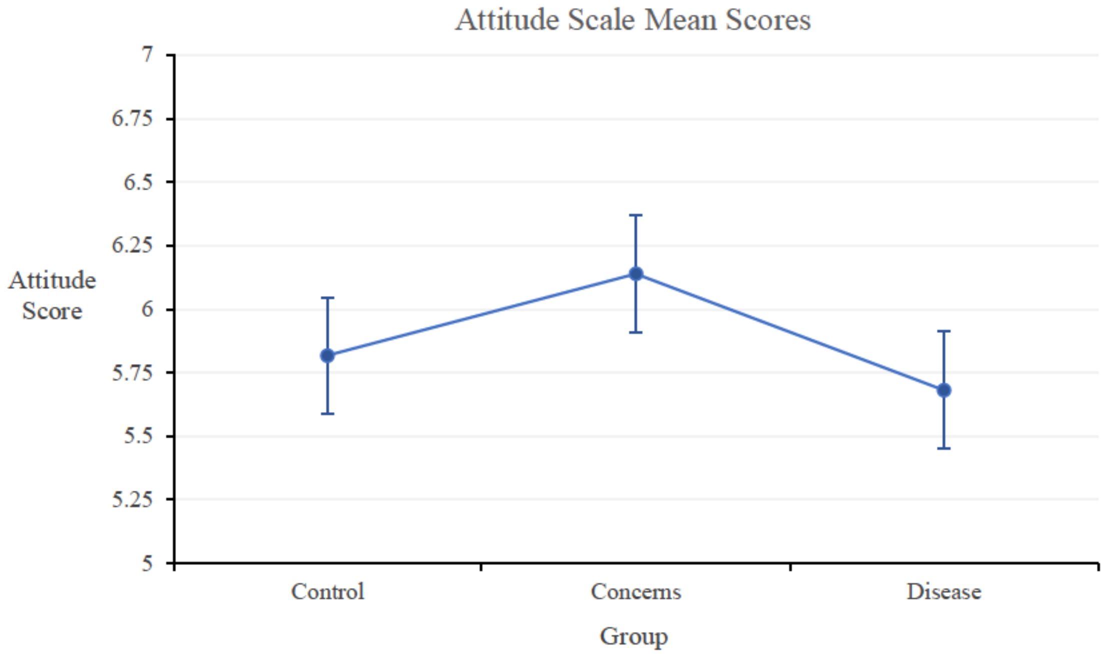

Figure 3.7. Differences attitude–scale scores, by group. Attitude range is 1 to 7, with the higher number being more favourable to vaccination. Concerns different than Disease, other comparisons not significant. Error bars indicate 95% confidence interval.

This study went beyond Horne et al. (2015) and measured an additional seven attitude questions (Figure 3.8). Scores were examined using Kruskal-Wallis tests, and three attitude questions had significant differences between groups: The *autism–vaccination link* ($\chi^2(2, 413) = 17.54$, $p = 0.001$); *barriers to vaccination* ($\chi^2(2, 413) = 12.28$, $p = 0.02$); and *pharmaceutical companies' motivation for money* ($\chi^2(2, 413) = 24.02$, $p < 0.001$). All showed very small effect sizes ($\omega^2 = 0.04$, 0.03, and 0.06 respectively) and in each, the effect was driven by more positive attitudes in the Concerns group (refer Appendix F for pairwise comparisons). These findings did not support the hypothesis, which expected more favourable attitudes in the Disease group.

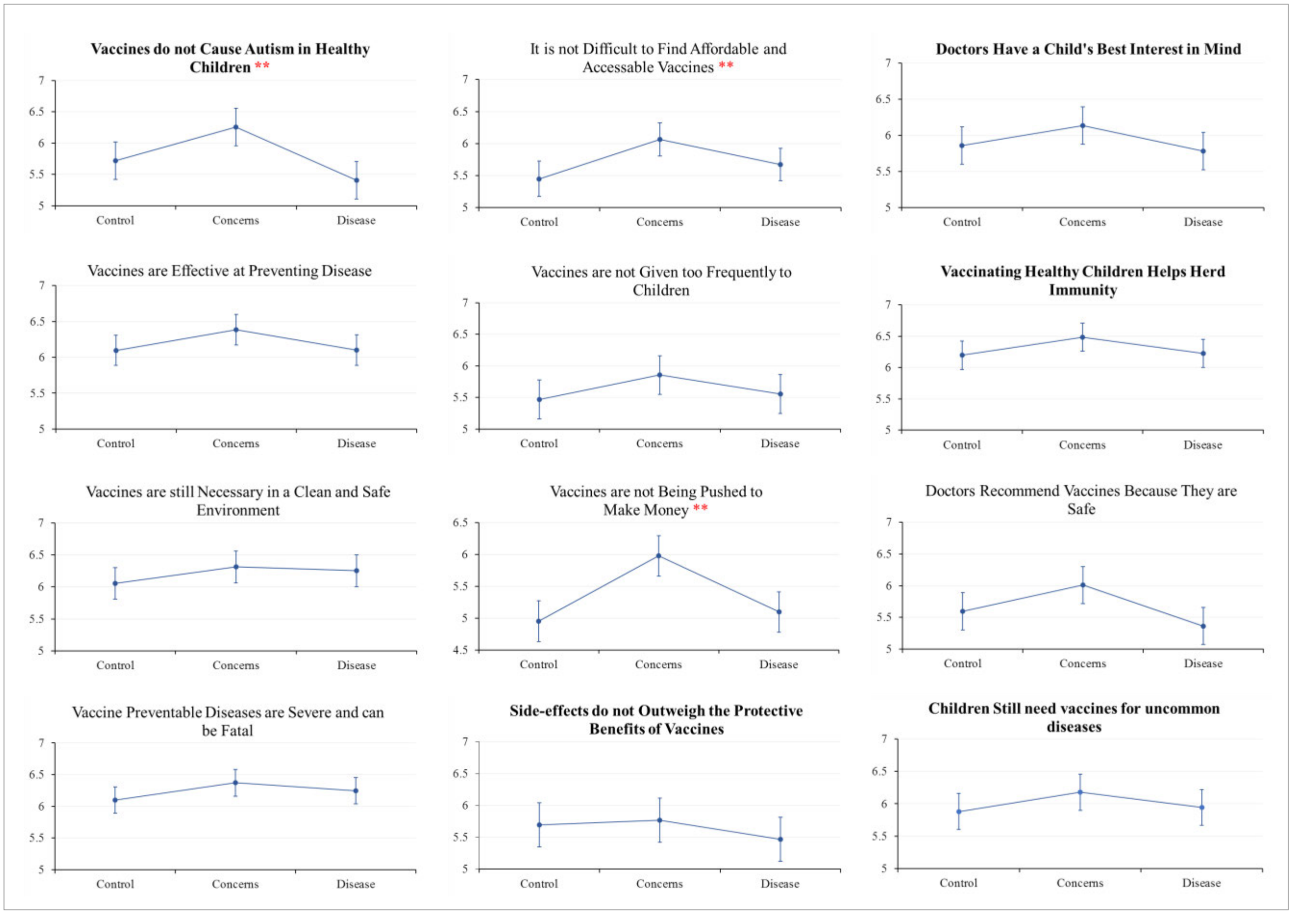

Figure 3.8. Differences in mean attitude scores, by group. ** = $p < 0.05$. Chart titles are modifications of the original questions in Appendix D, and are worded such that higher scores are more favourable towards vaccines. Test results are held in Appendix F. Titles in bold are attitudes used in the Horne et al. (2015) attitude scale. Error bars indicate 95% confidence intervals.

3.4 Hypothesis 4: Expected Utilities Will be Predictive of the Intention to Vaccinate

The fourth hypothesis states that the *EU* of vaccination will be predictive of the intention to vaccinate a child. *EU* values for each participant were calculated using their estimates of disease probability and utility. Due to extreme variation, severity ratings were rank-ordered before converting to a utility (for detailed explanation of *EU* procedure and generation, refer Appendix G). As a baseline, fever was assigned a utility of minus ten. Thus, if a participant rated whooping cough as ten times worse than fever, the rating was given a rank of four and multiplied by minus ten. Whooping cough then received a utility of −40 (−10 × 4). If instead, fever was considered five times worse than whooping cough, this rating was first ranked as three, and the values divided, so that whooping cough would receive a utility of −3.33 (−10 ÷ 3). The resulting utility of whooping cough was used to generate the utility of autism by the same procedure. Final *EU* values were calculated using Equation 1 (Section 1.3). The choice to vaccinate included the possible outcomes: Fever, autism, and no change. The choice to not vaccinate included the possible outcomes: Whooping cough, and no change. The *EU* from each choice was compared, and the highest value gave the prediction to either "vaccinate" or "not vaccinate". The prediction for each participant was then compared to their answer on the vaccination–intent question: "*Imagine that someday you have a/another child. Would you vaccinate them?*". An association test was significant $\chi^2(2, 410) = 94.2$, $p < 0.001$) with a large effect size ($V = 0.48$), indicating a strong association between *EU* and future vaccination intent (Figure 3.9). The results show that when *EU* values predicted vaccination, most people intended to vaccinate however, several people intended to vaccinate contrary to *EU* predictions. Conversely, when participants did not intend to vaccinate, *EU* correctly predicted all but one case. Those that were unsure are considered *vaccine hesitant*, and responded either: "Don't know", "yes, but only some vaccines", or "yes, but slower than the recommended schedule". Overall, the hypothesis is supported (refer Appendix H for post hoc testing).

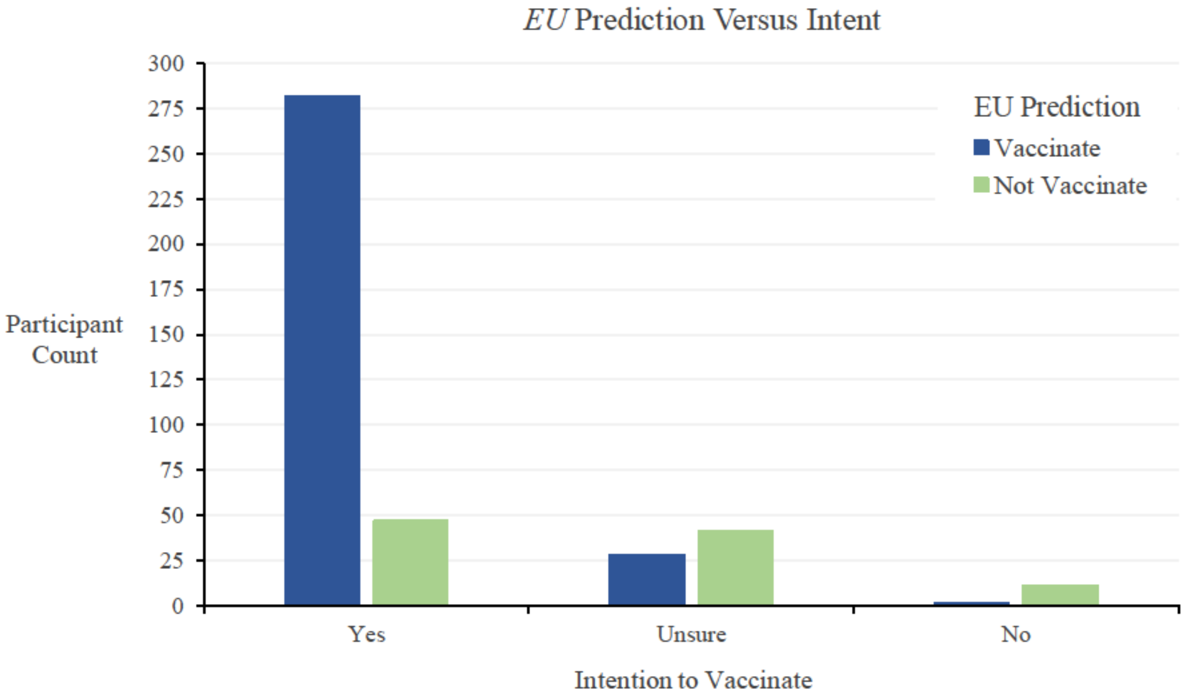

Figure 3.9. Participants' predicted intention, compared to actual intention to vaccinate. The *Yes* category contains correct predictions and some participants predicted to not vaccinate. The *Unsure* category is comprised of both prediction outcomes, and the *No* category contains all but one correctly predicted.

3.5 Hypothesis 5: Information About Certain Diseases Will Significantly Increase the Intention to Vaccinate

The fifth hypothesis predicts that the Disease group will have a significantly increased intention to vaccinate, above that of Control and Concerns. Responses to the intention to vaccinate a child were analysed by group using an association test however, the result was not significant ($\chi^2(4, 410) = 5.84$, $p = 0.21$). The intervention involving disease information did not seem to differentially influence vaccine intentions, and did not support the hypothesis (Figure 3.10). An interesting finding is that there are less participants "unsure" in their intentions from the Concerns group. Post hoc testing showed this difference is significant ($\chi^2(2, 69) = 6.87$, $p = 0.03$, $V = 0.32$) however, the test lacked statistical power (0.65) and would need 28 additional participants for a reliable result. Another interesting finding is a significant difference in attitude scores by vaccination intent ($\chi^2(2, 413) = 151.11$, $p < 0.001$, $\omega^2 = 0.37$). As the intention to vaccinate changes from "yes", to "unsure", to "no"; there is corresponding decrease in vaccine attitudes. These two findings are discussed in further detail in Section 4.1.5, and test details are held in Appendix I.

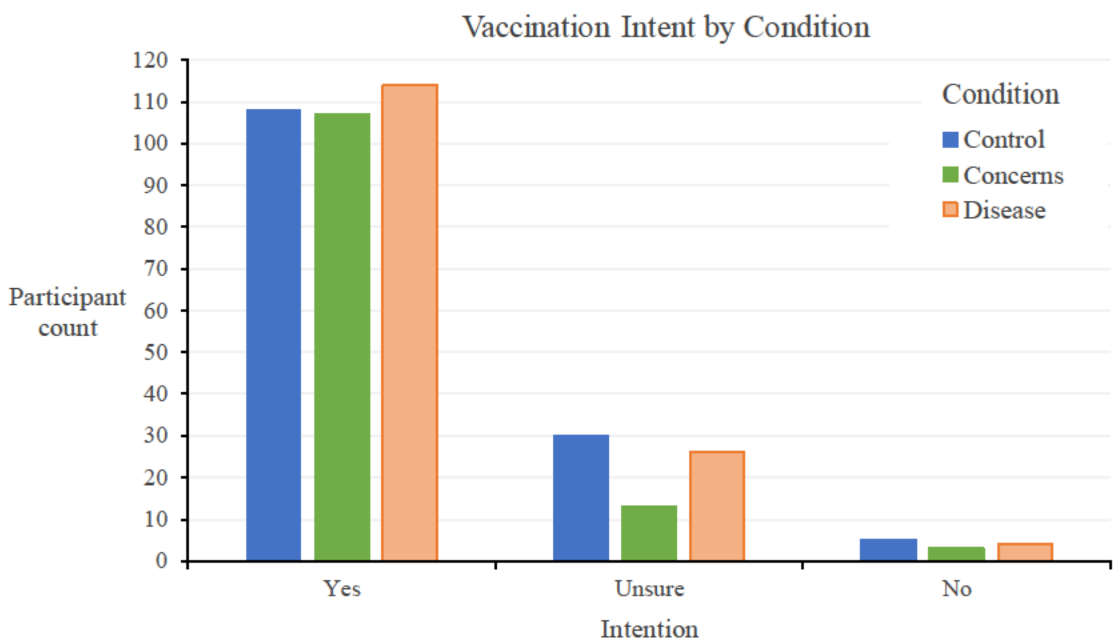

Figure 3.10. Participants' intention to vaccinate, by group. Each intention category shows the number of participants responding so in each group. No significant association was shown between Disease group and the *Yes* intention.

SECTION 4

Discussion

The present study aimed to examine parental vaccination choices from a decision–making framework, by using a novel approach that directly elicited individual estimates of probability and utility. Information about certain diseases was tested for an impact on individuals' utility assessments, attitudes towards vaccination, and intention to vaccinate. The main findings from each hypothesis are discussed in turn, which are then synthesised into the broader literature.

4.1 Main Findings

4.1.1 Probability and utility estimates. Under the first hypothesis, probability and utility estimates were compared between the Concerns group and Pilot study. The Control group had similar perceptions to the Pilot study regarding autism and whooping cough, which supported the hypothesis and suggests that perceptions of vaccination and vaccine preventable disease are generally stable within the population. Both groups estimated the probability of a child developing autism is between one and five percent, which captured the official statistic of 1.5% (Center for Disease Control and Prevention, 2017). Both groups estimated the chance of developing autism from a vaccination was practically zero; consistent with empirical research on the autism–vaccination link (Baker, 2008). However, 27% of the total participants in this study believed the chance of autism from a vaccination was 1% or greater. The proportion is similar to that of previous research, which found approximately 30% of participants also believed in this link (Salmon et al., 2015). It could be attributed to the persistence of misinformation in the population, or more interestingly, to the concept of *cultural cognition* (Kahan, 2010). This concept describes how group membership and values influence individual beliefs. People tend to adopt a position consistent with their group identity (Kahan, 2010). For example, an individual who strongly values an "alternative medicine" lifestyle, may accept that vaccines are harmful and cause autism if this position is held within that community.

On estimates of utility, both the Pilot study and Control group felt autism was ten times worse than whooping cough. It is not possible to prescribe the correct response—one condition is characterised by communication– and social–impairments of varying degrees; the other a fatal, highly contagious disease of the respiratory tract. Preferences in this case may not reflect an acceptance of possible death over life, rather the preference for life of a certain quality. While whooping cough might be considered a "one-time" event, autism is experienced over a much longer term. Despite the progress made on autism assessment, intervention, and outlook (see Fein et al. (2013) for discussion), the comparison may be one of permanence against transience; where transience is preferred. This is consistent with preferences under the *Quality–Adjusted Life Year* (QALY) model of health utility, which attempts to model choices for various states of health (Torrance, 1986).

4.1.2 The influence of disease information on utilities. The second hypothesis stated information about certain diseases should decrease the rated utility of those diseases. This was partially supported; participants exposed to information about whooping cough were more likely to respond that whooping cough was worse than autism and, the degree of severity between autism and whooping cough did decrease however, this decrease was not significantly different than Control. The pattern of results suggests that information on whooping cough had narrowed the difference in severity for those that maintained autism was worse, and where information switched preferences to whooping cough, the magnitude of preference was generally closer to the threshold required to switch. There is a distinction to be made between the limit of information's effect, and a limited effect of information. The former would result in a utility–rating arrived at by diligent consideration of the available information. The latter, may leave utility–ratings relatively unchanged, due to the insufficient ability of information to persuade. Which of these circumstances applies to this hypothesis is not known, so while disease information can influence preferences, the influence on severity associated with that preference is less clear. Another interpretation comes from *Prospect Theory* (PT) and risky decisions in medical contexts: While each outcome is assessed independently, under PT, alternate outcomes are considered against some current state of affairs as the reference point (Attema, Brouwer, & I'Haridon, 2013; Kahneman & Tversky, 1979). Utility is based on "deviation from a healthy state" for each outcome, rather than a direct comparison between alternates (Attema et al., 2013). As such, individuals can identify a preference, but may not be able to accurately gauge that preference using the comparison asked for in this study.

4.1.3 The influence of disease information on attitudes. The third hypothesis stated that information about certain diseases should significantly increase attitudes towards vaccination. This hypothesis was not supported; the replication of results from Horne et al. (2015) using the vaccine attitude scale was unsuccessful. Information about diseases did not improve attitudes beyond that of Control instead, higher attitude scores were obtained from the Concerns group. Within the attitude scale, the only significant attitude increase concerned the autism–vaccination link. The Concerns group had this link explained then refuted, and seemed to respond accordingly. A further two questions separate from the attitude scale were significant: The ease of vaccine accessibility, and the motivation of pharmaceutical companies. Higher scores were obtained from the Concerns group, and the overall pattern of results shows people exposed to information about vaccines tended to more favourable vaccine attitudes, and significant attitude changes occurred when the attitude question was directly addressed in the stimulus material. The presentation of stimulus material in this study is consistent with the *weight–of–evidence* format researched by Clarke et al. (2015). By presenting an issue that highlights the strength of evidence in support of a proposition, attitudes towards that proposition improve via a reduction in "information uncertainty"—as opposed to giving equal representation to contrarian view points (Clarke et al., 2015).

Cognitive phenomena such as the *backfire effect* or *belief polarisation* were not evident in the attitudes tested, which were expected from any existing negative attitudes and contributed to the motivation for this study (Lewandowsky et al., 2012). It is noted that attitudes towards vaccination were overly positive; mean scores were within the upper range across groups. From the significant attitude changes, it suggests the influence of information on attitudes is constrained by relevance. Given this, it is acknowledged that the attitude questions asked do not represent the entire set of attitudes relevant to vaccine decisions. The stimulus material used, may have been better suited to some other set of attitudes or vice versa, and is a limitation discussed in Section 4.3.

4.1.4 Using expected utility to predict vaccine choices. The fourth hypothesis stated that participants' *EU* values would be predictive of their intention to vaccinate. This hypothesis was supported by a strong association between *EU* predictions and vaccination intent, consistent with *EU* theory that holds the decision taken is one with the highest expected value (Von Neumann & Morgenstern, 1964). Approximately 86% of participants who intended to vaccinate were correctly predicted, and 92% of those who did not intend to vaccinate. It shows that people are indeed making rational choices based on a preferred outcome—or in the case of risky options, the least costly. The decision to vaccinate has been mapped on to the components of expected utility, which offers clues on the sort of information that would be useful to vaccine–decisions, and how to present it. Accurate probabilities ought to be available, as well as the scope and severity of those outcomes. Information on both sides of a decision should be accessible and comparable, the constraint being that the information should be presented in a non bias–inducing, or worldview–threatening manner.

In the majority of instances where a violation of *EU* theory occurred, it was in favour of vaccination. Participants were predicted not to vaccinate, but indicated a positive intent. The shortcoming here might be going from the *specific* to the *general*: This study assessed the general intent to vaccinate using the specific utilities between autism and whooping cough. Whereas intent may have been calculated on a different set of outcomes, or at least more than presented. It is recognised that the study design is a simplified model for vaccine decisions, for example, autism was chosen as it was the largest contributor to vaccine–hesitancy (Whyte et al., 2011). Another issue is uncertainty in the participants; decisions are often studied under forced–choice (Attema et al., 2013; Kühberger, 1998), so by allowing 'unsure' responses, a reduction in decision–model accuracy is experienced as a trade-off for more realistic decision–making behaviours. Uncertainty suggests an alternate outcome may need to be *sufficiently* different for a decision to be made. In such instances, uncertainty can be resolved by an extraneous factor—which in the case of vaccines, accounts for the initial success of vaccine mandates in schools (Briss et al., 2000). Apart from sufficiency, "unsure" responses represent a vaccine hesitant subgroup within which, reluctance to commit to the full vaccine schedule or, only accept certain vaccinations were the most common responses. This also suggests factors outside the utilities measured.

4.1.5 The influence of disease information on vaccination intent. The fifth hypothesis stated that information about certain diseases should increase the intention to vaccinate. This study did not find a significant influence of disease information on vaccination intent, which did not support the hypothesis. This is consistent with previous research from Nyhan and Reifler (2015), and Nyhan et al. (2014), who found no increased intention from disease images or narratives when applied separately whereas, this study used them in combination. The intention to vaccinate was relatively high across all groups, in line with the positive attitudes measured. The highest scoring attitude questions across all groups included "the severity of vaccine–preventable diseases", and "the effectiveness of vaccines" (Figure 3.10). Thus, the disease intervention may reached the limits of its' influence on an already pro-vaccine cohort, or there are factors driving vaccination–intent over and above that of disease.

An interesting finding was the difference in attitudes of those with different vaccination intent. Vaccine attitudes became significantly less positive between "yes", "unsure", and "no" responses (Appendix I). The lowest scoring attitudes for those who were unsure about vaccinating included the autism–vaccine link, whether doctors would recommend unsafe vaccines and, whether vaccines are given too frequently. Those who did not intent to vaccinate believed: That doctors would recommend unsafe vaccines; that vaccines are given too frequently to children, and; it is not necessary to vaccinate against uncommon diseases. Doctors' recommendation of unsafe vaccines is a common theme between these two groups, and while doctors are regarded as the most trusted source for vaccine advice (Edwards & Hackell, 2016; Sandhofer et al., 2017), distrust of doctors stems from the belief that they are not educated enough on the subject, and that the information provided is one–sided (Barrows, Coddington, Richards, & Aaltonen, 2015). Concern over the frequency of childhood vaccination is another shared theme and suggests vaccinations are viewed as a cumulative risk, a position that becomes much more influential when combined with the belief that vaccines are not necessary for uncommon diseases. These attitudes reflect the lack of perceived threat from diseases due to lack of exposure (Edwards & Hackell, 2016; Salmon et al., 2015), and a serious error in judgement over the causal role of vaccines in the reduction of disease.

4.2 Position Within the Existing Body of Knowledge

4.2.1 Vaccine–uptake interventions. The *health Belief Model* (HBM) was developed from the widespread under–utilisation of preventative and health–screening services (Appendix J; Rosenstock, 1974) and is based around two variables: "The desire to avoid illness" (Janz & Becker, 1984, p. 2), and; "the belief that a specific health action will prevent illness" (Janz & Becker, 1984, p. 2). Vaccination is regarded as an archetypal example, to which the HBM is directed (Janz & Becker, 1984). One class of interventions derived from the HBM are *Client–Demand Interventions* (Appendix K), which focus on vaccine–uptake by increasing *perceived susceptibility* and *perceived severity* in the HBM. This is achieved by providing information or advice to clients, thereby increasing their motivation to seek vaccination (Briss et al., 2000). While this study was not an uptake–intervention, it is situated alongside those of client–demand by examining the effect of information about diseases and vaccines on the intention to vaccinate however, highlighted some limitations of the HBM. Results showed information about disease could change disease preferences, but not reliably influence the relative severity. This is consistent with reports of severity being a poor measure under the HBM, due to the difficulties people have conceptualising this aspect when: "[T]hey are asymptomatic" (Janz & Becker, 1984, p. 36), and when "they have had little to no personal experience" (Janz & Becker, 1984, p. 36).

In addition to severity, participants who were unsure about vaccinating or did not intent to vaccinate had poorer attitudes regarding vaccination frequency, or lacked a perceived need due to disease rarity. These concerns increase *barriers* within the HBM in a unique way, as the mitigation of the perceived threat, is a threat in and of itself. Barriers are in direct tension with *perceived threat* as an alternate outcome, rather than a passive obstacle to action–taking.

4.2.2 Health decision–making. This study was a novel attempt at directly measuring *EU* values of vaccination, and testing these against participants' intention to vaccinate a child. Allowing participants to generate their own utilities was somewhat successful in making predictions. *EU* theory has been shown to obtain on decisions regarding vaccination, even though criticisms of *EU* Theory are well documented (Abellan-Perpiñan, Bleichrodt, & Pinto-Prades, 2009; Attema et al., 2013). One such criticism refers to *stochastic dominance*, or the general preference for one decision over another (Abellan-Perpiñan et al., 2009; Tversky & Kahneman, 1992). Violations in stochastic dominance were shown in those that were incorrectly predicted to not vaccinate and those unsure of their intent—at least to the extent the decision outcomes tested applied to the individual. Accuracy of predictions could thus be improved by Prospect Theory, which replaces probabilities with *decision weightings* that reflect a different impact on utilities (Kahneman & Tversky, 1979).

One way vaccination decisions are unique is that in the case of children, the decision is made on someone else's behalf. Zeigler and Tunny (2015) found when decisions were being made on behalf of others, participants tended to be less risk–seeking. Although this finding was in the context of monetary gambles, if there is a tendency towards more conservative choices on behalf of others, vaccine risks may be exaggerated and contribute to vaccine–hesitancy. When decisions impact other people, the realm of *moral psychology* also comes into play. Under this domain are the set of *trolley problems*, where the classic scenario is a decision between letting a runaway trolley kill five people, or pulling a lever to save them but kill a person on another track (Haidt, 2001). Another formulation asks whether to push a man onto the tracks to save five others (Cao et al., 2017). Most people would pull the lever however, few would push a man to his death (Cao et al., 2017). While a substantial amount of research has been done in this area (Cao et al., 2017), the tendency is to refrain from taking more active roles in harming others. This is particularly relevant to vaccine decisions, where a parent may view themselves in an active role by taking a child for vaccination, only to have them injured. Research shows emotional centres of the brain are involved in this kind of decision (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001), which could account for the inefficacy of factual data to change existing negative attitudes (Cornelia Betsch, Renkewitz, & Haase, 2013).

4.2.3 Vaccine messages and myth correction. There is a comprehensive body of evidence surrounding the way vaccine messages interact with the pre-existing attitudes of a target audience. Pro-vaccine or "corrective" information is effective on attitudes that are already positive however, corrective information is not persuasive and even has a reverse effect, when individuals have existing negative attitudes (Lewandowsky et al., 2012; Nyhan & Reifler, 2015; Nyhan et al., 2014). In these cases, individuals subject contrary information to increased scrutiny, and bring up additional concerns to protect the challenged belief (Lord et al., 1979; Nyhan et al., 2014). Results from this study found that addressing vaccine concerns directly improved some vaccination attitudes, consistent with previous findings however, analysis did not show evidence of any reversal or polarising effects.

The efficacy of disease information has mixed results in the literature. Papachrisanthou et al. (2016) found adherence to the vaccine schedule was better after exposure to disease imagery and verbal education, and Horne et al. (2015) found better attitudes from disease information and imagery. Whereas, this study did not find improved attitudes or intent from disease information, consistent with findings from Nyhan and Reifler (2015), and Nyhan et al. (2014). Negative or anti-vaccine information typically relies on imagery and narratives, and has an asymmetrical impact over positive information, which tends to be based in statistics (Cornelia Betsch et al., 2013; Nan & Madden, 2012). Despite no increase in intent or attitudes, the disease intervention in this study did contain imagery and narratives, which influenced disease preferences. This lends some optimism to future attempts at enhancing the emotive content of pro-vaccine materials.

The improvement in attitudes and reduction in uncertainty within the Concerns group is consistent with the *weight–of–evidence* model (Clarke et al., 2015) however, this finding should be interpreted cautiously due to the lack of statistical power. Under this model, information is framed in a way that accents the strongest position that data can support. This has practical implications on the presentation of information to the public. Consider this extract correcting vaccine misinformation from the Department of Health and Aging (2013): "Vaccines are unsafe…In general, no pharmacologic agent, including vaccines, can be considered 100 per cent safe." (p. 4). Current findings suggest a more effective format would be: "Vaccine safety…vaccines have the highest safety standards, and are tested more thoroughly, than any other pharmacological agent".[6] Such presentation highlights the current state of vaccine developmental standards, which is more convincing than the colloquial interpretation of the former: "Well, it's no worse than anything else".

[6] Vaccine safety comments taken from Edwards and Hackell (2016).

4.2.4 Current Attitudes. Attitudes towards vaccination are generally positive in the community (Campbell et al., 2015; Macdougall et al., 2016; Weiner, Fisher, Nowak, Basket, & Gellin, 2015), and was reflected in the findings of this study. However, the safety of vaccinations remains a concern and is likely to continue, while disease incidence is relatively low in Western societies (Boyd et al., 2013). Education about vaccines improves vaccine up–take, but only in cases where reluctance is due to a lack of knowledge (Campbell et al., 2015; Gilkey et al., 2016; Sandhofer et al., 2017; Weiner et al., 2015). In contrast, those who refused vaccinations typically had either: Higher educational levels, healthcare industry employment, or specific vaccine concerns (Biasio, 2016; Gilkey et al., 2016). Vaccines contingent on certain "lifestyle risks" are downplayed, such as the human immunodeficiency virus (HIV) vaccine (Ravert & Zimet, 2009) and the human papillomavirus (HPV) vaccine in the context of adolescent sexual activity—particularly in religious communities (Gilkey et al., 2016; Thomas, Blumling, & Delaney, 2015). Recent vaccines are thought of as less safe than older vaccines, and when mass–produced to meet a new epidemic (Boyd et al., 2013; Carlsen & Glenton, 2016; Salmon et al., 2015). There is also a level of distrust towards authorities (Shapiro et al., 2016).

In this study, differences in attitudes were made clearer once compared with the intention to vaccinate. Participants who were unsure about vaccination had neutral–to–positive attitudes however, those who did not intent to vaccinate had negative attitudes, specifically: Trust in authority over vaccine recommendations; the frequency vaccines are delivered to children, and; the surprising belief that vaccines are not needed for uncommon diseases. The proportion of participants who associated autism with vaccination was also consistent with previous findings (Salmon et al., 2015).

4.3 Limitations and Future Research

There are several limitations that restrict the generalisability of results. The sample was predominantly an American population recruited from MTurk. Although questions have been raised over the use of MTurk members—due to financial gain and familiarity from repeated testing—research found their performance is similar to other convenience samples, and are therefore good representatives of the American population (Berinsky, Huber, & Lenz, 2012). The MTurk sample drawn for this study were overly pro-vaccination, which makes testing harder as their existing attitudes are already consistent with the experimental intent across all conditions. Future research might seek a non-random sample, including those who identify as vaccine–hesitant or generally unsure about vaccination.

Expected Utility and intentions do not necessarily translate into action. While retrospective research has shown around one–third of parents who have ever refused a vaccination, had vaccinated at a later time (Gilkey et al., 2016); the conversion between vaccine *EU* and real-world action remains unstudied. Results suggest Prospect Theory may yield superior results by weighting decision outcomes, and *EU* calculations themselves were based on a simplified decision model between autism and whooping cough. Given most participants did not have a strong belief in the autism–vaccine link, future research may improve on results using Prospect Theory and choosing a more comprehensive set of outcomes to assess.

As previously mentioned, the set of attitude questions used does not cover all possible attitudes, and does not measure attitudes for specific vaccines. Interestingly, attitudes with the most change were influenced by factually–based data, when this is typically the least persuasive. This suggests participants in this study may favour rationally–based thinking over emotionally–based (Kahneman, 2011). Future research should examine relationship between vaccine attitudes and thinking styles, which could help develop tailored educational materials, or inform the content of publicly available information to meet the needs emotional thinkers in the wider community.

4.4 Concluding Remarks

This study attempted to examine vaccine attitudes and choices using a unique method to generate Expected Utility. Analysing how vaccine decisions are formed at the cognitive level offers a foundational basis to identify aspects that are inaccurate, incorrect, or those that need adjusting. In the present study, information about diseases could change disease preference and, the relative severity of disease to an extent. This supports the idea that a lack of interaction with vaccine preventable diseases has changed how people think about them specifically, a reduction in perceived severity. While most people are in favour of vaccination, it is those who are vaccine–hesitant that remain the biggest threat to the wider community. The reduction in disease rates are *because* of vaccination, not mere coincidence, and until a disease has been eradicated world–wide; shifting demographics through immigration, international travel, and random contact mean disease risks are a constant threat.

There are three overarching scenarios regarding vaccine information in the community: Inadequate dissemination; adequate dissemination but not communicated effectively, and; anti-vaccine information creating unrealistic doubt. By taking these into account, the varied and often specific parental concerns can be addressed by developing tailored content and delivery methods that target *EU* formulation. The attitudes shown by vaccine–hesitant individuals indicate trust in the healthcare provider is an important factor. Healthcare professionals remain at the frontline of vaccine programs; it is therefore essential that health professionals remain current with disease prevalence, and the “benefits versus risk” of vaccination, if we are to maintain the coverage needed to protect the wider community while working towards disease eradication.

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APPENDIX A

Probability Questions

1. What is the percentage chance of a child having autism?
2. What is the percentage chance of a child developing autism due to a vaccine?
3. What is the percentage chance of a child having a severe side-effect due to a vaccine?
4. What is the percentage chance of an unvaccinated child developing whooping cough?

Distractor question:

5. What is the percentage chance of a child getting the flu sometime during childhood?

Response options:

- Less than 0.00001
- Between 0.00001 and 0.1
- Between 0.1 and 1
- Between 1 and 5
- Between 5 and 10
- Between 10 and 25
- Between 25 and 75
- Between 75 and 90
- Between 90 and 95
- Between 95 and 99
- Between 99 and 99.9999
- Over 99.9999

APPENDIX B

Utility Questions

1. Which do you think is worse: Your child developing whooping cough or developing autism?
2. Which do you think is worse: Your child developing whooping cough or developing a 103F (40C) fever?

Distractor questions:

3. Which do you think is worse: Your child becoming blind or developing cancer?
4. Which do you think is worse: Your child going into a coma or developing a cold?
5. Which do you think is worse: Your child stubbing a toe or missing a nap?

After each question, a magnitude was asked:

1. How many times worse is it?
    - 2 times as bad
    - 5 times as bad
    - 10 times as bad
    - 50 times as bad
    - 100 times as bad
    - 500 times as bad
    - 1,000 times as bad
    - 5,000 times as bad
    - 10,000 times as bad

APPENDIX C

Intention Questions

For themselves:

1. Imagine that someday you have a / another child. Would you vaccinate them?

Response options:

- Yes, according to the suggested vaccination schedule.
- Yes, but slower than the suggested vaccination schedule.
- Only some of the vaccines, not all of them.
- I don't know.
- No, I don't think vaccines are a good idea.

For others:

1. Do you think other parents should be required to have their children vaccinated?

Response options:

- Yes, unless they are immunocompromised or can't medically tolerate it.
- No, but if they don't the children shouldn't be allowed in public schools.
- No, it's really only up to the individual and is not my business.
- I have no opinion either way on this issue.

APPENDIX D

Attitude Questions

Questions used to replicate Horne et al. (2015):

1. Some vaccines cause autism in healthy children. *****
2. Doctors would not recommend vaccines if they were unsafe.
3. The risk of side effects outweighs any protective benefits of vaccines. *****
4. Children do not need vaccines for diseases that are not common anymore. *****
5. Vaccinating healthy children helps protect others by stopping the spread of disease.

Additional questions:

6. Vaccines are given too frequently to children. *****
7. Vaccines are being pushed to make money for drug companies. *****
8. Vaccines are effective at preventing the disease they are developed for.
9. It is difficult to find a vaccine provider that is affordable and easy to access. *****
10. If parents maintain a clean and safe environment, vaccinations are not necessary. *****
11. The diseases that are vaccinated against are extremely severe and sometimes fatal.
12. Medical professionals in charge of vaccines generally have my child's best interests in mind.

13. This is a comprehension question; choose 'agree' to show you read it.

Note: ***** = questions reverse–scored for analysis.

APPENDIX E

Stimulus Materials

Control Group

Pumice

Description

Pumice is a rough-textured volcanic glass, typically light in color. It is formed when super-heated pressurized rock has been ejected from a volcano. The sudden drop in pressure causes gas bubbles to form.

Facts

- Ever since Roman times pumice has been used to make smooth concrete.
- Many people use pumice to remove excess skin and calluses from their feet.
- Underwater volcanoes can produce large pumice 'rafts' that are hazardous to ships at sea.

A typical piece of pumice. Note the gas bubbles formed throughout.

Information and picture from Wikipedia: Pumice.

Next

Volcanoes

Description

Volcanoes look a lot like mountains, although they are often more conical. They occur when there is a rupture in the earth's crust that allows molten lava to escape from below the surface. As the lava cools, it builds up on top of the older lava, creating a pyramid shape.

Facts

- The word 'volcano' comes from the Roman god of fire: Vulcan.
- Volcanoes can erupt continuously for a very long time; the longest eruption on record was Mt Yasur, for 111 years.
- Acid rain is formed when the chemicals in volcanic ash mix with the gases in the atmosphere.

An eruption of Mt Pinatubo in 1991, during which ash clouds reached 12 miles high.

Information and picture from Wikipedia: Volcanoes.

Next

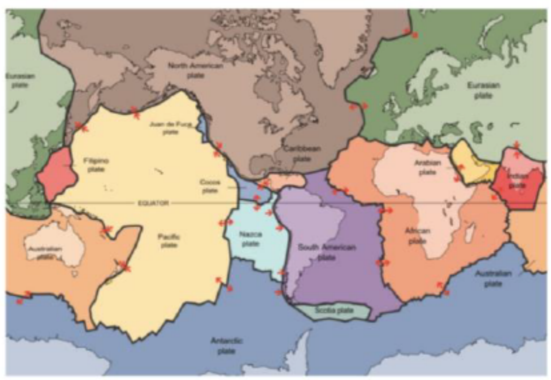
Plate tectonics

Description

The rigid outer shell of the earth's crust is split into different plates. These plates float on top of our planet's molten core. Convection currents in the magma cause the plates to move and slip relative to one another.

Facts

- Tectonic plates are typically over 60 miles (around 100km) thick.
- Australia is the fastest moving continent; it is on a collision course with China and moves about 70mm per year.
- The earth's magnetic poles change direction over time because the plate edges spreading on the ocean floor contain alternating magnetic fields.



These are some of the major tectonic plates on earth.

Information and picture from Wikipedia: Plate Tectonics.

Next

Pangaea

Description

Pangaea is the name of the super-continent that formed 335 million years ago when all of the tectonic plates that make up the earth's crust were shifted so the current continents were all touching. This kind of supercontinent has occurred cyclically throughout history.

Facts

- The first vertebrates began and spread across the land during the time of Pangaea.
- There were eight supercontinents before Pangaea.
- A new supercontinent is due to form at the north pole in about one million years.

A map of Pangaea that shows the outlines of the modern continents.

Information and picture from Wikipedia: Pangaea.

Next

Attention–Check Questions for Control Group

True or false:

1. Pumice can be used to make concrete. (T)
2. The longest continually erupting volcano erupted for about 12 years (F)
3. In about one million years, all the continents will come together at the north pole. (T)
4. There have only been four supercontinents like Pangaea in all of history. (F)

Concerns Group

Big Pharma

Concern

Some people fear that the government and vaccine companies are pushing people to vaccinate in order to make more money.

Facts

- Vaccines are so cheaply available that they make up only a small fraction of a pharmaceutical company's profit; sometimes they don't even break even.
- The government wants people to be vaccinated to remove the danger of an epidemic, which would greatly hurt GDP, productivity, and quality of life.
- The government has an interest in building herd immunity, so that people who cannot vaccinate for medical reasons are not at risk.

Vaccines are not big money makers for pharmaceutical companies.

Statistics and information reported in The Atlantic, Medscape, and the Department of Health and Human Services.

Next

Pain and side-effects

Concern

Some people are worried that vaccines can be painful and have negative side-effects that might be worse than the disease itself.

Facts

- Severe complications are very rare: about one in one hundred thousand (or even less) depending on the vaccine.
- Extreme side-effects are so rare that it is difficult to determine whether they are caused by the vaccine at all.
- Mild side effects like a low fever are quickly resolved and often hard to distinguish from typical childhood illnesses.

The pain of a needle is no fun, but it passes quickly and young infants especially retain no memory of the experience.

Statistics and information from the AAP website.

Next

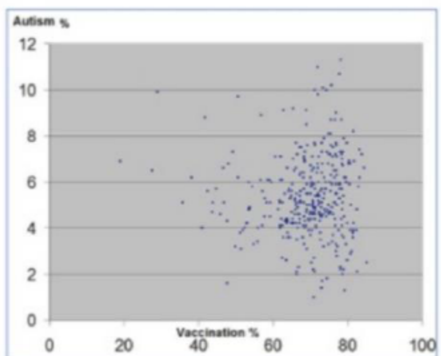
Autism

Concern

Some people are worried that vaccines, especially the MMR vaccine, may be linked to autism.

Facts

- The ingredient thought to be linked to autism, thimerosal, has been removed from all vaccines since 2001.
- Hundreds of studies have found no causal link between autism and either the MMR vaccine or thimerosal.
- The study upon which the autism-vaccination link was based has been retracted due to the omission of key data and undisclosed financial interests.



The percentage of children vaccinated, compared to the percentage of diagnosed cases of autism for each state in America. There is no relationship.

Statistics and information from the CDC. Image from *Discover* magazine.

Next

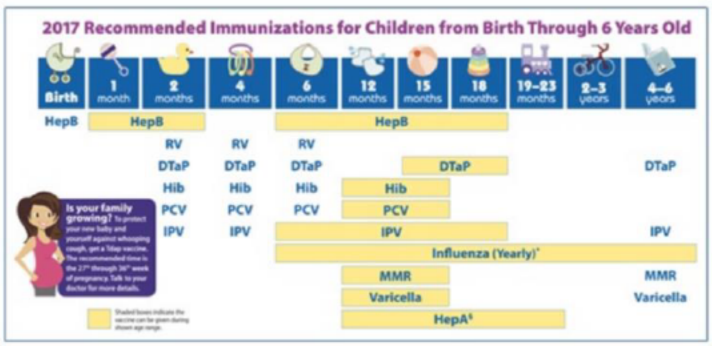
Vaccine Schedule

Concern

Some people are worried about the frequency of vaccines and the fact that so many are given at a relatively early age.

Facts

- Babies inherit some immunity from the mother, but this only lasts a short time and varies depending on the disease.
- Vaccinations are only given after a baby's immune system can cope with it.
- Delaying the vaccination schedule means that babies will be vulnerable to severe diseases in the interim.



Vaccines are staggered to occur when immunity from the mother wears off and the baby's immune system can cope.

Photo from the CDC. Statistics and information from the AAP website.

Next

Attention–Check Questions for Concerns Group

True or false:

1. The study upon which the autism-vaccination link was originally based has been retracted. (T)
2. Severe complications from vaccines occur for about one out of every thousand babies. (F)
3. Mild side effects of vaccines can be difficult to distinguish from typical childhood illnesses. (T)
4. Because babies inherit some immunity from their mother, vaccination can wait until their systems can cope; most vaccines are not given to newborns. (T)

Disease Group

Whooping cough

Death rate

The fatality rate of whooping cough is nearly 1% for children under 12 months of age.

Description

Whooping cough involves fits of coughing strong enough to break ribs. Complications include brain damage, pneumonia, and bleeding in the eye or brain.

Testimony

"It was horrifying. You ultimately watch your baby every day die. You know the cough's coming, you don't know when it's coming and you don't know if they're going to survive their next cough." - Dianne Cherrie, whose daughter had whooping cough.

7-week-old infant with whooping cough.

Photos from Waikato District Health Board. Information from the Center for Disease Control (CDC).

Next

Diptheria

Death rate

The fatality rate of diptheria is 20% in children under five.

Description

Diphtheria involves a membrane that can cover the throat along with glands so swollen it can be difficult to breathe. Toxins from the disease lead to heart failure, paralysis, or damage to kidneys, liver, tissues, or nerves.

Testimony

"My baby drew his last breath at 2am this morning. I never expected him to die." - Zalifah Hussin, who lost two children to diphtheria, 11 months and 2 years old

A child with diptheria, showing swollen glands.

Photo from Public Health Image Library of the Centers for Disease Control and Prevention. Statistics and information from the Center for Disease Control (CDC).

Next

Tetanus

Death rate

The fatality rate of tetanus is 10-30%.

Description

Tetanus involves spasms every few minutes over the entire body -- spasms so severe that bones can break. Symptoms may last for months.

Testimony

"It was hideous. He was spasming every three minutes. He was biting his tongue and bleeding. His arms were spasming and he was arching his back and his whole face and jaw was completely locked." - Linda Williams, whose son had tetanus at 7 years old.

A preschool child showing the characteristic muscle spasms.

Photo from the American Academy of Pediatrics. Statistics and information from the Center for Disease Control (CDC).

Next

Measles

Death rate

The fatality rate of measles is around 1%.

Description

Measles involves an extremely high fever, very itchy rash, and 30% chance of complications including pneumonia and encephalitis.

Testimony

"Olivia, my eldest daughter, caught measles when she was seven years old.. One morning, when she was well on the road to recovery... I noticed that her fingers and her mind were not working together and she couldn't do anything. 'Are you feeling alright?' I asked her. 'I feel all sleepy,' she said. In an hour, she was unconscious. In twelve hours she was dead. The measles had turned into a terrible thing called measles encephalitis and there was nothing the doctors could do to save her." - Roald Dahl, children's book author.

Typical measles spots covering a child's upper body.

Photo from the American Academy of Pediatrics.

Next

Check Questions for Disease Group

True or false:

1. Diphtheria can lead to heart failure, paralysis, or organ damage. (T)
2. Measles causes an itchy rash and low fever but death occurs only under very unhygienic conditions. (F)
3. Tetanus is characterized by spasms so strong they can break bones. (T)
4. Whooping cough is named that because the cough lasts a long time, but it's extremely mild. (F)

APPENDIX F

Post Hoc Testing for Attitude Questions

Table A1

Test results and pairwise comparisons for attitude questions

Question	$\chi^2(2, 413)$	*p*	ω^2	Pairwise Result (*p*)		
				Cont-Cons	Cont-Dis	Cons-Dis
A	17.54	**0.001**	0.04	**0.01**	0.13	**<0.001**
B	9.99	0.06	0.03	**0.05**	0.36	**0.01**
C	2.73	0.76	0.01	0.41	0.75	0.31
D	2.23	0.65	0.01	0.81	0.55	0.38
E	5.95	0.36	0.01	0.06	0.70	0.09
F	2.80	0.98	0.01	0.38	0.86	0.32
G	24.02	**<0.001**	0.06	**<0.001**	0.43	**<0.001**
H	5.28	0.43	0.01	0.13	0.80	0.09
I	12.28	**0.02**	0.03	**0.002**	0.21	**0.05**
J	3.45	0.89	0.01	0.23	0.51	0.31
K	0.73	0.69	0.002	1	0.93	1
L	7.29	0.21	0.02	**0.04**	0.85	**0.05**

Note. Kruskal-Wallis testing used due to violation of the normality assumption for ANOVA; Cont-Cons = Control versus Concerns group; Cont-Dis = Control versus Disease group; Cons-Dis = Concerns versus Disease group; All *p*-values have Holm correction applied; Values in bold represent statistically significant results.

Questions

A. Some vaccines cause autism in healthy children.
B. Doctors would not recommend vaccines if they were unsafe.
C. The risk of side effects outweighs any protective benefits of vaccines.
D. Children do not need vaccines for diseases that are not common anymore.
E. Vaccinating healthy children helps protect others by stopping the spread of disease.
F. Vaccines are given too frequently to children.
G. Vaccines are being pushed to make money for drug companies.
H. Vaccines are effective at preventing the disease they are developed for.
I. It is difficult to find a vaccine provider that is affordable and easy to access.
J. If parents maintain a clean and safe environment, vaccinations are not necessary.
K. The diseases that are vaccinated against are extremely severe and sometimes fatal.
L. Medical professionals in charge of vaccines generally have my child’s best interests in mind.

APPENDIX G

Expected Utility Calculation Procedure

Expected Utility was calculated using the probability estimates and severity ratings from each participant. The following possible outcomes are included under each choice:

Vaccinate	**Not Vaccinate**
Possibility of side-effect (fever)	Possibility whooping cough
Possibility of autism	Possibility of no change [1 – P(w. cough)]
Possibility of no change [1 – (P(autism)+P(fever))]	

The severity ratings from participants contain extreme values, so responses are first rank-ordered as per Table A2. Figures are then converted to a utility value as follows: Fever has a baseline of −10, so if whooping cough is rated 100 times worse than fever, the adjusted rank (6) is used, then multiplied by −10 to give a utility of −60. If autism is rated 1,000 times worse than whooping cough; its adjusted rank 8 is multiplied by the utility of whooping cough to receive a utility of −480 (8 × −60). Where preferences are reversed, ratings are divided, for example; if fever is 10 times worse than whooping cough, whooping cough receives −2.5 (−10 ÷ 4). Now if whooping cough is 100 times worse than autism, autism receives a utility of −0.42 (−2.5 ÷ 6). Once utilities are obtained; percentages for possible outcomes are converted to probabilities, multiplied by utilities, and summed under each decision as per the Equation 1:

$$EU(\mathrm{A}) = \sum_{\mathrm{o} \in \mathrm{A}} P(\mathrm{o})U(\mathrm{o})$$

The resulting *EU* values are compared, and the highest *EU* represents the preferred choice.

Example Responses:

1. Chance of a vaccine side-effect (fever)? *1%*
2. Chance of catching whooping cough? *5%*
3. Chance of autism from a vaccination? *0.1%*
4. Which is worse? *Whooping cough, and is 10 times worse than fever.*
5. Which is worse? *Autism, and is 10,000 times worse than whooping cough.*

Participants' Data:

- Fever: 1% chance; utility −10 (base figure)
- Whooping cough: 5% chance; utility −40 (10 times worse than fever)
- Autism: 0.1% chance; utility −400 (10,000 times worse than whooping cough)

<u>Vaccinate Decision</u>

EU(fever) = P(fever) × U(fever)
= 0.01 × −10
= −0.1

EU(autism) = P(autism) × U(autism)
= 0.001 × −400
= −0.4

EU(no change) = (1 – (P(fever) + P(autism))) × 0
= 0.999 × 0
= 0

EU(Vaccinate)
= EU(fever) + EU(autism) + EU(no change)
= −0.1 + (−0.4) + 0
= −0.5

<u>Not Vaccinate Decision</u>

EU(w. cough) = P(w. cough) × U(w. cough)
= 0.05 × −40
= −2

EU(no change) = (1 – P(w. cough)) × 0
= 0.95 × 0
= 0

EU(Not Vaccinate)
= EU(w. cough) + EU(no change)
= −2 + 0
= −2

Since −0.5 > −2, the decision is to vaccinate.

Table A2

Rank conversion for utility values

Severity (how many times worse)	Rank	Adjusted Rank
2	1	2
5	2	3
10	3	4
50	4	5
100	5	6
500	6	7
1,000	7	8
5,000	8	9
10,000	9	10

Note. Adjusted Rank = Rank + 1; adjusted rank is used to preserve preferences. For example, under rank 1 if fever is 2 times worse than whooping cough, both fever and whooping cough receive a utility of −10. Under rank 2, if fever is 2 times worse whooping cough, fever receives −10, whooping cough receives −5.

APPENDIX H

Mean EU Score Differential

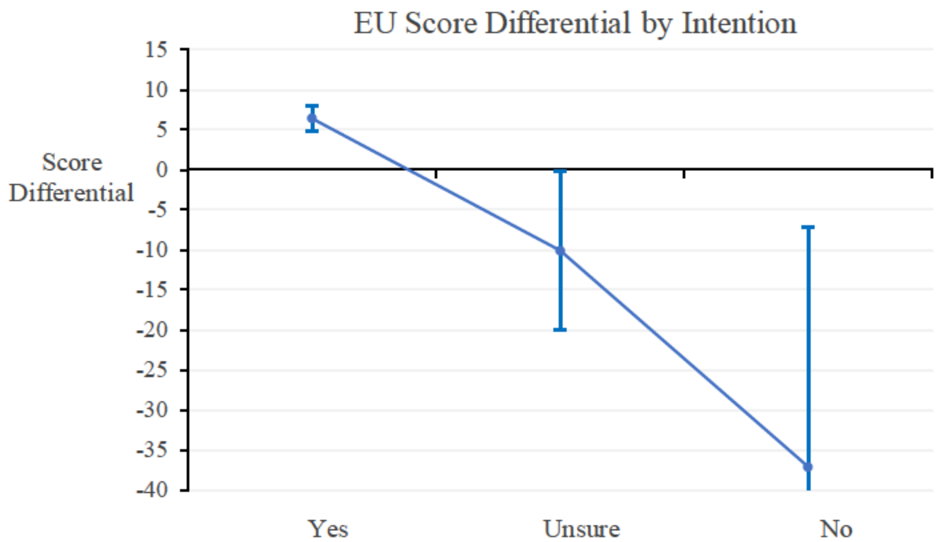


Figure A1. Mean *EU* score differential, by vaccination intent. Score differential is created by subtracting the final *EU* value for "not vaccinate" from the final *EU* value for the "vaccinate" prediction, such that a positive value will predict "vaccinate", while a negative value will predict "not vaccinate". Those who intend to vaccinate are sufficiently above zero. Those who are unsure are close to zero, and those who do not intent to vaccinate are significantly below zero. Error bars indicate 95% confidence intervals.

APPENDIX I

Post Hoc Tests on Vaccination Intent

Group Differences in the Unsure category

Goodness-of-fit contingency table:

Group	Observation (O)	Expected (E)	(O – E)	$(O – E)^2$	$(O – E)^2 \div E$
Control	30	23	7	49	2.13
Concerns	13	23	−10	100	4.35
Disease	26	23	3	9	0.39

Chi-square (χ^2) = 6.87

Degrees-of-Freedom = 2

n = 69

p-value = 0.03

Cramer's *V* = 0.32 (medium effect size)

Power ($1 – \beta$) = 0.65 (need 97 for sufficient power (0.8))

Differences in Vaccine Attitudes

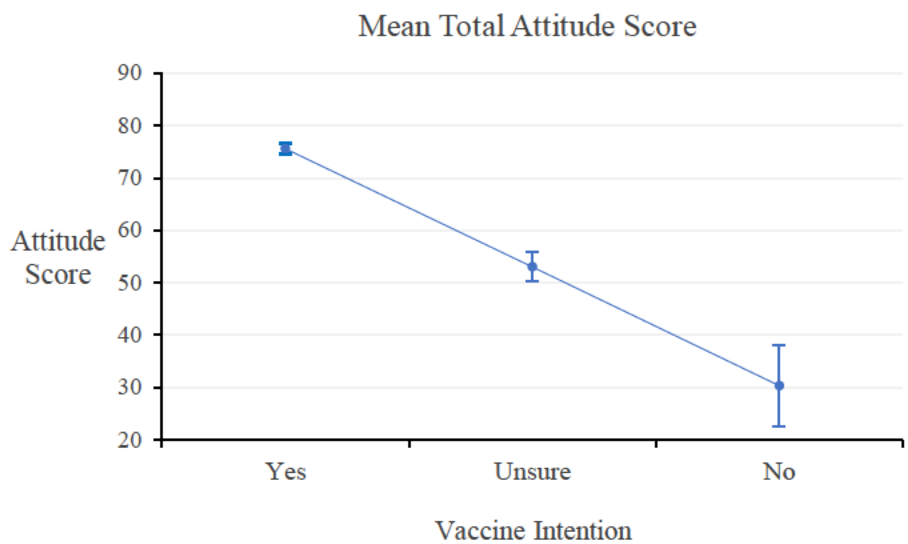


Figure A2. Differences in attitude score, by intention to vaccinate. There is a difference between the mean total attitude scores when grouped by intent. Scores represent the aggregate of all questions combined. Possible scores range from 12 to 84. Error bars represent 95% confidence interval.

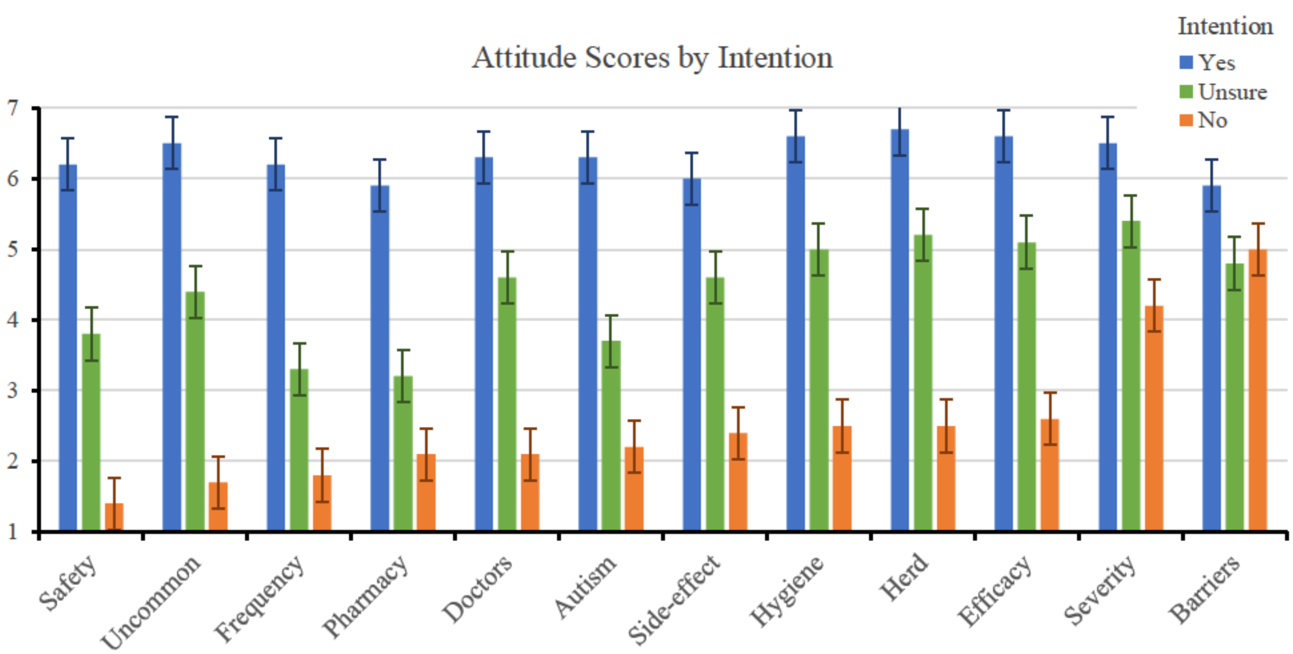


Figure A3. Differences in individual attitude scores, grouped by intention to vaccinate. Those who did not intend to vaccinate had the poorest attitudes towards vaccines. Refer below for category explanation.

Category Explanations For Figure A3

1. *Safety*: Medical professionals in charge of vaccines generally have my child's best interest in mind
2. *Uncommon*: Children do not need vaccines for diseases that are not common anymore
3. *Frequency*: Vaccines are given too frequently to children
4. *Pharmacy*: Vaccines are being pushed to make money for drug companies
5. *Doctors*: Doctors would not recommend vaccines if they were unsafe
6. *Autism*: Some vaccines cause autism in healthy children
7. *Side-effect*: The risk of side effects outweighs any protective benefits of vaccines
8. *Hygiene*: If parents maintain a clean and safe environment, vaccinations are not necessary
9. *Herd*: Vaccinating healthy children helps protect others by stopping the spread of disease
10. *Efficacy*: Vaccines are effective at preventing the disease they are developed for
11. *Severity*: The diseases that are vaccinated against are extremely severe and sometimes fatal
12. *Barriers*: It is difficult to find a vaccine provider that is affordable and easy to access

APPENDIX J

Health Belief Model

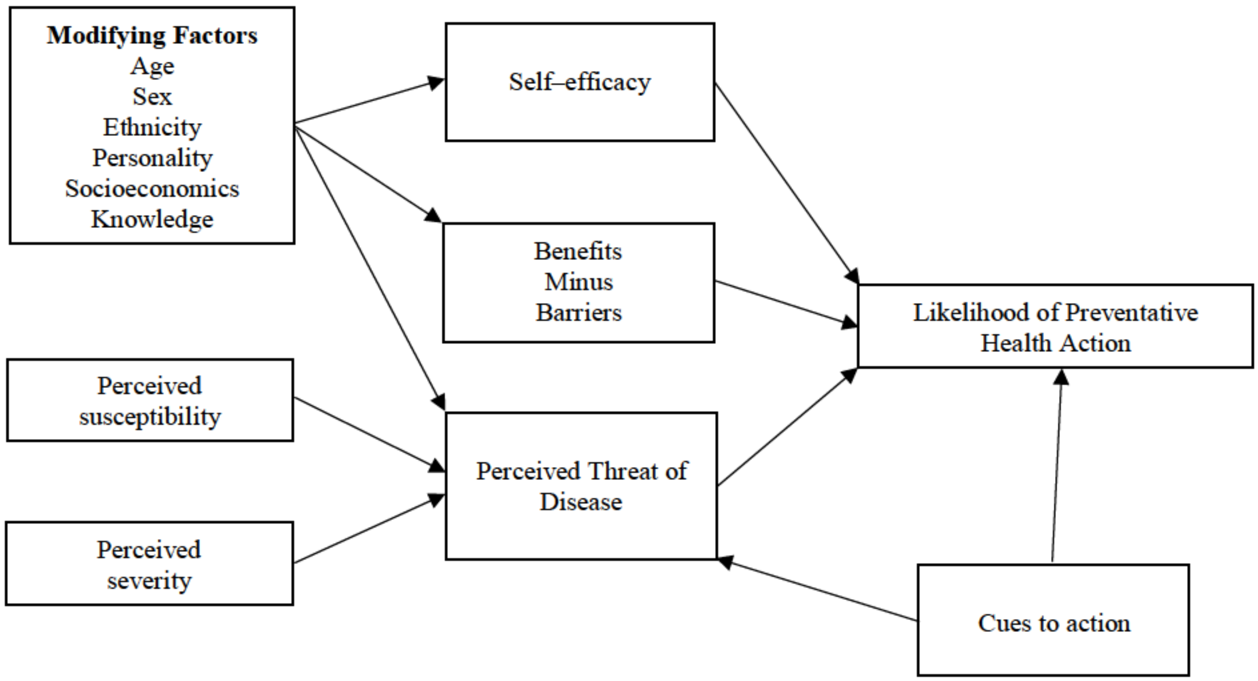


Figure A4. The health belief model. Adapted from: Glanz, Rimer, and Viswanath (2015).

APPENDIX K

Vaccine Program Application

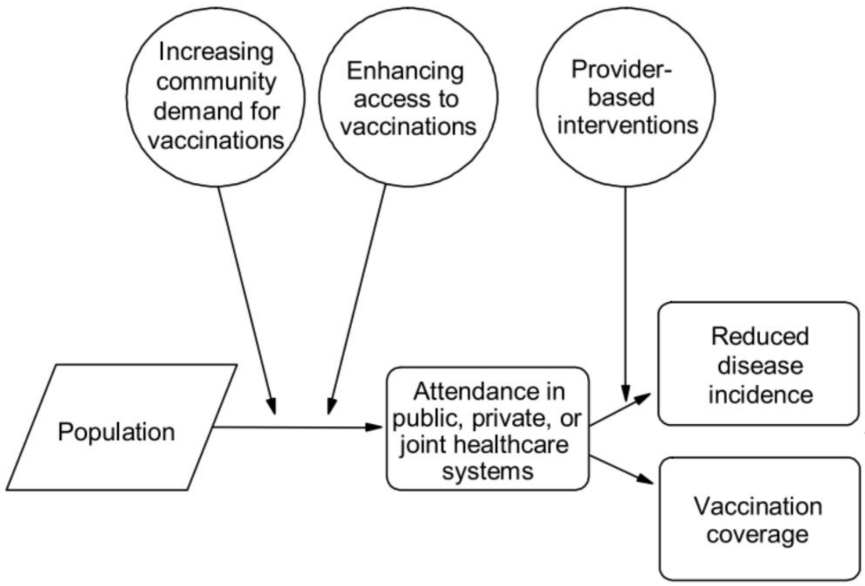


Figure A5. Application of vaccine interventions along the healthcare process. Adapted from Briss et al. (2000).