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Maastricht University

Faculty of Sciences
School for Information Technology

Master of Statistics

Master's thesis

Vaccination behaviour in Flanders: a discrete choice experiment including attitudes and risk perceptions.

Junior Ocira

Thesis presented in fulfillment of the requirements for the degree of Master of Statistics, specialization Biostatistics

SUPERVISOR :

dr. Pietro COLETTI

SUPERVISOR :

Prof. Dr. Frederik VERELST

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Transnational University Limburg is a unique collaboration of two universities in two countries: the University of Hasselt and Maastricht University.

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"Then Samuel took a stone, and set it between Mizpeh and Shen, and called the name of it Ebenezer, saying, Hitherto hath the LORD helped us" 1 Samuel 7:12

Abstract

Yearly, about 2 to 3 million deaths are averted by the use of vaccines. Despite this global achievement, since 1796, numerous concerns about vaccine effectiveness and side-effects have persisted. It is important therefore to be able to understand the vaccination behavior of different categories of people in Flanders. The objective of this study is to understand whether there exist heterogeneity in vaccination behaviors, risk perception, and vaccine related side effects misperception in Flanders. In addition we explore whether vaccination behaviors have impact on the results from discrete choice experiment

Data for this paper came from a combination of a survey and also a discrete choice experiments given to 1,919 Flemish respondents. Exploration was done by the help of graphical display, tables and univariate tests. Model based testing was done using latent class regression model to understand heterogeneity in vaccination behavior, risk perception and misperception. On the same note, a latent class model was also fitted on the data from the discrete choice experiment to understand drivers of choice between two vaccines.

Our research indicated that there exist three different vaccination behaviors in Flanders; acceptors, information searchers/reliers and self reliant (hesitant) people with different demographic characteristics. Regarding risk perception, some profiles perceived vaccines to be risky while others perceived otherwise. In addition, Flemish individuals do not misperceive vaccine related side effects. Taking unobserved heterogeneity into account gave us the flexibility to have a more broader understanding on vaccination behavior, results from discrete choice experiment and misperception of VRSE.

Keywords: *Vaccination behaviors, Vaccine related side effects (VRSE), Risk perception, Discrete choice experiment, Latent class regression models*

1 INTRODUCTION

1.1 Background

Since the first introduction of vaccine in 1796 by Edward Jenner who made the cowpox vaccine (Jenner, 1799), many lives have been saved from different diseases including measles, mumps, rubella, polio among others. World Health Organization (2016) estimates that yearly, about 2 to 3 million deaths are averted by the use of vaccines. Despite this global achievement, concerns about the side effects of vaccines have persisted since the breakthrough invention by Edward Jenner (Wolfe and Sharp 2002). This concerns and misconceptions when not addressed are likely to cause people refuse vaccination (Rosselli *et al.*, 2016).

In Belgium, the government encourages people to get vaccinated against several infectious diseases. Among all these, only polio vaccination is mandatory for everyone though there is an allowance for an exemption from polio vaccination if it can be proven that the child might have an adverse event from the polio vaccination. To add more light, Stafford (2008) documented an incident where two sets of parents in Belgium where convicted to pay about 5500 Euros and sentenced to five months in prison for refusing to have their children vaccinated against polio. This shows us clearly that even when vaccination is mandatory, there are still a section of the population who will not be willing to comply due to their own reasons.

Considering that people have got different behaviors towards vaccination initiatives, understanding the distinct vaccination behaviors is paramount. According to Leask et al. (2012), they found out from a review of several literatures that there exist five different vaccination behaviors of parents. These groups consists of people who are: unquestioning acceptors; cautious acceptors; the hesitant; Late or selective vaccinator and refusers. Different socio-demographic variables can influence an individuals' vaccination behavior. Literatures have shown that factors that affects vaccination behaviors includes: employment status (Azizi *et al.*, 2017); history of vaccination (Dubé *et al.*, 2013); religion (Ruijs *et al.*, 2012; *Pelčić et al.*, 2016). It would therefore be of much interest to understand these in the context of the Flemish population.

In their work investigating the link between perception and behavior, Ferguson and Bargh (2004) pointed out that the knowledge people get that is their perception guides and shapes their behavior. It is therefore of utmost importance to not only look at risk behavior but also vaccination risk perception. In order to understand the risk perception about vaccination and the susceptibility, the health belief model (Hochbaum, 1952) plays a very big role. The health

belief model consists of elements such as; perception about susceptibility to a disease; perception about the severity of the disease; perception of effectiveness of the vaccines and perception about the resulting side effects of using the vaccines. Modeling this four different aspects of health believe concurrently gives us the opportunity to understand what individuals perceive about vaccination and it's possible benefits or inadequacies.

Given that we know the vaccination behaviors, risk perception and misperception of side effects, it is paramount to understand whether in combination with other choice specific alternatives, these factors have an influence on what people choose and why how they choose. One better way to understand the driving force to why people make certain choices is to conduct a discrete choice experiment (Louviere and Woodworth, 1983) where choice profiles are constructed from which the participants choose from. This is advantageous because the cause and effects can be demonstrated. With discrete choice experiments (DCE), we can be able to understand the driving force towards choosing certain alternatives. In the case of vaccination where it is not possible to for example give vaccines with high side effects to see whether people will prefer it or not, discrete choice experiments helps us to explore this different good and worse scenarios. Linking the results from the DCE to socio demographic variables, vaccination behaviors, risk perception or misperception gives us an additional power in understanding vaccination behavior dynamics.

Verelst *et al.* 2018 conducted a study to understand vaccination behavior in Flanders using a discrete choice experiment. They looked at whether there exist observable preference heterogeneity based on background characteristics, vaccine attitudes and risk perceptions. Among their findings, they showed that age group and traditional media significantly interacted with vaccine related side effects (VRSE) and burden of the disease for the adult group. Meanwhile for the children group, being a vaccine acceptor was the only significant variable interacting with vaccine attributes (burden of disease).

When analyzing vaccination behaviors while taking only the observable heterogeneity into account, we make one assumption that everyone behaves in the same manner. But this necessarily might not be the case. Certain group of people with certain kind of response patterns or characteristics might be more alike than the others. Because of this, in this thesis, we extend on the work by Verelst *et al.* (2018) by taking the unobserved heterogeneity in vaccination behaviors, risk perception, misperception of vaccine related side effects (MMR vaccine) and results from the discrete choice experiment.

This Thesis is organized in the following ways. In this section, we provide introduction to the research problem, in Section 2, we describe the methodology used and in Section 3 the results of the analysis are shown. Section 4 elaborates the Discussion and Conclusion.

1.2 Research questions:

In this Thesis, our aim is to address the following questions.

- Can we identify heterogeneous vaccination behavior depending on socio-demographics or attitudes (5P-Likert scale)? How does this impact the results of a discrete choice experiment?
- Do risk perception of vaccination and infectious disease susceptibility have an impact on vaccination behavior? Can we distinguish risk profiles? Which socio-demographics are correlated with distinct profiles?
- Do Flemish individuals misperceive MMR vaccine side-effects or Measles susceptibility? How does this impact their vaccinating behavior?

1.3 Data Description

In this subsection, we provide a brief overview of the structure of the data used for this Thesis. A more general overview about the design and survey can be found in Verelst *et al.* (2018).

We used dataset coming from an interview administered to Dutch fluent Flemish individuals (N=1,919) in Flanders, Belgium during the period of February to March 2017. The sampling was done in a way such that in a household selected, only one respondent was interviewed . The respondents were divided into two groups. The first group (N=1,091) consisted of individuals with no children (herein referred to as the adult group). The second group (N=828) is made up of individuals with the youngest child at least one child under 18 years old (herein referred to as children group).

The questionnaire administered to the respondents had four different sections. The first part of the questionnaire consisted of 15 questions relating to socio-demographics of the respondents including sex, province, age, education level, occupation/profession, marital status, number of children under 18 years, age of the youngest child, mother's country of birth, whether a health worker, history of serious illness, annual flu vaccination status, smoking status, religion and frequency of attending religious services. Additional data was collected on the measles vaccination status, history of measles infection and reasons for vaccination.

The second section consisted of 13 attitudinal statements questioning the respondents' attitudes on vaccinations measured on a 5 point likert scale. For respondents in the adult group, they were asked about the extent to which they agree with statements regarding vaccinating themselves. For those in the children group, they answered how they agree with statements regarding vaccinating their youngest child. These statements are shown in the upper section of Table 1.

The questions relating to the discrete choice experiment (DCE) was presented in the third section of the questionnaire. The respondents were presented with 10 different choice sets where in each choice set, they had to choose one of the two vaccines. Each vaccine had 6 attributes where in each choice set, three attributes had varying levels while the remaining three attributes were held constant. The DCE attributes and levels is shown in Table 2.

The final part of the survey examines the respondents' risk perception towards Measles, Mumps, and Rubella (MMR) vaccine and the susceptibility to Measles for those who reported having been vaccinated. The respondents provided answers on a 5 point likert scale on the chance of them/their child to contract measles, how severe the impact of measles is on their health/their child's health, perception about the effectiveness of the MMR vaccine, perception about the chance of MMR vaccine side effects and the perception about the impact of the MMR vaccine side effects. The respondents also were presented with a number of postulated conditions as side effects. The respondents were asked to indicate which of the postulated conditions, they perceive is MMR vaccine side effects. The list of the postulated conditions is shown in Table 3.

2 METHODOLOGY

2.1 Exploratory Data Analysis

In the exploratory analysis, both graphical and non-graphical methods were used. Graphical methods like bar charts, divergent stacked bars (Robbins and Heiberger, 2011) for likert scale data were implemented. Frequency tables and cross tabulation tables were also employed in the exploratory analysis.

The presence of association between the various independent variables (vaccination attitudes questions, risk perception, mis-perception of vaccine side effects, source of information) and vaccination behavior (measured by the degree of agreement of a respondent on vaccination being a good way to protect individuals against the disease) was analyzed using chi-square/fisher's exact tests at 0.05 level of significance. The expected value for each category combination (cell) was checked if it was less than 5. If at least one cell has expected value less than 5, we used fisher exact test.

2.1.1 Measuring the reliability of the questions relating to vaccination behavior, mis-perception and risk perception

Since we are interested in responses that are not straightforwardly measured by one variable, but can be measured by several different questions, the reliability of these questions is very important. If an instrument (set of questions) can measure the latent construct consistently, then we refer to it as being a reliable instrument. Therefore in order to measure reliability, we used Cronbach's alpha (Cronbach, 1951).

This Cronbach's alpha measures how the different questions measuring a certain latent constructs are related to each other. This value ranges from 0 to 1 with 1 showing that the items are perfectly correlated to each other meanwhile a zero Cronbach's alpha indicates that the items are not related to each other. Cronbach's alpha can be defined as;

$$\alpha = \frac{K\bar{c}}{\bar{\nu} + (K-1)\bar{c}} \tag{1}$$

where K is the number of items (questions measuring the vaccination behavior or risk perception or mis-perceptions), $\bar{c}$ is the average inter-item covariance and $\bar{\nu}$ is the average variance.

As seen in Equation 1, items with high intercorrelations results to high Cronbach's alpha hence Cronbach's alpha measures internal consistency. The cut off for good reliability using Cronbach's

alpha is not clear. There are literatures that suggest a cut off of 0.7 is acceptable (DeVellis, 2012; Kline, 2000). However some do recommend a cutoff of 0.6 to be acceptable (Moss *et al.* 1998; Hair *et al.* 2006). In this study, we will consider a cut-off of 0.6 to be acceptable.

2.2 Handling heterogeneity using latent class regression model

When modeling human behaviors, perceptions or attitudes, the concept of heterogeneity is very important. This concept of heterogeneity points out that in a population, people behave differently depending on their socio-demographics or other observable characteristics (independent variables) and more interestingly, factors that can not be measured or observed by the researcher.

There are several ways of modeling heterogeneity in a population. One can assume that every individual in the population behaves in a different way from each other hence assuming a continuous underlying latent distribution (using mixed model). Secondly, one could use cluster analysis that is an unsupervised statistical learning technique. This technique does not specify the response variables but uses all the observed variables (both independent and dependent variables) to identify groups of similar individuals in the dataset. However according to James *et al.* (2013), clustering methods are not robust enough to handle presence of outlying observations or perturbations to the data (that is when a sample of data is removed from the data, it alters the clusters) hence recommending the use of mixture models. This approach of mixture models assumes that within the population, there are subgroups of individuals who tend to behave in a similar manner but completely different from other subgroups' behavior (McLachlan and Peel, 2000). In our case, where we focus on vaccination behaviors, risk perceptions and misperception, it is more appropriate to adopt the mixture modeling approach as we will be taking a model based approach to clustering and in addition, the results can be more useful when it comes in taking policy formulations and interventions towards specific groups of people.

Since we are modeling behaviors or perceptions which can not be measured using a single response variable, but several different response variables, we implement Latent class regression approach which is the mixture of multivariate categorical outcomes. This model is also referred to as Latent structure analysis and was pioneered by (Lazarsfeld, 1950, Lazarsfeld and Henry, 1968) with the aim of identifying unseen homogeneous groups of individuals with multivariate categorical responses. The basic latent class model can be extended to incorporate independent variables in predicting the latent class an individual belongs to (Dayton and Macready 1988). With this model, one is able to estimate the important attributes of each latent group that

distinguishes them from other groups and also the probability of an individual to belong to each group.

2.2.1 Latent Class Regression Model

An important assumption made in Latent Class Modeling is the "conditional" or "local" independence assumption. This assumption is that within each latent group, the response variables are statistically independent of each other (Coway, 1998). This assumption however can be violated when the individuals take into account the answers of some response variables to answer other response variables measuring the same latent construct. Nevertheless, the presence of local independence can be solved by increasing the number of latent classes as in the end respondents who tend to be consistent in their responses can be grouped together (Oberski, 2016). The challenge of this, however, is that it can result into a higher number of classes which might not be easily interpretable.

In this analysis, we adopt the model specification implemented by (Dayton and Macready, 1988; Linzer and Lewis, 2011). We start by specifying a latent class model with no covariates.
Assume J ($j = 1, 2, ..., J$) polytomous(or dichotomous) categorical response variables each with K ($k = 1, .., K$) outcome levels were observed for i individuals (i = 1,2,...,N) belonging to R unobserved classes (r=1,2,...,R). A more general latent class model can be defined as (Dayton 1988);

$$f(Y_i; \pi_r) = \prod_{j=1}^{J} \prod_{k=1}^{K} (\pi_{jrk})^{Y_{ijk}} \tag{2}$$

Where: $f(Y_i; \pi_r)$ is the product of the probability for the i^{th} individual belonging to the r^{th} class producing a set of J outcomes on the response variables while making the assumption of conditional independence of the outcomes Y given the latent class they belong to.
π_{jrk} is the probability of observing the k^{th} outcome level of the j^{th} response variable given that the observation belongs to the r^{th} class. Therefore in every r^{th} class, for each of the response variable j, $\sum_{k=1}^{K} \pi_{jrk} = 1$.
Y_{ijk} is the observed k^{th} response level on the j^{th} response variable for the i^{th} individual. These means that $Y_{ijk} = 1$ if the i^{th} individual produces the k^{th} response level to the j^{th} response variable, and $Y_{ijk} = 0$ otherwise.
Assuming the proportion of each of the latent class in the population r (prior probabilities of a latent class) are $p_1, p_2, ..., p_R$ and restricted to sum to 1 ($\sum_r p_r = 1$), this leads to the probability

density function for all latent classes to be weighted sum shown by

$$P(Y_i|\pi, p) = \sum_{r=1}^{R} p_r \prod_{j=1}^{J} \prod_{k=1}^{K} (\pi_{jrk})^{Y_{ijk}} \tag{3}$$

This probability density function is used to estimate the class probabilities (p_r) and the probability of observing the k^{th} response level of the j^{th} response variable given that the observation belongs to the r^{th} class (π_{jrk}) by the means of maximum likelihood. Meanwhile, in order to allocate each individual to each of the latent class, the expectation maximization algorithm is used (Dempster, Laird, and Rubin 1977) where the underlying classes are considered as missing data.

An extension of the latent class model can be made by the inclusion of covariates in the model resulting in latent class regression models. These covariates can be included in the latent class model in two ways; either by affecting the distribution of the latent classes or affecting the observed responses. In this analysis, we choose the inclusion of covariates to directly affect class membership in order to be able to understand which covariates have an effect on belonging to a particular class. Dayton and Macready (1988) provided a methodology that aids the inclusion of the covariates in the prediction of the class an individual can belong to where the independent variables are estimated concurrently with p_r and π_{jrk}.

Restricting for every individual, the class probability to one ($\sum_r p_{ri} = 1$), the prior probabilities are related to the covariates through a multinomial logit link function (Agresti, 2002). Assuming there are M covariates ($X_{1i}, X_{2i}, ..., X_{Mi}$) for each individual i and β_r is the r^{th} latent class coefficient vector. Fixing the first latent class to be the reference class, the prior probabilities for an individual i to belong to class r is;

$$p_{ri} = p(R_i = r|X_i = x) = \frac{e^{\beta_{0r} + \sum_{m=1}^{M} \beta_{mr} x_{mi}}}{1 + \sum_{p=1}^{R-1} e^{\beta_{0p} + \sum_{m=1}^{M} \beta_{mp} x_{mi}}} \qquad r = 1, 2, .., R-1 \tag{4}$$

Where β_{0r} is the class specific constant, β_{mr} are the unknown parameters. Taking the first latent class as baseline, these can also be written as

$$log \frac{p_{ri}}{p_{1i}} = \beta_{0r} + \sum_{m=1}^{M} \beta_{mr} x_{mi} \tag{5}$$

The exponent of the regression estimates β_{mr} can be interpreted as the odds of observing a

change in odds for success for the category of interest as compared to the reference category of the variable in the r^{th} latent class compared to the first latent class.

From these equations, β_r and π_{jrk} estimates are then used to obtain the posterior probabilities to belong to a latent class by replacing p_r with $p_r(X_i, \beta)$.

$$\hat{P}(r_i|X_i; Y_i) = \frac{p_r(X_i; \hat{\beta}) f(Y_i; \hat{\pi}_r)}{\sum_{q=1}^{R} p_q(X_i; \hat{\beta}) f(Y_i; \hat{\pi}_q)} \tag{6}$$

$f(Y_i; \hat{\pi}_r)$ is the mixture components or classes

The estimates of the latent class model is got by maximizing the log-likelihood function of

$$lnL = \sum_{i=1}^{N} ln \sum_{r=1}^{R} p_r(X_{mi}; Y_i) \prod_{j=1}^{J} \prod_{k=1}^{K} (\pi_{jrk})^{Y_{ijk}} \tag{7}$$

Since the number of latent classes are not known a priori, information criterion was used to determine the optimal number of classes. Among the various information criterion, (McLachlan and Peel 2000) pointed out that the number of classes tends to be overestimated when one uses AIC. Lin and Dayton (1997), Forster (2000) postulated that BIC tends to be more simple and more appropriate for latent class models. In addition, Dillon (2010) noted that as the sample size increases, the probability of BIC or AIC to identify the correct number of underlying latent groups converges to one. In a simulation study to determine the ability of the different information criterion techniques to identify correctly the number of latent classes among the different information criterion by Nylund *et al.* (2007), BIC outperformed other information criterion. Therefore in this analysis, we use the BIC statistic to determine the total number of underlying classes in the model.

2.3 Heterogeneity in Vaccination behavior

In this study, vaccination behavior was measured by 13 questions on a 5 point likert scale from Totally Agree to Totally disagree (See Table 1). In order to have a more reduced level of the response variables, the 5 point likert scale was recoded to a 3 level with Totally Agree and Agree merged to one level (Agree), Totally Disagree and Disagree merged to one level (Disagree) and then the third level being Neutral.

Table 1: *Attitude questions used to measure vaccination behavior*

Item 1: A good way to protect against disease	Item 7: If others vaccinate, I also
Item 2: Acceptable in family/friends	Item 8: I make my own decision
Item 3: Weigh vaccine Pros and Cons before making decision	Item 9: Doctor's opinion important
Item 4: I don't ask Questions, I just do	Item 10: Experiences shows side effects
Item 5: Articles/books informs me	Item 11: Society expects me
Item 6: Vaccine generally accepted	Item 12: Decision influenced by others
	Item 13: Internet source of information
Independent Variables	Independent Variables
Age group (Four Levels)	Sex (Two Levels)
Province (7 levels)	Education Level (4 levels)
Employment Status (2 levels)	Marital Status (3 levels)
Annual flu vaccination status (3 levels)	Number of Children (5 levels)
History of measles infection (3 levels)	Mother's country of birth (2 levels)
Health Worker (2 levels)	Smoking Status (2 levels)
Religion (10 levels)	Frequency of attending religious service (4 levels)

In order to understand the heterogeneous vaccination behavior based on socio-demographics, latent class regression models explained in Section 2.2.1 was implemented using the covariates shown in Table 1. Since we did not know a priori from literature the possible number of underlying vaccination behavior, three different latent class regression models (with number of classes R being 2, 3 and 4) were fitted assuming linear functional form of the covariates. The model with the lowest BIC was considered the best model for further interpretation. The covariates that were used in the analysis were;

2.3.1 Understanding impact of Socio-demographics and Vaccination behavior on discrete choice experiment results

A discrete choice experiment was carried out where the respondents were given two different vaccines to choose from (Vaccine A and Vaccine B). Every individual had 20 different choice situations to make decision from. This gives rise to panel data as each individual has repeated choices taken. Though it is a strong assumption, it is still assumed that this different choice situations are independent. Each vaccine had a varying levels of attributes as shown in Table 2.

Table 2: *Discrete Choice Experiment Vaccine attributes and levels*

Attributes	Level Description
1. Vaccine effectiveness	a) Protects 50% of vaccinated
	b) Protects 90% of vaccinated
2. Burden of disease	a) The disease against which the vaccine protects is rare and often mild"
	b) The disease against which the vaccine protects is rare and often severe"
	c) The disease against which the vaccine protects is common and often mild"
	d) The disease against which the vaccine protects is common and often severe"
3. VRSE (Vaccine Related Side Effects)	a) Side-effects are common
	b) Side-effects are rare
4. Accessibility	a) The vaccine is provided for free and available at the vaccinator
	b) The vaccine is not reimbursed and is only available with a prescription
5. Local coverage	a) 30% of your acquaintances (friends and family is already vaccinated
	b) 60% of your acquaintances (friends and family is already vaccinated
	c) 90% of your acquaintances (friends and family is already vaccinated
6. Population coverage	a) 30% of the population in general is already vaccinated
	b) 60% of the population in general is already vaccinated
	c) 90% of the population in general is already vaccinated

Using the socio demographic variables shown in Table 1, we fitted a latent choice regression model for the discrete choice experiment data. The specification of this model does not differ much from the specification in Section 2.3. We follow the specification provided in Greene and Hensher (2003). The underlying principal in this latent class model is the logit model describing the choice between J_i alternatives for every i^{th} individual for the choice situation T_i. The probability of an individual i taking the j^{th} alternative in choice situation t given that they belong to r^{th} class ($Prob(y_{it} = j|class = r)$) is;

$$Prob(y_{it} = j|class = r) = P_{it}|r = \frac{exp(X_{it}^{'}\beta_r)}{\sum_{j=1}^{J_i} exp(X_{it}^{'}\beta_r)} \tag{8}$$

where $J = 1, 2$ that is Vaccine A and Vaccine B, $T = 1, .., 10$. (every individual had 10 choice situations).

To be able to assign an individual i in a respective latent group, the posterior probability H_{ir} takes the form of a multinomial logit shown as;

$$H_{ir} = \frac{exp(X_{i}^{'}\beta_r)}{\sum_{r=1}^{R} exp(X_{i}^{'}\beta_r)} \qquad q = 1, .., Q, \beta_Q = 0, \tag{9}$$

Where X_i is the covariates, $\theta_Q = 0$ because of normalization.

To get the likelihood for the i^{th} individual, we take the expectation of the contribution made by each class. $P_i = \sum_{r=1}^{R} H_{iq} Prob(y_{it} = j|class = r)$

Our likelihood function is;

$$lnL = \sum_{i=1}^{N} lnP_i = \sum_{i=1}^{N} ln \left[\sum_{r=1}^{R} H_{ir} \left(\prod_{t=1}^{T_i} P_{it|r} \right) \right] \tag{10}$$

This likelihood function is then maximized with respect to R. More information can be got from Greene and Hensher (2003), Greene (2001) More about the parameter estimation and The parameter estimation

We also checked whether VRSE misperception, risk perception and infectious disease susceptibility have an impact on the vaccination behavior. To measure the vaccination behavior, after fitting the latent class regression model in Section 2.3, the underlying latent groups determined were used as a describer for vaccination behavior and therefore we check any relation between class membership and the risk perception and infectious disease susceptibility using Equation 5 where x_{mi} are the VRSE misperception or risk perception or infectious disease susceptibility, p_{ri} is the probability to belong to the r^{th} latent class, p_{1i} is the reference group.

2.4 Risk Perception about vaccination and infectious disease susceptibility

In order to understand the risk perception about vaccination and the susceptibility, the health believe model (Hochbaum, 1952) plays a very big role. The health believe model consists of elements such as; perception about susceptibility to a disease, perception about the severity of the disease, perception of effectiveness of the vaccines and perception about the resulting side effects. Modeling this four different aspects of health believe concurrently gives us the opportunity to understand what individuals perceive about vaccination and it's possible benefits or inadequacies.

Every respondent (whether answering the questions on behalf of their child or for themselves) was asked to rate a number of questions regarding different diseases (Influenza, Leukemia, Cystitis, Measles) but our focus will be on measles related questions. The questions asked were; the perceived chance of contracting measles, the severity of measles on themselves or their children, their perception about measle vaccine effectiveness, perceived chance of vaccine side effects and the severity of the vaccine side effects. These questions were further used as the vector of the response variables in the latent class regression model.

Latent class regression model described in subsection 2.2.1 was used to better understand the presence of some underlying groups that might have distinct profiles concerning perception about risk and susceptibility. Using this model, we are able to know which socio-demographic

characteristics (See Table 1) are significantly different between the various latent groups.

2.5 Mis-perception of MMR Vaccine side effects or Measles Susceptibility

The questionnaires given to the respondents had a section that asked the respondents which of the postulated side-effects they thought were the potential side-effects of vaccination. There were in total twelve side effects provided with a yes or no response to whether they are potential side effects. Among these side-effects, only six were true side effects of vaccination (See Table 3). An individual who indicated that a condition was a vaccine side effect when it was truly a vaccine side-effects or an individual who indicated that a condition was not a side effect when truly its not a side effect were considered as having true perception about vaccination side-effects. For those who indicated that a potential condition was a vaccine side-effect when its not a true vaccine side-effects or those who indicated a true vaccination side-effects as not being a potential side effect were considered as those who misperceived the vaccination side effects. We show which potential conditions are true vaccine side-effects in Table 3.

Table 3: *Table showing the postulated conditions presented to respondents and whether they are true vaccination side effects*

Side effects	Vaccination side effect?	Side effects	Vaccination Side effect?
Fever	Yes	Blue spot at injection site	Yes
Injection site Swelling,pain	Yes	Diarhoea	Yes
Death	No	Autism	No
Chronic fatigue	No	Nasal Congestion, sore throat, URTI	Yes
Skin rash	Yes	Infertility	No
Overloaded Immune System (OIS)	No	Allergic reaction	No

Since mis-perception of side-effects can not be measured with only one variable but all the twelve variables, we end up in a multivariate binary response problem. In addition, because of the interest in understanding the presence of heterogeneity concerning mis-perception of vaccine side-effects, we use latent class regression models. We use the model specification described in Section 2.2 to model vaccine side-effects mis-perception. Using BIC, we compare models with different number of latent classes (2, 3, 4) and select the one with the lowest BIC.

3 RESULTS

The methodology described in the previous chapter was implemented in providing answers to the different objectives of this study. We organize this section in such a way that exploratory analysis is presented in Sub-section 3.1, heterogeneity in vaccination behavior results is shown in Section 3.2. In Sub-section 3.3, we show the results for risk perception about vaccination and infectious disease susceptibility. Finally mis-perceptions of vaccine related side-effects is covered in Sub-section 3.4.

3.1 Exploratory Data Analysis

In this sub-section, we provide a detailed scrutiny of the data collected on the different variables through the use of summary statistics, graphical displays and univariate statistical tests.

3.1.1 Socio-demographic characteristics of respondents

Table 4: *Summary Statistics of Survey respondents with respective Belgium national statistics; (*married include those living together but not married)*

Variable	Total	Survey Percentage	National Percentage	Variable	Total	Survey Percentage	National Percentage
Gender				**Age group**			
Female	937	48.8	51	18-34	536	27.93	26
Male	982	51.2	49	35-49	581	30.28	25
Province				50-64	411	21.42	26
Antwerpen	579	30.17	28	65-85	391	20.37	22
Brussels	31	1.61		**Employment Status**			
East Flanders	447	23.29	23	Employed	1055	54.98	
West Flanders	320	16.68	18	Unemployed	864	45.02	
Flemish Brabant	255	13.29	17	**Marital Status**			
Limburg	268	13.97	13	Single	562	29.29	
Others	19	0.99		Married*	1274	66.39	
Education Level				Others	83	4.32	
Low	83	4.33	25	**Number of Children**			
Medium	943	49.14	41	None	1080	56.28	
High	879	45.80	34	One	405	21.10	
Others	14	0.73		Two	297	15.48	
Annual Vaccination against flu				Three	104	5.42	
Never	1038	54.09		> Three	33	1.72	
Sometimes	358	18.66		**Past Measles infection: Adult group**			
Usually	523	27.25		Infected	87	37.02	
Adult's Vaccination status against measles				Not Infected	74	31.49	
Yes	197	83.83		No Idea	74	31.49	
No	38	16.17		**Past Measles infection: Child group**			
Child's vaccination status against measles				Infected	170	20.53	
Yes	727	87.80		Not Infected	618	74.64	
No	101	12.20		No Idea	40	4.83	

In this report, the data coming from 1,919 respondents was analyzed of which 1,091 respondents answered the questionnaire concerning themselves while 828 people answered some sections of the questionnaire regarding decisions on behalf of their youngest child, though their socio-demographics characteristics and other variables were collected. As shown in Table 4, 48.8% of the respondents were female which is approximate to the Belgian national statistics of 51%. The distribution of the respondents across the provinces in Flanders are also closely approximating the national statistics. Out of all respondents, 30.2% of respondents came from the province of Antwerp. About 1% were from other provinces outside Flanders (Wallonia). These were individuals that filled out an unclear postal code, or were Flemish individuals living in Brussels or in Walloon parts close to the border. All the respondents indicated they were fluent in Dutch before they got assigned to the survey.

Though about 83% of the Adult's seems to be vaccinated against measles, about 54% indicated that they never get annual flu vaccine. About 31% of the adult's indicated never infected with measles compared to the 74% of children below 18 years who were never infected by measles.A Summary of a handful of variables (though not all) in Table 4 seems to show that the survey samples are representative for the Flemish population.

3.1.2 Respondents Attitudes towards Vaccination

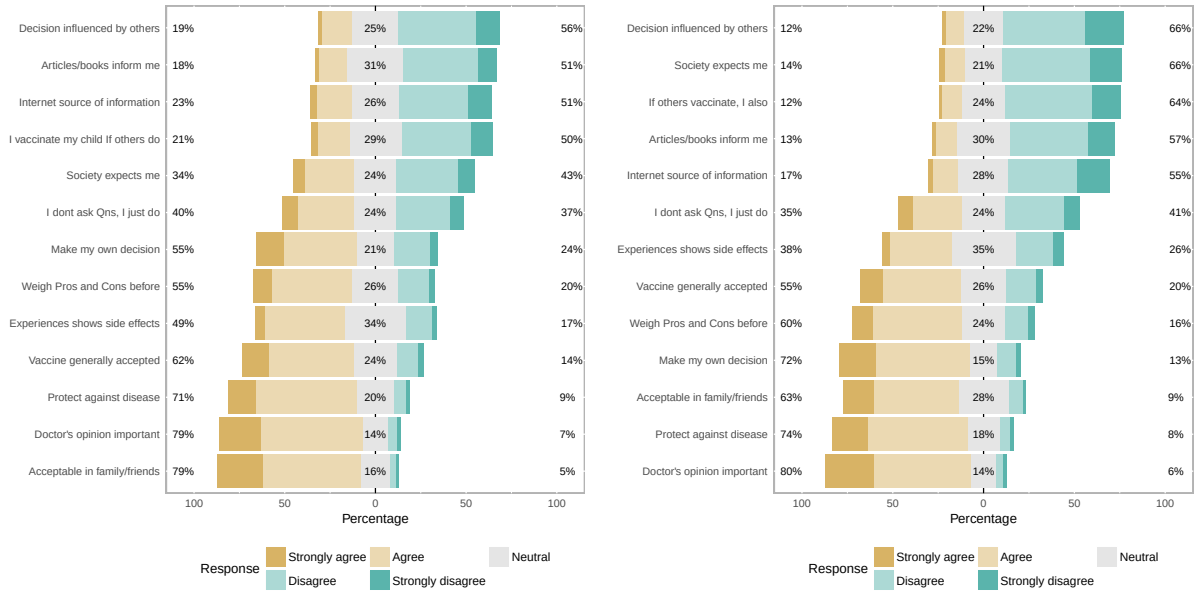

Figure 1: *Left: Attitudes towards vaccinating a child. Right: Attitude towards vaccination of adults.*

We explored respondents attitudes towards vaccinating their child or themselves measured by 13 different 5 point likert scale attitude questions. Left of Figure 1 shows the respondents opinion towards vaccinating their youngest child below 18 years. This illustration suggests that, 19% had their decision influenced by others (friends, acquaintances, colleagues and family), articles/books influenced decision for 18% while 21% vaccinates their children if other parents vaccinates theirs. However, 71% of the respondents agree to making decisions about vaccinating their youngest child based on the fact that vaccines protects individuals against diseases. About 79% considered doctor's opinion about vaccination and acceptability of vaccination by their family and friends as influencing their decision to vaccinate their children. For adults, the right panel of Figure 1 shows that the decision regarding vaccination for 12% of adults are influenced by others, 13% being influenced by articles/books while 14% vaccinates because society expects them to vaccinate. About 72% makes their own decision to vaccinate, 74% vaccinate because it protects others against diseases while 80% considers doctors opinion about vaccination important.

3.1.3 Chance of contracting and Impact of various diseases

The respondents were asked to rate their perception about their susceptibility and impact of various diseases on their health.

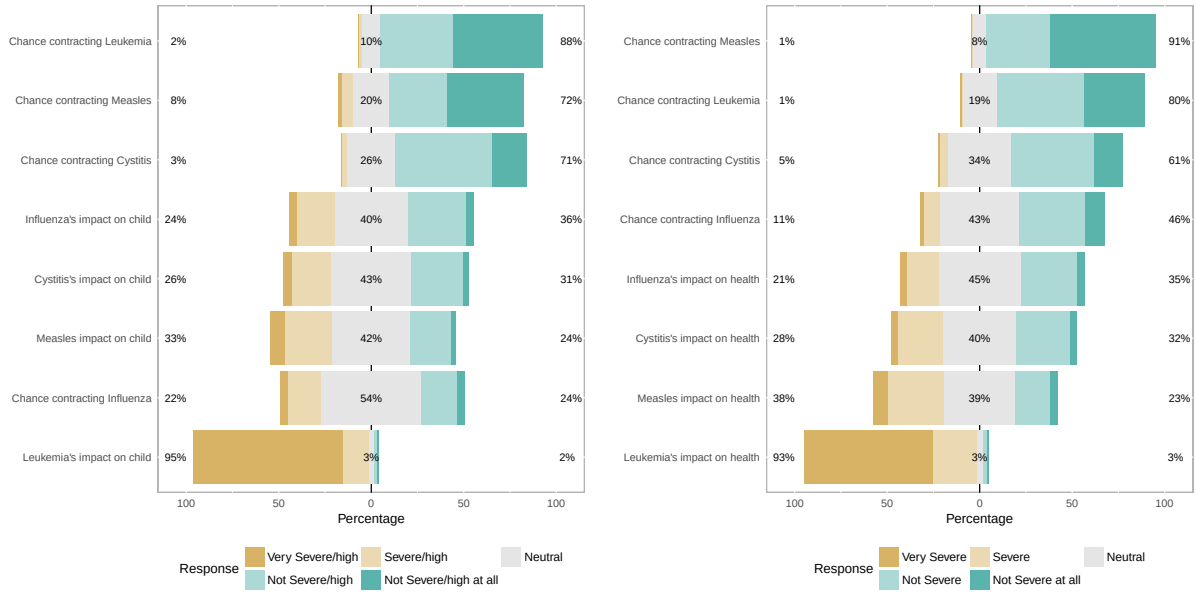

Figure 2: *Left: Chance of children to contract diseases and the impact on their health. Right: Chance of adults to contract diseases and the impact on their health*

In the left panel of Figure 2, the respondent's perceptions about the chance of their child contracting Influenza, Leukemia, Cystitis, Measles and also the impact on the health status of

their youngest child is shown. The results suggests that about 88% of the respondents thinks there is a small chance of their child contracting leukemia while 72% perceive a lower chance of their child contracting measles and 71% perceiving a lower chance of contracting cystitis. However about 54% of the respondents are not sure whether their children have a high or low chance of contracting influenza. An overwhelming 95% perceive a severe impact of leukemia on their child while about 22% thinks the impact of measles is severe on their child. A similar distribution of perception is also witnessed among the adults (right panel of Figure 2). Even if 91% perceives a lower chance of contracting measles, about 38% perceive the impact of measles on their health to be severe .

3.1.4 Important Reasons for getting vaccinated

The respondents were asked to rate from 1 to 7 (with 1 the main reason and 7 the least important reason) what were the most important reasons they considered for vaccinating themselves or their children against measles.

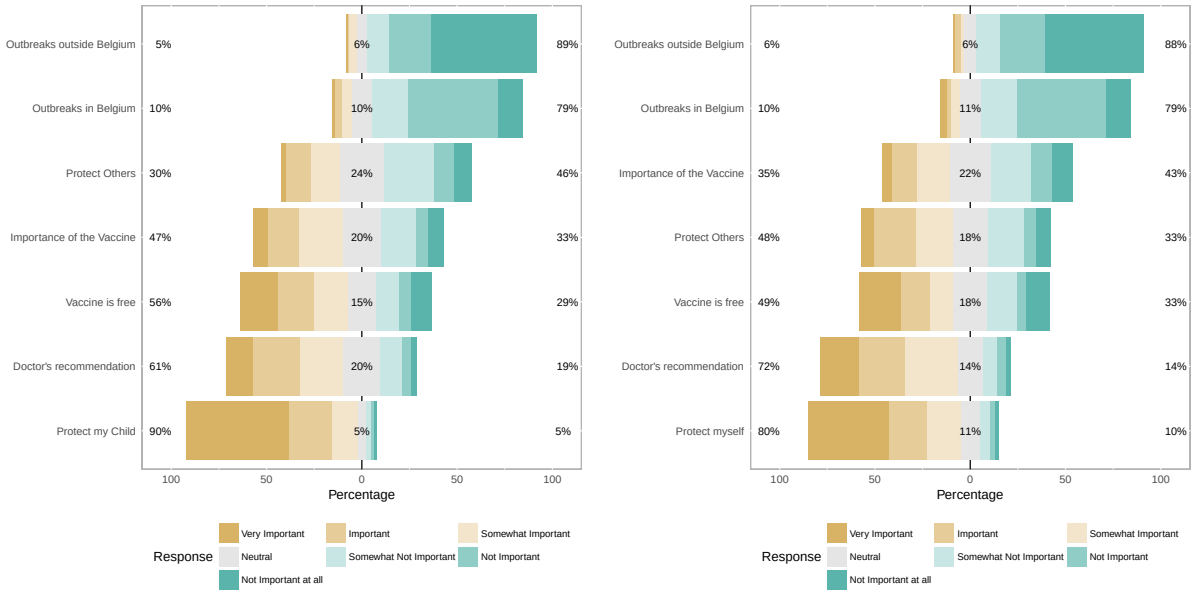

Figure 3: *Left: Reasons for Vaccinating Children. Right:Adult's reasons for getting vaccinated*

In the case of vaccinating a child,left panel of Figure 3 shows that parents tend to think that outbreaks in other countries outside Belgium and within Belgium are not important reasons to vaccinate (89% and 79% respectively). However 61% and 90% of parents indicates that doctors' recommendation and the knowledge that vaccine protects their child against measles were the important reason for vaccinating a child. In addition 56% considers vaccination being free as an important reason. This same reasons for vaccinating did not differ from the reasons of adults

getting themselves vaccinated as shown in right panel of Figure 3. This might suggest that there seems to be no difference when it comes to reasons for getting vaccinated for both children and adults.

3.1.5 Risk Perceptions on vaccination

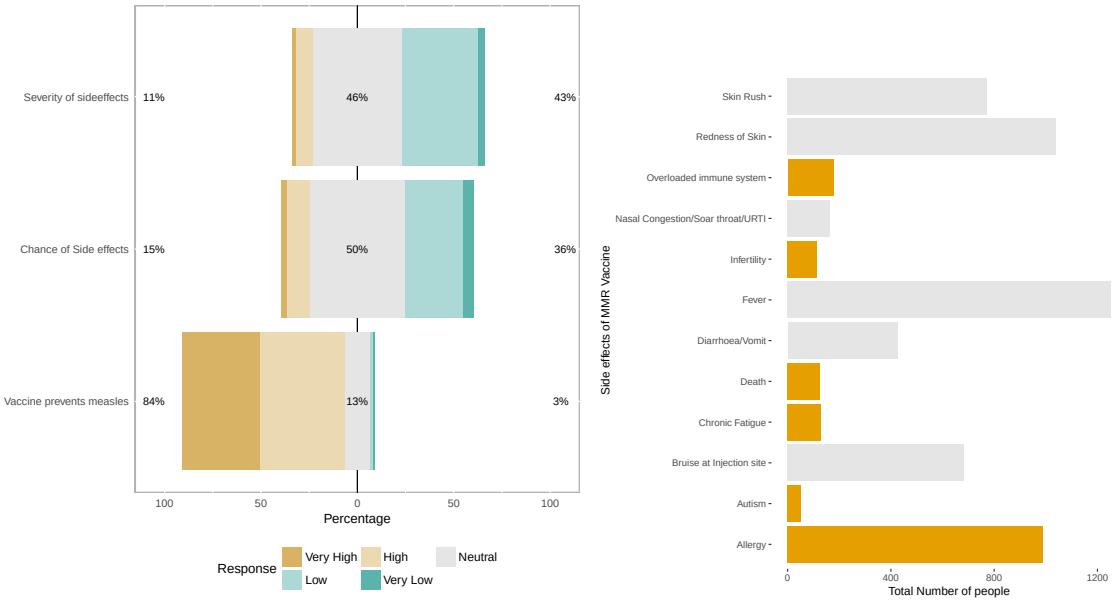

Figure 4: *Left: Perceptions on Vaccine effectiveness, Side-effects occurrence and severity. Right panel: Respondent's Perception of Side-effects of MMR vaccine (Grey color correct side-effects and orange misperceived side-effects)*

For adults less than 33 years with no child or other adults with at least one child less than 18 years, they were asked about their perception on the vaccine effectiveness, vaccine side-effects and the severity of the side effects. In the left panel of Figure 4, 84% of the respondents think that the vaccine given prevents measles, though 15% estimates a high chance of side-effects and 50% are neutral concerning chance of side-effects. In addition 11% of the respondents think that there is a high chance of getting severe side-effects after vaccination meanwhile 46% are neutral.

In Table 5, we show the summary of the respondents' perception to questions concerning measles susceptibility, severity and measles vaccine related side effects for both children group and adult group. Considering measles susceptibility, only 3% of adults perceive that they have a high susceptibility to measles meanwhile about 8% of parents who responded on behalf of their children (children's group) perceive that their children are highly susceptible to measles. It can be seen that in both group tend to perceive that the severity of measles and chance of getting

VRSE is moderate. Above 80% of people in both group thinks measles vaccines are highly effective. Meanwhile 7.2% and 11.7% in the adult and children group respectively perceives that vaccine related side effects are severe on their health or their children's health. In all these five elements, respondents seems to suggest that their children are more susceptible and slightly have a higher risk of VRSE.

Table 5: *Summary of respondents perception about measles susceptibility, severity and measles vaccine related side effects for the child and adult group*

	Adult Group				Children's Group			
Perception	Low (%)	Moderate (%)	High (%)	Total	Low (%)	Moderate (%)	High (%)	Total
Measles Susceptibility	83.40	13.61	2.98	235	72.10	20.05	7.85	828
Measles Severity	24.26	45.532	30.21	235	24.40	42.27	33.33	828
Vaccine Effectiveness	3.40	14.47	82.13	235	2.30	12.68	85.02	828
Chance of VRSE	30.21	55.32	14.47	235	37.32	47.95	14.73	828
Severity of VRSE	39.58	53.19	7.23	235	43.84	44.44	11.72	828

3.1.6 Mis-perception of MMR vaccine side-effects

All respondents (1919) were asked the possible side effects of MMR vaccines. In the right panel of Figure 4, the different side-effects as perceived by people in Flanders are shown with the orange color representing the misperceived side-effects. The top five side-effects of MMR vaccine perceived by respondents were; Fever (65%), Redness, pain and/or swelling at the injection site (54.1%), Allergic reaction (51.5%), Skin rash (40.2%) and blue spot at the injection site (35.6%). However, the 51.5% of respondents misperceived that allergic reaction was a vaccine side-effect. In addition, 6.6% and 6% also misperceived that death and infertility respectively are side effects of the MMR vaccine.

3.1.7 Testing for association between variables and vaccination behavior

Table 6: *Univariate Chi-square/fisher's exact test on vaccination behavior (measured by the degree of agreement of a respondent on vaccination being a good way to protect individuals against the disease)*

Variables	P-Value (Adult;Child)	Variables	P-Value (Adult;Child)
Socio-Demographics factors		Attitudes towards Vaccination	
Gender	0.1870; 0.6699	Acceptable in family/friends	0.0000; 0.0005
Age group	0.0056; —		
Province	0.6117; 0.7351	Weigh Pros and Cons before	0.0001; 0.0093
Education level	0.6012; 0.4303	I don't ask Qns, I just do	0.0000; 0.0000
Employment Status	0.02517; 0.3527	Articles/books informs me	0.0000; 0.0170
Family Situation	0.0730; 0.0074	Vaccine generally accepted	0.0000; 0.0000
Number Children	1; 0.7226	If others vaccinate, I also	0.0003; 0.0893
Mother's origin	0.6981; 0.4623	Make my own decision	0.0140; 0.0893
Health worker or not	0.2917; 0.1891	Doctor's opinion important	0.0000; 0.0000
History of serious illness	0.0623; 0.0207	Experiences shows side effects	0.0001; 0.0000
Annual flue vaccination	0.0000; 0.0011	Society expects me	0.0000; 0.3457
Smoking Status	0.8699; 0.171	Decision influenced by others	0.0042; 0.0017
Religion	0.0881; 0.5827	Internet source of information	0.5204; 0.1779
Frequency of religous service	0.0896; 0.8011		
Risk Perception about different diseases			
Flue Impact	0.0022; 0.2831	Flue infection chance	0.4442; 0.5481
Leukemia Impact	0.0050; 0.0005	Leukemia Infection chance	0.5192; 0.0415
Cystitis Impact	0.3889; 0.0429	Cystitis Infection chance	0.2354; 0.0065
Measles Impact	0.02451; 0.0595	Measles Infection chance	0.7856; 0.0809
Sources of Information About Infectious Diseases			
Social Media (SM)	0.4922; 0.3053	Friends/Family	0.7427; 0.9449
Traditional Media	0.2584; 0.1455	My Physician	0.0568; 0.2590
The Internet (not SM)	0.8409; 0.1650		

From Table 6, the test for the association between the various covariates and vaccination behavior were tested. The univariate test suggested that among the socio-demographic variables, only age group, employment status, and whether someone received annual flue vaccination (p-value 0.0056, 0.0252, $< 10^{-4}$ respectively) were associated with looking at vaccination as a good way of protecting individuals against the disease. Other variables with significant association were the respondents' perception about the impact of flu (p-value 0.0022) and measles (p-value 0.0245) on their health. Among the questions asked concerning attitudes towards vaccination, only using Internet as a source of information about vaccinations was insignificant (p-value 0.5204).

Concerning the behavior of parents towards vaccinating their youngest child ($< 18yrs$), the

following variables had a significant association with vaccination behavior; whether someone is single with children or living together (married or not) with children (p-value 0.0074), history of serious illness of the respondents (p-value 0.0207), whether someone receives annual flu vaccination (p-value 0.0011), parents' perception about the impact of their child getting infected with leukemia (p-value 0.005), the chance of their children getting infected with leukemia or cystitis (p-value 0.0415, 0.0065 respectively). Among the parent's attitude towards vaccination variables, vaccinating your child because others vaccinated theirs, a parent making his/her own decision irrespective of government's recommendation, vaccinating because society expects them to do so and using the Internet as the source of information about vaccinations were not significantly associated with the tendency for parents to vaccinate their children as a good way to protect individuals against the disease.

It should however be noted that this independent chi-square tests can not be relied on since they don't take possible confounding variables into account in their significance estimation. Therefore formal modeling offers a better choice.

3.1.8 Reliability of Vaccination Behavior

Cronbach's Alpha was used to check for the internal consistency of data across responses to items measuring the vaccination behavior of each individual. This was possible because Cronbach's alpha measures the proportion of variance attributable to a common source. In Table 7, the Cronbach's alpha was calculated for the questions measuring vaccination behavior of both respondents in children's group and adult's group.

Table 7: *Cronbach's Alpha values for items measuring vaccination behavior in Children group and Adult group when the i^{th} item is deleted*

Items	Cronbach's Alpha if Item Deleted (Children)	Cronbach's Alpha if Item Deleted (Adults)
Item 1: A good way to protect against disease	0.577	0.685
Item 2: Acceptable in family/friends	0.581	0.679
Item 3: Weigh vaccine Pros and Cons before making decision	0.617	0.722
Item 4: I don't ask Qns, I just do	0.585	0.683
Item 5: Articles/books informs me	0.586	0.684
Item 6: Vaccine generally accepted	0.572	0.670
Item 7: If others vaccinate, I also	0.561	0.672
Item 8: I make my own decision	0.648	0.738
Item 9: Doctor's opinion important	0.582	0.693
Item 10: Experiences shows side effects	0.567	0.693
Item 11: Society expects me	0.588	0.684
Item 12: Decision influenced by others	0.567	0.687
Item 13: Internet source of information	0.588	0.700

For adult respondents, when all the 13 items questioning the vaccination behavior of an indi-

vidual's reliability was tested, it resulted to a Cronbach's alpha of 0.709 that already meets the rule of thumb. Checking on the Cronbach's alpha if each item is deleted indicated that deleting item Q16˙8 (I make my own decision about vaccination) resulted to the highest increase in Cronbach's alpha of 0.738. Since this was not a big improvement in the Cronbach's alpha score and the fact that this is an important question, we decided not to delete further any item from among the 13 attitude questions and therefore use it as a measure of vaccination behavior in Adults.

A similar scenario was also shown for the children's group respondents with the Cronbach's alpha of 0.606 for 13 items. This according to literature already indicates good reliability. After deleting item Q16˙3 (Weighing advantages and disadvantages of vaccine before vaccination), Cronbach's alpha increased to 0.617 which is not a big improvement so we do not delete any question further.

Since the attitudinal questions toward vaccination were measuring three different aspects of attitudes that is acceptors to vaccination, those actively searching for information and reliers (those who rely on other people's decision or information), the 13 questions were sub-divided into these different categories and the respective chronbach's alpha calculated.

For the questions measuring tendency of a person being an acceptor (item 2, 4, 6, 11), for adults, the overall Cronbach's alpha was 0.717 and further deleting of any item did not cause a big change in the Cronbach alpha. Meanwhile for children's group, the Cronbach alpha was 0.654 and further deleting item 11 increases the Chronbach alpha to 0.679 and not any further. Considering questions measuring the degree of agreement towards actively searching for information (item 3, 5, 8), the resulting Cronbach's alpha for adults was 0.361. Further deleting item 8 results to an increase in Cronbach's alpha to 0.383. Meanwhile for children's group, the Cronbach alpha was 0.438 with no further improvement if any item is deleted. Further more the Cronbach's alpha for the reliability of questions measuring a person's tendency of being a relier (item 7, 9, 10, 12) was 0.525 and deleting item 9 increases the Cronbach's alpha to 0.597 for adults. Any further deletion did not increase Cronbach's alpha. In the case of children's group, Cronbach's alpha was 0.679 with no further improvement when an item is removed.

In summary, in both adult group and children group, the statistics seems to point out that reliability of questions measuring the degree of acceptability of a respondent to vaccination is high meanwhile for questions measuring the tendency of a person to be a relier is medium. For questions looking at searchers, the reliability is low as shown by the data. Because of

this therefore, we ended up not dividing the 13 attitudinal questions into different subgroups and modeling them differently but rather using all the 13 attitudinal questions to measure the vaccination behavior as it gives a greater deal of explanatory power.

3.2 Vaccination Behaviors in Flanders

In this subsection, we analyze the underlying latent classes in vaccination behaviors of both adult group and children's group. We then provide an explaination of the socio-demographic variables that affects behaviors. Finally we present the impact of socio demographic variables and vaccination behaviors on results from discrete choice experiment.

3.2.1 Heterogeneity in vaccination behavior

For the Adult population, the latent class regression model, the model with three latent classes was identified as the best model in terms of the BIC (22895.51) as shown in Table 8. Classifying the respondents based on the predicted class membership, 32.6% were grouped in the first class, 33.4% in the second class and 34% in the third class. The Top right and Bottom right of Figure 5 shows the probability of agreeing and probability of disagreeing to the 13 different attitudinal questions measuring vaccination behavior.

Table 8: *BIC value for models with different latent classes*

Number of Latent Classes	Adult group BIC	Children's group BIC
2	23175.06	19144.19
3	22895.51	19036.43
4	23005.81	19388.19

Adult's Group vaccination behavior

Respondents that belongs to the first class (32.6%) tend to have a lower probability of agreeing to most of the attitudinal questions compared to other groups. They only have the highest probability of agreeing to making their own decision's regarding vaccination (Q8). They consistently have a higher probability of disagreeing to attitude questions measuring whether someone is an acceptor or not (Question 2,4,6,11) compared to other groups. We could define this group as those who make their own decision regarding vaccination irrespective of other information.

Respondents in group two (33.4%) tend to have higher probability of agreeing to questions probing whether someone is actively searching for information (Questions 3,5,8) compared to other classes. They also have a high probability of agreeing to relier questions measuring whether

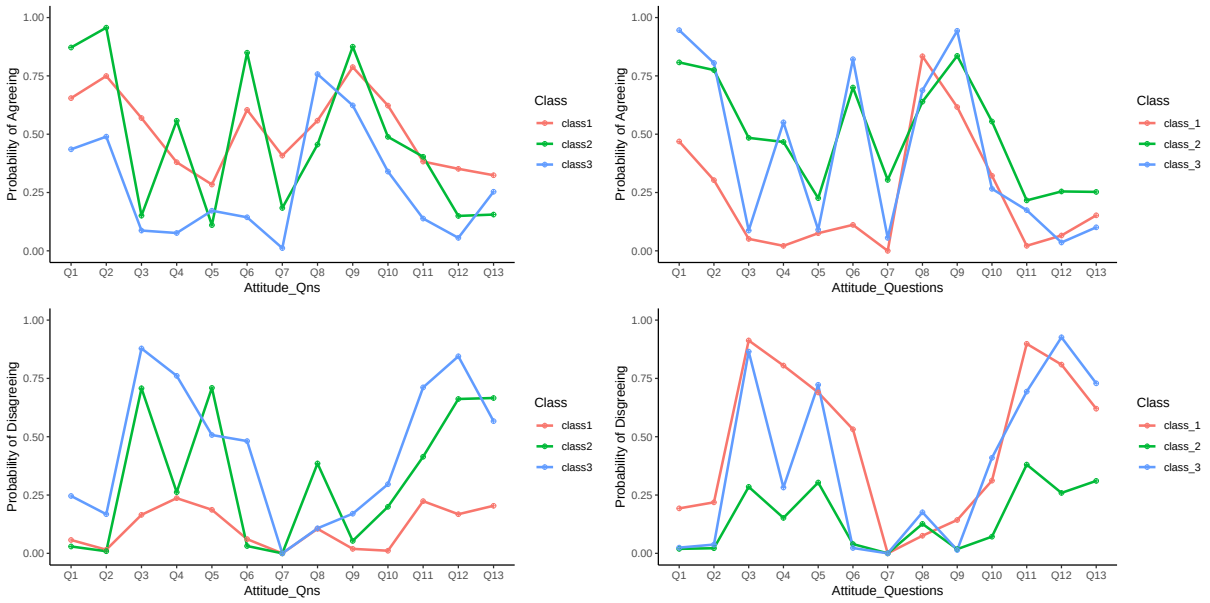

Figure 5: *Profile plots illustrating the identified subgroup probability of agreeing or disagreeing to attitudinal questions measuring vaccination behavior. Top Left: Probability of agreeing in the Children's group. Bottom Left: Probability of disagreeing in Children's group. Top Right: Probability of agreeing in Adult's group. Bottom Right: Probability of disagreeing in Adult's group.*

someone looks to other people for vaccination information (question 7,9,10,12) and also using Internet as a source of information (question 13). We could refer to this group as vaccination information searchers.

For those that belong to the third class (34%), compared to other classes, they tend to have a higher probability of agreeing to questions checking whether someone is a vaccination acceptor or not (question 1,2,4,6). They also have the highest probability of agreeing to taking doctor's opinion about vaccination as important. However, they tend to have a higher probability of disagreeing to statements measuring whether someone is an information searcher (question 3,5,8). They also have a high probability of disagreeing to using experiences about side effects from others (Q10) and using vaccination decision of friends and family in making their decision (Q12) which are relier questions. We can therefore refer to this group as vaccine acceptor group.

Socio-demographic characteristics of the latent groups (Adult's group)

Table 9: *Significant socio-demographic variables affecting vaccination behaviors in the Adult's group. Odds refers to the Exponentiated parameter estimates showing the odds of belonging to second class (information searchers) or odds of belonging to third class (vaccine acceptor) compared to first class (self reliant). Ref shows the reference category*

Variable	Levels	P-Value (2/1)	P-Value (3/1)	Odds (2/1)	Odds (3/1)	Class 1 (%)	Class 2 (%)	Class 3 (%)	Total
Age group	18-34 (Ref)								
	35-49	0.000	0.349	1.393	0.670	20.480	63.450	16.060	249
	50-64	0.000	0.649	0.253	0.830	41.920	30.540	27.540	167
	65-85	0.000	0.107	0.142	0.486	31.660	22.960	45.380	379
Province	Antwerp					32.060	33.820	34.120	340
	Others	0.728	0.000	1.317	0.000	55.560	44.440	0.000	4
	High (Ref)					26.840	35.660	37.500	488
Education	Low	0.054	0.169	0.324	0.464	38.180	23.640	38.180	55
Level	Medium	0.005	0.011	0.530	0.536	37.430	31.930	30.640	545
	Others	0.000	0.000	21642450	0.000	0.000	100.000	0.000	3
Employment	Employed (Ref)					38.060	34.080	27.860	402
Status	Unemployed	0.001	0.029	2.467	1.909	29.460	32.950	37.590	689
Mother's	Belgian (Ref)					33.130	31.630	35.240	996
Country	Non-Belgian	0.036	0.949	2.257	0.965	27.370	51.580	21.050	95
Health	No (Ref)					32.430	35.260	32.320	919
Worker	Yes	0.006	0.612	0.396	0.845	33.720	23.260	43.020	172
History of	Yes (Ref)					32.080	24.210	43.710	318
Illness	No	0.023	0.831	1.801	1.057	32.860	37.130	30.010	773
Flu	Never (Ref)					51.360	30.740	17.900	553
Vaccination	Sometimes	0.000	0.013	4.042	2.468	27.220	51.670	21.110	180
Status	Usually	0.000	0.000	1.641	3.609	6.420	28.210	65.360	358
Religion	None (Ref)					36.970	33.330	29.700	495
	Catholic	0.078	0.018	1.660	2.021	27.870	29.710	42.420	488
	Protestant	0.407	0.000	3.338	0.000	12.500	87.500	0.000	8
	Orthodox	0.890	0.000	1.190	0.000	16.670	83.330	0.000	6
	Jewish	0.000	0.000	795394	610104	0.000	66.670	33.330	3
	Hindu	0.000	0.000	0.009	167399	0.000	0.000	100.000	1
	Budhist	0.000	0.000	0.047	242268	0.000	50.000	50.000	2

We checked on the socio-demographic variables that might be significant in predicting class memberships. It was found that age group of a respondents, whether he/she is from other provinces, the education level, employment status, his/her mother's country of birth, whether they are health workers or not, any history of serious illness, vaccination status and the religion showed a significant difference as shown in Table 9.

From Table 9, respondents within the age of 18-34 years, those living in other province, those with other levels of education, unemployed individuals, respondents with non-Belgian mothers, those with no history of serious illness, those who receive annual flu vaccination sometimes or always and belonging to either Protestant, Orthodox or Jewish religion have a higher odds (almost twice and above) compared to their respective reference categories to belong to second class (vaccine information seekers) other than first class (self reliant). We see a very high estimate for the odds of other levels of education because all of these respondents were grouped

in the second class.

For the odds to belong to the third class (vaccine acceptors) compared to the first class (self reliant) , unemployed respondents, those who sometimes or usually have flu vaccination, catholics, Hindu and Buddhist have higher odds (almost twice and above) than their respective reference categories. Jewish, Hindu and Buddhists have higher estimates because none of these individuals were allocated to the first class.

Comparing the magnitude of the odds ratios to belong to the second class or third class compared to first class, unemployed individuals are 29% more likely to belong to the information seekers group than to the vaccine acceptors group. Those who sometimes receive annual flu vaccines have higher odds (about 64%) of belonging to the information seekers group than vaccine acceptor group. In addition, those who usually receive annual flu vaccination have a higher odds of belonging to the acceptor group than information seeking group.

Children's Group vaccination behavior

For respondents who answered the questions on behalf their children (Children group), the model with three latent classes had the lowest BIC value (19036.43) among all models as shown in Table 8. The predicted class memberships showed that of all the 828 respondents, 234(28.3%) are in the first class, 406(49%) belong to the second class and the third class consists of 188(22.7%). Figure 5 top left and bottom left shows the profile plots of the class specific probability of agreeing and disagreeing respectively to the 13 attitudinal questions. The following observations were made from the profile plots.

The first class (28.3%) consists of respondents who tends to have higher probability of agreeing to questions regarding searching of vaccination information (Questions 3,5,8) and also questions measuring whether someone relies on other people and Internet to get information about vaccination (Questions 7,9,10,12,13). In terms of the probability of disagreeing to attitudinal questions, they are the group with the lowest probability to disagree to all the questions. Based on these features, we can refer to this group as those who actively research for information before vaccinating their children.

In the second class (49.0%), compared to other groups, there is a high probability of agreeing to vaccinating their children because it is generally accepted by friends/family and people close to them are vaccinated (acceptor questions 2,4,6,11). In addition, they also have a higher probability of taking doctors opinion as important (question nine). However, they have a higher probability of disagreeing to questions regarding to searching for information about

vaccination from other people (questions 3,5,8) and also using Internet (question 13).This group can therefore be named as acceptor group.

The third group (22.7%) are the group with the lowest probability of agreeing to most of attitudinal questions except when it comes to making their own decisions about vaccination where they have a high probability of agreement. It is seen however that this group tends to have the highest probability of disagreeing to most questions compared to other groups except for questions 7 and 8. We can refer to this group those who make their own decisions regardless of other recommendations (self reliers).

Socio-demographic characteristics of the latent groups (Children's group)

Table 10: *Significant socio-demographic variables affecting vaccination behaviors in the Children's group. Odds refers to the Exponentiated parameter estimates showing the odds of belonging to second class compared to first class or odds of belonging to third class compared to first class. Ref shows the reference category*

Variable	Levels	P-Value 2/1	P-Value 3/1	Odds 2/1	Odds 3/1	Class 1 (%)	Class 2 (%)	Class 3 (%)	Total
Gender	Female (Ref)					22.470	56.400	21.120	445
	Male	0.000	0.829	0.381	0.932	34.990	40.470	24.540	383
Flue	Never (Ref)					23.300	43.090	33.610	485
Vaccination	Sometimes	0.120	0.000	0.653	0.155	46.630	44.940	8.430	178
Status	Usually	0.031	0.025	2.042	0.192	23.030	70.910	6.060	165
Religion	None (Ref)					23.560	49.190	27.250	433
	Hindu	0.000	0.000	0.000	0.000	100.000	0.000	0.000	2
	Non-disclosed	0.051	0.025	0.381	0.204	47.620	38.100	14.290	42
Employment	Employed					27.870	52.680	19.450	653
Status	Unemployed	0.263	0.047	0.707	2.001	29.710	35.430	34.860	175

In order to predict the latent class memberships taking class one as a reference class for members in the children group, gender, flu vaccination status, religion and employment status were the significant variables as shown in Table 10. In determining membership, the odds to belong in the second class compared to first class for those who usually receive annual flu vaccination is twice the odds of those who never receive annual flu vaccination. Meanwhile males ,those who sometimes vaccinate, Hindus, those who did not disclose their religion and unemployed individuals have a lower odds than their respective reference category to belong to second class rather than first class.

Checking on the odds to belong to the third class compared to first class, employed respondents are more likely to belong to third class with twice the odds of unemployed individuals. However males, those who sometimes or usually receive annual flu vaccination, Hindu's and individuals

with non disclosed religion have a lower odds of belonging to third class than first class compared to their respective reference categories.

3.2.2 Integrating vaccination behavior and socio-demographic variables in the discrete choice model

In this discrete choice experiment (DCE), all of the 1091 adult individuals were given 10 different choice sets with two vaccines to choose from. Overall, 52.8% choose Vaccine A meanwhile 47.2% choose Vaccine B. We accounted for heterogeneity that exists in choices of respondents by fitting a latent class regression model with 2,3 and 4 presumed latent class. From the BIC of these models as shown in Table 11, the model with two latent classes had the lowest BIC (14245.38) and was chosen. This model with two latent classes indicates that the first latent class consists of 25.92% of the adult respondents while 74.08 of the adult respondents belongs to the second latent group.

Table 11: *Summary of BIC of latent class regression models with 2,3 and 4 presumed latent classes for both Adult group and Children group. Low BIC indicates the best model*

Number of latent class	BIC (Adult Group)	BIC (Children Group)
2	14245.38	10838.08
3	14396.53	11012.36
4	14645.97	11249.04

Adult's Group DCE results

The results of the discrete choice latent class regression model is presented in Table 21. It is evident that for the first latent class, all attributes except vaccine's population coverage had significant effect on the vaccine respondents chose. Respondents in class one have a strong aversion to disease burden compared to those in the second class. They have a lower odds (0.564 and 0.619) of choosing a vaccine that protects against any severe disease whether its common or rare in comparison to vaccines that protects against diseases that are common and mild. In addition, in comparison to group two, this group highly prefers vaccines with rare VRSE (odds of 3.217) compared to those with common VRSE. They have a lesser preference for choosing vaccines that requires co-payments compared to those that are free. Considering the percentage of acquaintances that are immunized (local coverage), this group tends to choose vaccines that have higher local coverage.

For the adult respondents in the second class, all the attributes had a significant effect on the

vaccine choices. In comparison to respondents in the first class, they tend to have a stronger preference for vaccines with higher effectiveness. Contrary to the first class, given vaccines that protects against diseases that are common and mild, this group have a higher preference for vaccines that protect against severe diseases whether common or rare (odds of 6.109 and 3.654 respectively). Distinct to group one, respondents in group two tend to prefer more vaccines with a higher percentage of the population already vaccinated (60% and 90%) compared to those with a lower population coverage (30%).

A further investigation on the socio-demographic characteristics that significantly affect class memberships is shown in Table 21. Checking the odds to belong to the second class instead of the first class; males, respondents belonging to older age groups, those from East Flanders, Flemish Brabant, Limburg and other provinces, those with low and medium education level, single respondents, those whose mothers were born outside Belgium, always vaccinate, go for church services monthly or weekly, had a lower odds (less than one) compared to their respective reference levels to belong to the second class rather than first class. However, respondents who from the vaccination behavior analysis were grouped as information searchers (searchers and reliers) and vaccine acceptors, had a higher odds compared to self reliant individuals to belong in the second class than first class. In addition, health workers, those who had history of serious illness, sometimes receives annual flu vaccination, Muslims, catholics and other religious individuals have a higher odds of belonging to the second class compared to their respective reference categories.

Children's group DCE results

All the 828 respondents in the children's group were tasked with making choices between two vaccines given 10 different choice sets with varying levels of attributes. Overall, 54.32% of respondents chose Vaccine A while 45.67% chose Vaccine B. A latent class regression model was fitted to this discrete choice data with 2,3, and 4 latent classes. As shown in Table 11, the latent class model with two class had the lowest BIC (10838.08). This model resulted into allocating 32.96% of respondents in latent class one and 67.04% in the second latent class.

We present the results of the latent class discrete choice model for the children's group in Table 22. For the respondents allocated in the first class, all the attributes significantly affected the vaccine choices. In comparison to class two; the respondents have a lower preference for vaccines that protect against any rare disease whether mild (odds 0.633) or severe (odds 0.727) with respect to vaccines against common and mild diseases. They also tend to less prefer vaccines that involve co-payment other than free of charge. In addition, this group has higher

odds of preferring vaccines that have been used by a higher percentage (60%, 90%) of their acquaintance compared to only 30%.

For respondents in the second class (67.04%), all the attributes other than vaccine's local coverage was insignificant. They have strong preference for vaccines that are highly effective compared to their counterparts in group one. Considering disease burden, this individuals have higher odds of preferring vaccines that protects against severe diseases whether common or rare. They also have a higher preference for vaccines with rare side effects than group one individuals. Given a vaccine with 30% population coverage, this groups have a high odds (2.122) of preferring a vaccine with 90% global coverage.

Table 22 (Appendix) also shows the significant socio-demographics. In comparison to their respective reference categories; males, respondents between 50 and 64 years of age, those from Brussels, Limburg and West Flanders, individuals with medium level of education, usually vaccinate against flu, orthodox/protestant with monthly or often frequency of attending religious services, all have lower odds (less than one) to belong to the second class than the first class. Those with a higher odds of belonging to the second class are individuals in the age group of 65 - 85 years of age, those belonging to other provinces, respondents with low and other levels of education, employed individuals and those whose mothers were born in other countries.

Investigating the impact of vaccination attitude on the results from the discrete choice experiments, vaccination acceptors are not significantly different from self reliant individuals in the way they make their choices or value specific attributes. However, those who are information searchers (searchers and reliers) are significantly different from self reliant individuals. In fact information searchers have are less likely to belong to the group of individuals who highly value vaccine effectiveness, prefer vaccines against severe diseases, and do not care about local coverage of a vaccine but population coverage (class two) than class one. Therefore one could say that searchers and reliers are more likely to have lower preference on vaccines against rare diseases and involving a co-payment while having higher preference for vaccines with a high local coverage.

3.3 Risk Perception about vaccination and infectious disease susceptibility

In answering this research question, we analyzed data for only those who answered questions on vaccination risk perception. This included all the respondents in the children group and also respondents less than 33 years of age in the adult group. In this subsection, we analyze the impact of risk perception and infectious disease susceptibility on vaccination behavior. In sub-

section 3.3.1, We dig deep into the underlying groups in Sub-section 3.3.2 and finally determine which socio demographics are related to distinct profiles of individuals in different latent groups (Sub-section 3.3.3).

3.3.1 Impact of risk perception about vaccination and infectious disease susceptibility on vaccination behavior

In understanding the impact of risk perception on vaccination behavior, the results of the number of latent classes found in Section 3.2 was used as a proxy for measuring the vaccination behavior of an individual. The three latent group in Adult's vaccination behavior corresponded to self reliant individuals (group one), searchers/relier's on information (group two) and vaccine acceptors (group three). These three groups (exhibiting different vaccination behavior) was taken as a response variable. Risk perception about vaccination and infectious disease susceptibility were measured by perception towards measles susceptibility, measles severity, vaccine effectiveness, chance of VRSE and severity of VRSE all measured in three categories as either Low, Moderate or High.

Table 12: *Adult group Results of Impact of risk perception and measles susceptibility on the odds to belong to the group of individuals who searches for vaccination information (group 2) or vaccination acceptors (group 3) taking self reliant group as a baseline vaccination behavior group*

		Class Two vs Class One			Class Three Vs Class One		
Variables	Levels	Estimates	OR	Pvalue	Estimates	OR	Pvalue
Intercept		15.605	5986395	0.000	-5.397	0.005	0.000
History of Measles Vaccination	No (Ref)						
	Yes	0.883	2.418	0.082	0.540	1.716	0.420
History of Measles Infection	No (Ref)						
	Yes	-0.177	0.838	0.648	-1.250	0.287	0.021
Measles Severity	High (Ref)						
	Low	-0.755	0.470	0.146	-0.278	0.757	0.860
	Moderate	0.115	1.122	0.549	-0.252	0.777	0.670
Measles Susceptibility	High (Ref)						
	Low	-16.507	0.000	0.000	4.552	94.822	0.000
	Moderate	-13.831	0.000	0.000	6.715	824.684	0.000
Vaccine Effectiveness	High (Ref)						
	Low	0.089	1.093	0.946	-14.154	0.000	0.000
	Moderate	-0.224	0.799	0.665	-0.523	0.593	0.462
Chance of VRSE	High (Ref)						
	Low	1.403	4.067	0.027	0.660	1.935	0.370
	Moderate	0.593	1.809	0.272	-0.736	0.479	0.261
VRSE Severity	High (Ref)						
	Low	0.870	2.387	0.255	1.093	2.983	0.295
	Severe	0.942	2.565	0.199	0.822	2.275	0.418

In Table 12, we present the impact of these variables on the odds of an individual to belong

to either information searchers/reliers or vaccine acceptors compared to belonging to the self reliant group. Three variables were significant; measles susceptibility, chance of VRSE, vaccine effectiveness and history of measles infection. Considering the information searchers/reliers (group 2), measles susceptibility and chance of VRSE were significant. For those who perceive they have a low or moderate chance of contracting measles (measles susceptibility), they have a zero odds of belonging to the searchers/reliers group compared to the self reliant group. All the seven individuals who perceive they are highly susceptible to measles were allocated to the group of information searchers/reliers (group two). However, comparing those who perceives low and moderate susceptibility to measles to those who perceives high susceptibility to measles, they have a considerably higher odds (94.8 and 824.7 respectively) of belonging to the group of vaccination acceptors rather than being self reliant.

In addition, adults who perceive that there is a low chance of VRSE compared to those who perceives a high chance of VRSE are four times more likely to belong to the group of respondents who are searching for information compared to belonging among the self reliant individuals (group one). Those who had been previously infected with measles have a lower odds (0.287) of being vaccine acceptor than being a self reliant compared to those who have not been infected with measles before.

Table 13: *Children group Results of Impact of risk perception and measles susceptibility on the odds to belong to the vaccine acceptors (group 2) or self relier's (group 3) taking vaccine information searchers group as a baseline vaccination behavior group*

		Class Two vs Class One			Class Three Vs Class One		
Variables	Levels	Estimates	OR	Pvalue	Estimates	OR	Pvalue
Intercept		-0.934	0.393	0.042	-1.454	0.234	0.007
History of Measles Vaccination	No (Ref)						
	Yes	-0.020	0.980	0.943	-0.240	0.787	0.442
History of Measles Infection	No (Ref)						
	Yes	-0.183	0.833	0.390	-0.387	0.679	0.126
Measles Severity	High (Ref)						
	Low	0.369	1.446	0.125	0.815	2.259	0.004
	Moderate	0.135	1.145	0.480	0.132	1.141	0.579
Measles Susceptibility	High (Ref)						
	Low	0.201	1.223	0.516	0.990	2.691	0.015
	Moderate	0.132	1.141	0.697	0.078	1.081	0.863
Vaccine Effectiveness	High (Ref)						
	Low	-1.616	0.199	0.056	1.366	3.920	0.016
	Moderate	-0.298	0.742	0.312	0.951	2.588	0.001
Chance of VRSE	High (Ref)						
	Low	0.475	1.608	0.082	0.243	1.275	0.452
	Moderate	0.463	1.589	0.073	0.338	1.402	0.257
VRSE Severity	High (Ref)						
	Low	1.245	3.473	0.000	0.017	1.017	0.000
	Severe	0.750	2.117	0.011	0.103	1.108	0.737

For those answered the questionnaires on behalf of their children (children group), it was found that perceptions about measles severity, measles susceptibility, vaccine effectiveness and severity of VRSE were significant in determining the vaccination behavior of parents towards their children (See Table 13). Parents who perceives that the impact of measles on the health of their children is less severe other than high have twice (2.259) the odds to belong to self reliant group of respondents (group 3) than the information seeking group (group one). In addition, also those parents who perceive that their children are less susceptible to measles rather than highly susceptible tend to have higher odds (2.691) to be self reliant respondents compared to information seekers.

Those who perceive low or average vaccine effectiveness, have a higher odds (3.920 and 2.558 respectively) of belonging to the self-reliant group than information seeking group when compared to their fellow parents who perceive a high vaccine effectiveness. Parents who perceive that there is a low VRSE have over three times (3.473) the odds to belong to the vaccine acceptors group instead of information seekers compared to those who think the vaccine is highly

effective.

3.3.2 Distinguishing profiles in vaccination risk perception and measles susceptibility

In Table 5, we presented the summary statistics for the different categories of the five elements based on the concept of the health belief model (Hochbaum, 1952) with respect to measles. To further understand the presence of underlying population in the data, a tent class regression model was fitted with a presumed two and three latent classes as shown in Table 14. The model with two latent class had the smallest BIC (2082.155 and 7220.019) for both the Children and Adult group respectively.

Table 14: *Summary of BIC values for two and three latent classes in the children group and adult group*

Number of Latent Classes	Children Group BIC	Adults Group BIC
2	7220.019	2082.155
3	7428.172	2349.734

Examining the results from Adult group (235 individuals), 21.3% (50) of the individuals were allocated to the first latent group while 78.7% (185) were allocated to the second class. We used profile plots to visualize the Conditional item response probabilities by latent group as shown in the right of Figure 6.

Considering the children group, out of the total 828 respondents, 411 (49.6%) were allocated in the first latent class while 417 (50.4%) were allocated to the second latent class. In the left panel of Figure 6, it can be seen that compared to the second latent class, the individuals in the first latent class tend to have higher probability of perceiving that there is high chance of vaccine related side effects and its' severity. Also, they have a lower probability compared to the second group to perceive vaccine as highly effective. However, for individuals that belong to the second latent class (50.4%), they tend to have a higher probability compared to the first class concerning perception about: vaccines being highly effective; having low chance of VRSE and VRSE not being serious (low VRSE severity); lower susceptibility to measles.

For the adult group, as shown in the right panel of Figure 6, they show completely different patterns of response from the children group. In this group, both class one and class two tend to exhibit similar patterns. They both have a lower probability of perceiving a high severity of measles and susceptibility to measles. Both have a high probability of perceiving vaccines as

effective. However, class one perceives a low chance of VRSE and a low severity of VRSE. For class two, they perceive that the chance of VRSE and VRSE severity is moderate.

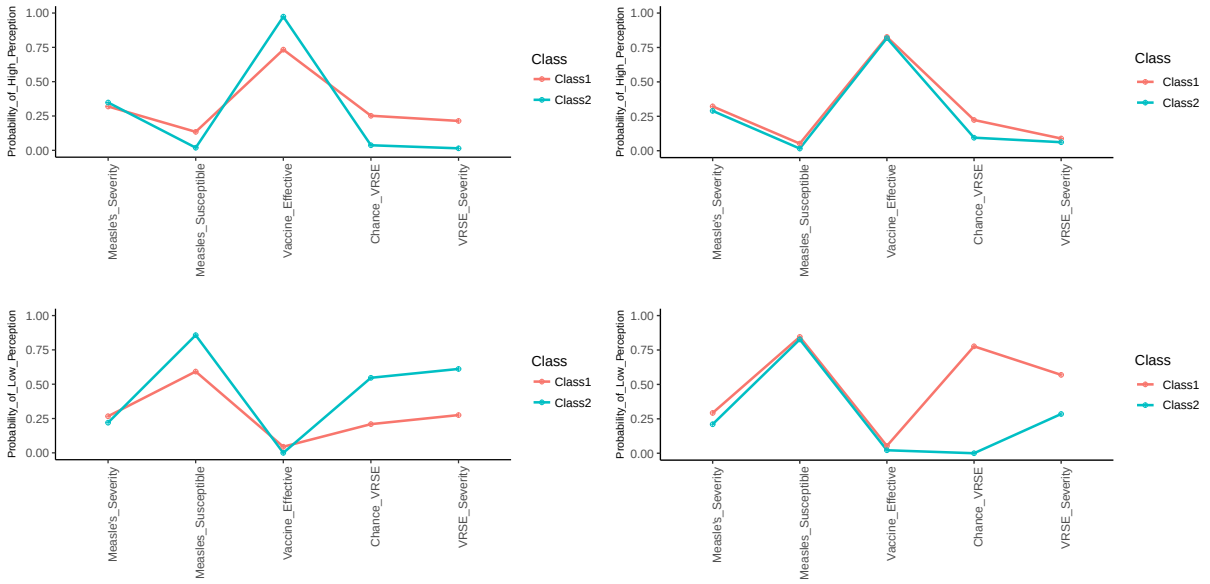

Figure 6: *Profile plots illustrating the identified subgroup probability of having high and low perception on measles susceptibility, severity and vaccine related side effects (VRSE) in Flanders. Top Left: Probability of having high perception in the Children's group. Bottom Left: Probability of having low perception in the Children's group. Top Right: Probability of having high perception in the Adult's group. Bottom Right: Probability of having low perception in the Adult's group.*

3.3.3 Socio-demographic variables related to Distinguished group of Profiles

For the Adult group, the significant socio-demographics variables that affect the risk profiles are shown in Table 15. This result shows that sex of a respondent, province where a person lives, frequency of religious service and whether someone had previously been infected with measles or not shows significant difference in the odds to belong to second class other than first class. It is seen that there is a high odds of individuals in Brussels or East Flanders compared to those from Antwerp to belong to the group that perceives a moderate chance and severity of VRSE (group two) than perceiving a lower risk of vaccination (group one). Summary statistics shows that all the 5 respondents in Brussels are classified in group two as well as 74.6% of those in East Flanders being allocated in the second class. Male respondents compared to female respondents, have a lower odds to belong to the group perceiving a moderate chance and severity of VRSE (group two) compared to those that perceives vaccine less risky (group one). This is because only 56% of the males are allocated in the second group compared to 64% of the females classified in group two.

Those who attend religious service monthly compared to those who attend religious service few times have almost zero odds to belong in the second group compared to the first group. In fact 60% of the individuals who attend religious services monthly were allocated to the first class while 73% of those who attend religious services few times a year are classified in the second group. In addition, those who had experienced measles before in comparison to those who were not infected with measles had a lower odds (0.257) of perceiving a moderate chance and severity of VRSE (group two) than those that perceives vaccine less risky (group one).

Table 15: *Results of socio-demographic characteristics associated with the two different latent groups for the adult group. OR (2/1) shows the odds ratio of belonging to the second class (perceiving a moderate chance and severity of VRSE) instead of first class (perceiving vaccine as less risky)*

Variable	Levels	Estimates (2/1)	OR (2/1)	P-Value	Class 1 (%)	Class 2 (%)	Total
Intercept		1.319	3.741	0.461			
Sex	Female (Ref)				35.380	64.620	130
	Male	-0.918	0.399	0.033	43.810	56.190	105
Province	Antwerp (Ref)				45.450	54.550	77
	Brussels	10.329	30604.122	0.000	0.000	100.000	5
	East Flanders	1.253	3.499	0.021	25.450	74.550	55
	Flemish Brabant	-0.371	0.690	0.546	50.000	50.000	32
	Limburg	-0.391	0.676	0.466	46.150	53.850	39
	West Flanders	0.563	1.756	0.319	33.330	66.670	27
Frequency of	Few times a year (Ref)				26.090	73.910	23
religious service	Monthly	-2.488	0.083	0.040	60.000	40	10
	Rare/Never	-0.840	0.432	0.375	38.970	61.030	195
	Weekly/Often	-2.002	0.135	0.213	57.140	42.860	7
History of Measles	No (Ref)				31.080	68.920	148
Infection	Yes	-1.357	0.257	0.001	52.870	47.130	87

It was also investigated whether the socio demographics of parents have an impact on their risk profiles. Based on the results from the two latent class regression models, age group of the parent, the province, history of serious illness, smoking status of the parent, whether the child is vaccinated against measles and whether their children were infected with measles previously were found to be significantly predicting the class memberships/profiles. The result of these variables are shown in Table 16.

It is evident that as the age of the parents increases, their odds to have a good perception about vaccination than perceive vaccines as more risky increases. Considering province of an individual, all the 10 individuals from other provinces outside Flanders were categorized in class 1 hence having a zero odds of belonging to the second class compared to respondents from Antwerp. For parents who had history of serious illness versus those who did not have any serious illness, they have a lower odds (0.411) of belonging to the class with good perception about vaccination (class two) compared to class one.

All the 101 parents whose children were not vaccinated against measles, were classified in the group of individuals perceiving vaccines as risky and less effective. This therefore explains why there is a very high Odds to belong in the second class than first class for parents whose children were vaccinated against measles versus those whose children were not vaccinated. However, parents whose children were once infected with measles compared to those whose children were not infected with measles have a lower odds (0.252) of having a good perception about vaccination than perceiving vaccination as risky and less effective.

Table 16: *Results of socio-demographic characteristics associated with the two different latent groups for the children group. OR (2/1) shows the odds ratio of belonging to the second class (good perception about vaccination and infectious disease susceptibility) instead of first class (perceiving vaccine as risky and less effective)*

Variables	Levels	Estimates (2/1)	OR (2/1)	P-Value	Class 1 (%)	Class 2 (%)	Total
Intercept		-17.048	0.000	0.000			
Age group (years)	18 - 34 (Ref)				77.700	22.300	287
	35 - 49	1.937	6.939	0.000	37.440	62.560	414
	50 - 64	2.669	14.419	0.000	27.830	72.170	115
	65 - 85	4.634	102.933	0.091	8.330	91.670	12
Province	Antwerp				52.300	47.700	239
	Brussels	-0.327	0.721	0.933	70.000	30.000	10
	East Flanders	0.451	1.570	0.342	41.000	59.000	200
	Flemish Brabant	0.861	2.367	0.114	41.510	58.490	106
	Limburg	0.201	1.222	0.696	47.500	52.500	120
	Others	-17.542	0.000	0.000	100.000	0.000	10
	West Flanders	-0.463	0.629	0.373	60.140	39.860	143
History of Serious illness	No (Ref)				46.950	53.050	656
	Yes	-0.888	0.411	0.050	59.880	40.120	172
Smoking Status	No (Ref)				43.950	56.050	603
	Yes	-1.109	0.330	0.005	64.890	35.110	225
Vaccinated against measles	No (Ref)				100.000	0.000	101
	Yes	16.916	22210817.435	0.000	42.640	57.360	727
History of Measles Infection	No (Ref)				45.440	54.560	658
HadMeaslesYes	Yes	-1.378	0.252	0.003	65.880	34.120	170

3.4 Mis-perceptions of vaccine's side-effects.

In analyzing whether Flemish individuals misperceive vaccine side effects or not, a latent class model was fitted to account for heterogeneity that might underlie the population. The results of fitting models with 2, 3 and 4 latent classes indicated that the model with two latent classes had the smallest BIC as indicated for both the children's group and adult group as shown in Table 17.

Table 17: *AIC and BIC for the vaccine side effects mis-perception latent class model*

Number of Latent Classes	Adult Group BIC	Children's group BIC
2	11620.09	8789.657
3	11808.6	8909.061
4	12644.99	No Convergence

Children's group vaccine related side effects misperception

Among the respondents in the children group, two latent classes were identified consisting of 62.3% and 37% in class one and class two respectively. From Figure 7 top left we see the probability of having true perception and bottom left the probability of misperceiving the vaccine related side effects.

The children group respondents that were grouped in class one (62.3%) tend to have a higher probability of having true perception on postulated side effects that are not real side effects. That is they have higher probability of identifying among the list, the conditions that are not vaccine related side effects like chronic fatigue, autism, infertility, death and overloaded immune systems. However, this group tend to also have a high probability of indicating true vaccine side-effects as not being side-effects except allergy.

The respondents that were grouped in the second class (37.7%) exhibits a higher probability of having true perception about the true vaccine related side effects and also most of the non-vaccine related side effects. They also tend to consider diarrhea and URTI as not being a vaccine side effects but considers allergy as a vaccine related side effect (misperceived). In general they have a higher probability of identifying the true vaccine related side-effects and non-vaccine related side effects.

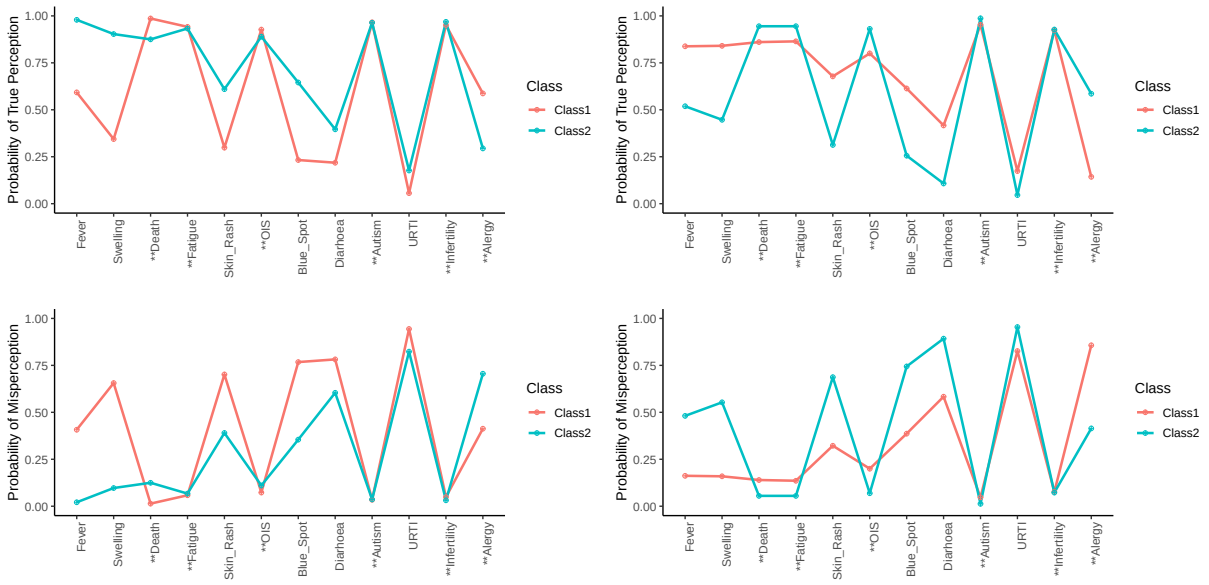

Figure 7: *Profile plots illustrating the identified subgroup probability of having true perception and misperception of vaccine related side-effects in Flanders. Top Left: Probability of having true perception in the Children's group. Bottom Left: Probability of having misperception in the Children's group. Top Right: Probability of having true perception in the Adult's group. Bottom Right: Probability of having misperception in the Adult's group. ** indicates conditions that are not side effects*

Table 18: *Significant variables for Children group vaccine side effects misperception and class specific summary statistics. Exponentiated parameter estimates shows the odds of belonging to second class compared to first class. Ref shows the reference category*

Variable	Levels	Estimate (Exponentiated)	P-value	Class 1 (%)	Class 2 (%)	Total
Gender	Female (Ref)			45.620	54.380	445
	Male	0.256	0.000	82.250	17.750	383
Education Level	High (Ref)			64.450	35.550	391
	Low	0.000	0.000	100.000	0.000	28
Health Care Worker	No (Ref)			67.540	32.460	650
	Yes	1.97	0.013	44.380	55.620	178
Flue Vaccine Status	Never (Ref)			57.730	42.270	485
	Sometimes	0.522	0.026	70.790	29.210	178
	Usually	0.511	0.027	67.880	32.120	165
Religion	None (Ref)			58.200	41.800	433
	Orthodox	0.000	0.000	100.000	0.000	7
	Hindu	0.000	0.000	100.000	0.000	2
Frequency of Service	Rare/Never (Ref)			59.250	40.750	643
	Monthly	0.000	0.000	100.000	0.000	30

We checked among all the socio-demographic characteristics which factors might be significantly predicting class memberships. The results of the model (shown in Table 18) indicated that there was a significant difference between class one and class two for gender, education level, whether

the respondent is a health worker or not, annual flu vaccination status, religion and frequency of attending religious service. The percentage of respondents in each latent class for these significant variables is also shown in Table 18

For gender, Among all the male respondents, 82.25% belongs to the first class meanwhile for female respondents, about 54.38% are grouped in the second class. In addition, the odds of a male compared to a female respondent to belong to second class rather than first class is 0.26. Considering education level, the odds of those with low education status compared to high education status was 0. This is because of the 28 respondents with low education status, none was allocated to the second class meanwhile 65.45% of respondents with high education status belong to the first class. For health care workers, they have almost twice the odds to belong to second class rather than first class compared to those who are not health workers.

Considering those who sometimes or usually vaccinate get annual flu vaccination status, their odds of belonging to the second class compared to first class is half the odds of those who never vaccinate against flu. Looking at religion of the respondents, all of the orthodox and Hindu respondents belongs to the first class hence they have a zero odds belonging to second class compared to those with no religion. Evaluating the frequencies of religious services, the respondents who go for religious services about monthly have a zero odds of belonging to second class other than first class compared to those who rarely or never go for religious service. A summary statistic shows all the 30 respondents who go to religious services monthly belong to first class.

Adult's group vaccine related side effects misperception

For the adult group respondents, the predicted class memberships in class one and two consisted of 18.8% and 81.2% of the respondents respectively. By using the help of profile plots in Figure 7, the Top right visualizes the probability of having true perception about the postulated side-effects while bottom right indicates the probability of misperceiving vaccine related side-effects. This plot reveals different behaviors in the two classes.

The respondents grouped in the first class (18.8%) tend to have a higher probability of identifying and answering correctly the real vaccine side effects (true perception) except for URTI and diarrhea. For non-vaccine related side effects except allergy, this group tend to have high probability of identifying the non-vaccine related side effects conditions correctly as not being a vaccine side effect (example fatigue, death, OIS, Autism, infertility).

The second class (81.2%) differs from the first class in that they have a higher probability

of misperceiving real vaccine related side effects like (fever, blue spot and swelling/redness of the injection site, skin rash, diarrhea and URTI). They are a group of individuals with a high probability of taking vaccine as not having many of the side effects.

Table 19: *Significant variables for Adult group vaccine side effects misperception and class specific summary statistics. Exponentiated parameter estimates shows the odds of belonging to second class compared to first class. Ref shows the reference category*

Variable	Levels	P-Value	Estimate (Exponent)	Class 1 (%)	Class 2 (%)	Total
Gender	Female (Ref)			22.760	77.240	492
	Male	0.012	2.130	8.010	91.990	599
Age group	18 - 34 (Ref)			36.950	63.050	249
	35 - 49	0.005	3.047	16.770	83.230	167
	50 - 64	0.000	9.866	5.410	94.590	296
	65 - 85	0.000	9.649	6.330	93.670	379
Province	Antwerp (Ref)			21.470	78.530	340
	Brussels	0.000	2021093	0.000	100.000	21
	West Flanders	0.025	3.041	7.910	92.090	177
Education Level	High (Ref)			17.010	82.990	488
	Others	0.000	538360	0.000	100.000	3
Health Care	No (Ref)			12.620	86.250	919
Worker	Yes	0.031	0.457	25.580	74.420	172
History of	Yes (Ref)			15.410	84.590	318
Serious illness	No	0.049	1.868	14.360	85.640	773
Religion	None (Ref)			21.010	78.990	495
	Hindu	0.000	0.000	100.000	0.000	1
	Budhist	0.000	128917	0.000	100.000	2
	Non disclosed	0.000	245661	0.000	100.000	42

In Table 19, we present only the result of the significant variables in predicting the odds of belonging to class two compared to class one. Variables like gender, age group, province, education level, health care worker, history of serious illness and religion were significant. From the results, it can be seen that the odds of a male to belong to the second group instead of first group is twice the odds of females belonging to the second class. In addition, the odds of belonging to the second class compared to the first class increases as we move from a younger age group to a older age group taking age group 18-34 years as the reference group. Among the provinces in Belgium, only Brussels and West Flanders was significantly different from Antwerp. For Brussels, all the 21 respondents were categorized in the second class hence making the odds of belonging to the second class compared to first class very high. In a similar sense, respondents from West Flanders have about 3 times the odds of belonging to the second class rather than first class compared to Antwerp respondents.

Concerning education status, only individuals with other levels of education were significantly different from higher educated individuals. These individuals with other levels of education had extremely higher odds of belonging to class two versus class one because out of all the three respondents with other education level, all of them were classified in the second class. Health care workers have almost half the odds of non healthcare workers to belong to class two compared to first class. For those who do not have any serious history of illness, they had almost twice the odds of those who had serious illness to belong to the second class other than first class.

Looking at religious affiliations of respondents, there was only one Hindu respondent who was in the end classified to the first class. Also there were two individuals who were Budhist and were all allocated to the second class. In addition, out of the 42 individuals who did not disclose their religion status, all of them were allocated to the second class. This explains why the odds ratios for Budhist and non disclosed religion status individuals to belong to second class rather than first class compared to non religious individuals are very high.

We checked for the impact of the various misperception of vaccine related side effects (VRSE) on the vaccination behavior of individuals by fitting a multinomial regression model. The vaccination behavior here is whether a respondents is self reliant in regards to vaccination decisions, an information searcher/relier or an acceptor. The results of these analysis is shown in Table 20.

Table 20: *Results showing the significant variables having impact on the odds to belong to the three different vaccination behavior latent group for both Adult and Children*

Disease True Perception (Ref is respective disease Misperception)	Estimates	OR	P-Value	Estimates	OR	P-Value
		Children's Group				
Intercept	-2.888	0.056	0.000	1.209	3.350	0.084
Swelling	0.672	1.958	0.000	0.230	1.259	0.172
Fatigue	1.024	2.784	0.012	-0.315	0.730	0.376
Blue Spot	0.411	1.508	0.026	0.111	1.117	0.615
		Adult's Group				
Intercept	0.022	1.022	0.985	-1.108	0.330	0.447
Swelling	-0.801	0.449	0.046	0.707	2.028	0.202

For the children group, perceptions about swelling, fatigue and blue spot at the vaccination site were significant. Respondents who have true perception about swelling, fatigue and blue spot have a higher odds (1.958, 2.784, 1.508) to belong to the vaccination acceptors group (group two) rather than the first group (information searchers) taking those who misperceive

these as reference. However, there was no significant relationship between misperception and belonging to the third class (self reliant group). For the adult group, swelling (redness, pain at the injection site) was significant. The respondents who truly perceive swelling as a side effect, they have a lower odds compared to those who misperceive swelling as not being a VRSE to belong to the second group (those who seeks for information) compared to first group (self reliant respondents).

4 DISCUSSION AND CONCLUSION

This thesis expands on the work by Verelst *et al.* (2018) who carried out a study to understand individual decisions to vaccinate themselves or their children in Flanders. They carried out a survey of Flemish respondents fluent in Dutch who had to answer some part of the questions either on behalf of their youngest child below 18 years or about themselves. Comparing the survey respondent's socio-demographic characteristics with the Flemish national statistics, there was a good representation of the Flemish people in terms of sex, province and age group. This is helpful in generalization of the results.

The main interest of our study was to understand whether there is some unobserved heterogeneity in how people make their vaccination decisions and make choices, perceive risks and susceptibility to infectious diseases and misperceive vaccine related side effects (VRSE). This work is an important contribution to the literature of vaccination behaviors since most often focus is made only on the observable heterogeneity for example socio-demographic characteristics but not on the unmeasured factors.

Understanding behavior is not a straight forward task as it involves a combination of actions, emotions and cognitions. Because of this, using just a single variable to measure behavior would not give us an accurate results. Therefore to understand vaccination behavior, we used 13 attitudinal statements that measures vaccination sentiments and habits (Verelst *et al.*, 2018). These 13 statements meant that we had multivariate categorical response variables to be modeled. Latent class regression model was used to identify heterogeneity in vaccination behavior.

Three different vaccination behaviors were identified. These heterogeneous vaccination behaviors are; individuals who will accept to vaccinate themselves or their children without further questioning, those who seek for information about vaccination from other sources or people and those who make their own decisions (self reliant) without being influenced by other people. Leask *et al.* (2012) provided a framework that described five different vaccination behavior of parents as; unquestioning acceptors, cautious acceptors, the hesitant (self reliant in our case), Late or selective vaccinator and refusers. Our results however conforms with two of the categories in this framework. We would argue that our group of vaccine acceptors could probably combine the two unquestioning and cautious acceptors in Leask *et al.*, (2012).

For the adult group, there was commensurate allocation of respondents in these three groups. However, for the children's group, about half of the respondents were allocated in the acceptor group. These group allocation seems to be in line with what Leask *et al.* (2012) postulated.

Furthermore, our exploratory analysis showed that individuals are more likely to make their own vaccination decision when it comes to vaccinating themselves rather than their children. This was further confirmed by our analysis showing that in the adult population, about 33% of the respondents were classified self reliant meanwhile only about 23% of those who responded on behalf of their children were classified as self reliant. We could therefore argue that parents are more willing to accept vaccinating their children more easily than when it comes to vaccinating themselves.

As shown in the exploratory analysis, in both adult and children's group, about 80% of the respondents agree to taking doctors opinion about vaccination as important, the latent group specific profile plots also indicated that all these three latent groups had higher probability of agreeing to taking doctor's opinion as important information for vaccinating themselves or their children. Gargano *et al.* (2013), Dempsey and Zimet (2015) found out that the recommendations made by physicians to parents was a main reason for respondents to vaccinate. It was also found that unemployed individuals were more likely to be information searchers than employed individuals. In situations were these unemployed individuals do not get persuaded to vaccinate, it might lead to higher odds of being vaccine hesitant (Azizi *et al.* ,2017).

In addition, those with no history of serious illness, or sometimes vaccinates were more likely to search or rely on others for information about vaccination. Dub*é et al.* (2013) stated that future vaccination decision can be influenced by previous experiences with vaccination services and therefore this might explain why these group of people would be searching for information. Our results further showed that respondents who are protestant by religion were more likely to be searchers/reliers on others for vaccination information. This might be explained by Ruijs *et al.* (2012) work on knowing how protestants make their decision to vaccinate in Netherlands which found out that most protestants heed to their family traditions while making vaccination decision. However, for Catholic respondents, they are more likely to accept vaccination without much questioning. This might be because the catholic doctrine allows their believers to vaccinate when there is no alternative available for the protection of the overall population (*Pelčić et al.*, 2016).

In regards to discrete choice experiment results, heterogeneity in choices made by respondents between two vaccines was addressed through using discrete choice latent class regression model. With this model, two underlying groups of individuals with different choices were found. The first group had lower preference for vaccines that prevents severe diseases and they put more preference on vaccines that their acquaintances have used. The second group highly values

vaccine effectiveness, prefers more vaccines that protects against severe disease and value more the population coverage of the vaccination to local coverage.

Taking the heterogeneity into account added additional explanatory power that could not be seen in Verelst *et al.* (2018). In their results, even if local and population coverage was significant, their effect was limited. But taking the heterogeneity into account, we noticed that there are one group of respondents to whom local coverage is important and the other group who tend to value more population coverage. In another dimension, Verelst *et al.* (2018) results singles out that with respect to disease prevalence, disease severity is more important. Our results is in line with this but posses additional information in that some other groups of individuals would be discouraged to choose a vaccine that protects against severe diseases while one group tend to choose the vaccine that protects against a severe disease.

The impact of vaccination behavior on the results from the discrete choice experiment was further expounded. In the children's group, there was no difference between a vaccination acceptor and a self reliant individual (hesitant). We found out that for adults, information searchers/reliers and vaccine acceptors had significantly higher odds of belonging to the group that values more population coverage of vaccines, highly values vaccines with high effectiveness and protects against severe diseases. This could be because as someone searches for information about the vaccine effectiveness, its related side-effects and the benefits other people get that outweigh severe diseases, it exposes them to the vaccines are highly effective and used mostly by the population. In addition, Verelst *et al.* (2018) also found out that in comparison to vaccines against diseases that are rare and mild, some people attach more utility to vaccines that protects them against severe and common diseases. We anticipate that some people might choose drugs that protects against severe diseases because from economic point of view, it guarantees them a higher utility.

Risk perception about vaccination and infectious disease susceptibility was further examined. For the children's group, two distinct profiles were uncovered with one group exhibiting a high chance of VRSE occurrence and high VRSE severity (about 50%). On the contrary, the profiles of those in the second group indicates high perception about vaccine being highly effective with a low chance of VRSE and not severe VRSE. For adult group, two distinct profiles were witnessed. The first profile (consisting of 21% of individuals) perceives that there is a low chance of VRSE and less severe VRSE. The second group (about 79%) however perceives a moderate chance of getting VRSE and moderately severe VRSE. This conforms with our exploratory result showing about half of the population perceiving moderate chance and severity of side-effects.

Looking at the socio demographic characteristics and vaccine perception, we found that female respondents were more likely to perceive a moderate chance of getting VRSE and moderate severity of VRSE than male respondents which is supported by Freimuth (2017). We also found that those who were not infected with measles previously, were more likely to perceive a moderate chance of VRSE and moderate severity of VRSE with respect to those who were not. This was also witnessed in a study done by *Toure et al.* (2014) were they found out that after measles infection, the perception of adult respondents became more positive towards vaccination. Meanwhile for children's group, it was found that as the parent's age increases, they tend to perceive that there is a low chance and severity of VRSE.

It was checked whether perceptions also have an impact on vaccination behavior. The results for the children's group indicated that having a perception that one's child is less prone to contracting measles or less severe impact of measles on a child's health is related to being a self reliant (making own vaccination decision). This seems plausible because when the chance to contract a disease is minimal or the disease is not severe, people tend not to look for information about vaccination and so they take their own time to decide. In addition, a lower or moderate perception of severity of VRSE is related to being a vaccine acceptor. This is logical because when there is low risk of developing side-effects, people are more willing to get vaccinated. Mean while in the adult's group, perception about measles susceptibility and vaccination effectiveness had a significant impact on vaccination behavior.

We also looked at whether Flemish individuals misperceive vaccine side-effects. Our findings suggested that there exists two groups of respondents. One group knows among the postulated conditions, which ones are not VRSE. They also tend to misperceive the true vaccine related side effects as not being VRSE. In other-words to this group, vaccines are less likely to have any side-effects. The next group could distinguish between most true VRSE and non VRSE. In both the group, the respondents did not consider diarrhea and URTI as VRSE but rather perceived allergy as a MMR VRSE. Our analysis did not find any significant misperception of VRSE like autism, death, infertility or overloaded immune system (OIS) within the Flemish respondents.

Our findings revealed that when making vaccination decisions for children, men were more likely to take vaccine as not having related side effects compared to females which is supported by Freimuth (2017). In addition, all those with low education level were classified in the group with positive perception about vaccines. This is supported by Toure *et al.* (2014) study that found out that adults with low education level had a positive vaccination behavior. Another

finding showed that health workers were more likely to correctly perceive vaccine side-effects.

In conclusion, we showed from different aspects how taking unobserved heterogeneity into account greatly gives us the flexibility to have a more broader understanding of vaccination behavior, results from discrete choice experiment and misperception of VRSE. Our research indicated that there exist three different vaccination behaviors in Flanders; vaccination acceptors, information searchers/reliers and self reliant (hesitant) people. Understanding individual group's attitude is paramount if vaccination coverage is to be increased. Across all the groups, doctors recommendation was the most important. Health workers therefore, are very pivotal in trying influencing vaccination behaviors. Regarding risk perception, some profiles perceived vaccines to be risky while others perceived otherwise. Finally, most Flemish individuals do not regard autism, overloaded immune system, infertility or death to be vaccine side effects. However they are more likely to take allergic reaction as vaccine related side effects.

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6 APPENDIX

Table 21: *Adult group discrete choice latent class model result showing class specific attributes and influence of the socio demographic factors and attitudinal class memberships on the odds to belong to the second latent class compared to the first latent class. All the reference categories are indicated as Ref*

Variables	Levels	Class One Estimate		P-Value	Class Two Estimate		P-Value
Vaccine Effectiveness	Protects 50% (Ref)						
	Protects 90%	0.564	1.758	0.000	1.088	2.968	0.000
Disease Burden	Common & Mild (Ref)						
	Common & Severe	-0.579	0.560	0.000	1.810	6.109	0.000
	Rare & Mild	-0.060	0.943	0.557	-0.063	0.939	0.520
	Rare and Severe	-0.480	0.619	0.000	1.296	3.654	0.000
Side effects (VRSE)	Common (Ref)						
	Rare	1.168	3.217	0.000	0.836	2.307	0.000
Accessibility	Free (Ref)						
	Co-payment & Prescription	-0.863	0.422	0.000	-0.567	0.567	0.000
Local Coverage	30% (Ref)						
	60% Vaccinated	0.254	1.289	0.001	0.076	1.079	0.251
	90% Vaccinated	0.314	1.369	0.000	0.203	1.225	0.004
Population Coverage	30% (Ref)						
	60%	0.058	1.060	0.432	0.232	1.261	0.001
	90%	0.080	1.083	0.279	0.469	1.598	0.000
		Estimates (2/1)	Exponent (Odds 2/1)	P-value			
Class	(2)	1.050	2.858	0.000			
Sex	Female (Ref)						
	Male	-0.214	0.807	0.001			
Age group (years)	18 - 34						
	35 - 49	-0.700	0.496	0.000			
	50 - 64	-0.151	0.860	0.122			
	65 - 85	-1.058	0.347	0.000			
Attitude Class	1. Self Reliant (Ref)						
	2. Searchers and Reliers	0.264	1.303	0.001			
	3. Acceptors	0.218	1.244	0.009			
Province	Antwerp (Ref)						
	East Flanders	-0.630	0.532	0.000			
	Flemish Brabant	-0.416	0.660	0.000			
	Limburg	-0.665	0.514	0.000			
	Others	-0.872	0.418	0.006			
Education level	High (Ref)						
	Low	-0.862	0.422	0.000			
	Medium	-0.560	0.571	0.000			
Marital Status	Married/ together (Ref)						
	None	0.154	1.167	0.221			
	Single	-0.379	0.685	0.000			
Mother's birth Country	Belgium (Ref)						
	Other Country	-0.664	0.515	0.000			
Healthworker	No (Ref)						
	Yes	0.333	1.394	0.000			
History of Serious Illness	No (Ref)						
	Yes	0.243	1.276	0.000			
Annual flu vaccination status	Never (Ref)						
	Sometimes	0.368	1.445	0.000			
	Always	-0.506	0.603	0.000			
Religion	None (Ref)						
	Muslim	12.223	203465	NA			
	Catholic	0.255	1.291	0.000			
	Others	0.740	2.095	0.000			
Frequency of Religious service	Rare/Never (Ref)						
	Monthly	-0.576	0.562	0.001			
	Weekly/Often	-0.669	0.512	0.000			

Table 22: *Children group discrete choice latent class model result showing class specific attributes and influence of the socio demographic factors and attitudinal class memberships on the odds to belong to the second latent class compared to the first latent class. All the reference categories are indicated as Ref.*

Variable	Levels	Class One			Class Two		
		Estimates	Odds	P-Value	Estimates	Odds	P-Value
Vaccine Effectiveness	Protects 50% (Ref)						
	Protects 90%	0.705	2.024	0.000	1.417	4.125	0.000
Disease Burden	Common & Mild (Ref)						
	Common & Severe	-0.134	0.875	0.263	3.510	33.460	0.000
	Rare & Mild	-0.456	0.633	0.000	0.172	1.188	0.474
	Rare & Severe	-0.319	0.727	0.002	5.565	13.000	0.000
Side Effects (VRSE)	Common (Ref)						
	Rare	0.865	2.375	0.000	1.121	3.067	0.000
Accessibility	Free (Ref)						
	Co-Payment	-0.810	0.444	0.000	-0.772	0.462	0.000
Local Coverage	30% Vaccinated (Ref)						
	60% Vaccinated	0.354	1.424	0.000	0.094	1.098	0.363
	90% Vaccinated	0.450	1.568	0.000	-0.038	0.963	0.746
Population Coverage	30% Vaccinated (Ref)						
	60% Vaccinated	0.125	1.133	0.055	0.063	1.065	0.564
	90% Vaccinated	0.238	1.269	0.000	0.752	2.122	0.000
Variable	Level	Estimate	Exponent (Odds)	P-Value	Class One (%)	Class Two (%)	Total
Class	Class Two	0.710	2.034	0.000			
Gender	Female (Ref)						
	Male	-0.595	0.552	0.000			
Age group (Years)	18 - 34 (Ref)						
	35 - 49	-0.062	0.940	0.431			
	50 - 64	-0.486	0.615	0.000			
	65 - 85	0.987	2.684	0.000			
Attitude Class	Self Reliant (Ref)						
	Searchers & Reliers	-0.284	0.753	0.000			
	Acceptors	-0.118	0.889	0.204			
Province	Antwerp (Ref)						
	Brussels	-2.165	0.114	0.000			
	Limburg	-0.255	0.775	0.013			
	Others	0.613	1.846	0.014			
	West Flanders	-0.294	0.745	0.003			
Education level	High (Ref)						
	Low	1.038	2.823	0.000			
	Medium	-0.403	0.668	0.000			
	Others	0.688	1.990	0.014			
Employment Status	Unemployed (Ref)						
	Employed	0.402	1.495	0.000			
Marital Status	Married/Together (Ref)						
	Single	-0.228	0.796	0.006			
Number of Children		-0.256	0.774	0.000			
Mother's Country of birth	Belgium (Ref)						
	Other Countries	0.576	1.778	0.000			
Annual Flu Vaccination Status	Never (Ref)						
	Usually	-0.299	0.742	0.001			
Religion	None (Ref)						
	Orthodox/Protestant	-0.729	0.482	0.003			
	Others	-0.379	0.685	0.004			
Frequency of Religious Service	Rare/Never (Ref)						
	Monthly	-0.426	0.653	0.044			
	Weekly/Often	-0.779	0.459	0.008			

6.1 R CODES

```
Question 1: Heterogenious Vaccination Behavior
library("poLCA")
attach(vacbehave_adult)
## response items -- behaviors qn1 to 12
resp <- cbind(Adq16a_1, Adq16a_2, Adq16a_3, Adq16a_4, Adq16a_5, Adq16a_6, Adq16a_7,
Adq16a_8,    Adq16a_9, Adq16a_10, Adq16a_11, Adq16a_12,  Adq16a_13) ~q1+ qage+
Province+ Educlev+ EmployStat+ q6+  MumbCtry+ q10a+ q11+ q12+ q13+ q14+ q15



#Fitting the model
mod_lc2 <- poLCA(resp, vacbehave_adult, nclass = 2, graphs=TRUE, nrep=50)
mod_lc3 <- poLCA(resp, vacbehave_adult, nclass = 3, graphs=TRUE, nrep=50) ##Lowest
mod_lc4 <- poLCA(resp, vacbehave_adult, nclass = 4, graphs=TRUE, nrep=50) ##Lowest

#############################################################################
                DCE and Vaccination behavior Model
#############################################################################
Trial.lc3 <- gmnl(prefer ~ efficacy_new+impact_new+sideeff_new+reim_new+localcov_new+
globalcov_new| 0 | 0 | 0 | Sex.Male+ Age_group.35y.49y + Age_group.50y.64y+
Age_group.65y.85y+class_new.B +class_new.C +Province.Brussels+Province.East.Fland+
Province.Flemish.B+ province.Limburg+Province.Others+Province.West.Fland+
Educlev.Low+Educlev.Medium+EmployStat_new+Marital_Stat.None + Marital_Stat.Single +
MumbCtry.Not_Belgium+  Health_worker.Yes+ Illness.Yes + Flue_Vaccin.Sometimes +
Flue_Vaccin.Usually +Religion.Catholic+Religion.Muslim+Religion.Ortho_Protestant+
Religion.Others+Freq_RelService.Few.times+Freq_RelService.Monthly+Freq_RelService.
Weekly_Often,data = Trial_log,#subset = 1:3000,model = 'lc',panel = TRUE,
Q = 2)
summary(Trial.lc3)
For latent class 2,3,4, change Q=2 to Q=3,4 and Extract the BIC
#############################################################################
                    Objective two: Risk Perception
#############################################################################
```

```
## Fitting the Latent Class Regression Model
## response items -- behaviors qn1 to 12
resp <- cbind(MeasSeverity, MeasSuscept, VacEffective, ChanceVRSE, VRSESeverity) ~
Sex+q2+ Province+ Educlev+ + Marital_Stat + MumbCtry+ q10a  +  Health_worker +
Illness+ Flue_Vaccin+ Smoke_stat+ Religion+ Freq_RelService + VacMeas25a + HadMeasles

# Fitting the model
set.seed(1991)
mod_lc2 <- poLCA(resp, vacbehave_adult, nclass = 2, graphs=TRUE)
mod_lc3 <- poLCA(resp, vacbehave_adult, nclass = 3, graphs=TRUE)

##############################################################################
# Fitting multinomial model for impact of risk perception on vaccination behavior. We
#use the data from vaccination behavior heterogeneity and regress the risk perception
# on the three latent classes to see if they are significantly related to one class
# or not. Finally, All Variables with 3LatentClasses Adults Vac Behavior.csv
##############################################################################
datamultin <- read.csv("Final All Variables with 3LatentClasses Adults Vac
Behavior.csv", header=T)
datanew <- datamultin[datamultin$q2<33, ]
write.csv(datanew, "datanew2.csv")
#Delete the levels none from the data set and then re-read the data
datanew2 <- read.csv("datanew2.csv", header=T)
summary(datanew2)
require(foreign);require(nnet);require(ggplot2);require(reshape2)
test <- multinom(class ~ VacMeas25a + HadMeasles +
MeasSeverity + MeasSuscept + VacEffective + ChanceVRSE + VRSESeverity,
data = datanew2)
(summary(test))

# Test statistics
z <- summary(test)$coefficients/summary(test)$standard.errors
# 2-P-value
```

```
pvalue <- (1 - pnorm(abs(z), 0, 1)) * 2


################################################################################
# Objective Three: Impact of Misperception on Vaccination Behavior
################################################################################
testmisp <- multinom(class ~ Fever + Swelling + Death + Fatigue + SkinRash + OIS +
BlueSpot + Diarrhea +Autism + URTI + Infertility + Allergy)
(summary(testmisp))

zmisp <-summary(testmisp)$coefficients/summary(testmisp)$standard.errors
# 2-tailed z test
pvaluemisp <- (1 - pnorm(abs(zmisp), 0, 1)) * 2

################################################################################
##          Latent Class Regression Model for Misperception of VRSE
################################################################################
library("poLCA");attach(datamisp)
## response items -- behaviors qn1 to 12
resp_misperc <- cbind(q31_1fever,  q31_2Swelling, q31_3Death,q31_4Fatigue,
q31_5SkinRash,q31_6OIS, q31_7BlueSpot, q31_8Diarhoea, q31_9Autism,q31_10URTI,
q31_11Infertility, q31_12Alergy )~ q1+ qage+ Province+ Educlev+ EmployStat+ q6+
TotChild+ MumbCtry+ q10a+ q11+ q12+ q13 + q14+ q15

# Fitting the model
mod_lc2 <- poLCA(resp_misperc, datamisp, nclass = 2, nrep=20, graphs=TRUE) ##
mod_lc3 <- poLCA(resp_misperc, datamisp, nclass = 3, nrep=20, graphs=TRUE) ##
mod_lc4 <- poLCA(resp_misperc, datamisp, nclass = 4, nrep=20, graphs=TRUE) ##
```

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Richting: **Master of Statistics-Biostatistics**
Jaar: **2018**

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Datum: **20/08/2018**