Modeling the population's perception of security over time in Democratic Republic of Congo

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1 Introduction

Over the past ten years, there has been continuous armed conflict and economic and political instability in the Democratic Republic of the Congo (DRC). In 1997, Laurent Desire Kabila ended rule under Mobutu Sese Seko through a violent campaign. During the ongoing war, the country was divided into rebel-controlled, foreign-occupied territories. In 2002, the open armed conflict officially came to an end with the signing of a peace agreement. However, local conflicts still remains in the eastern Congo even now, fifteen years later. Despite the effort made by the Congolese government to rebuild the country and the ongoing United Nations peacekeeping mission, there has been little improvement in terms of peace and justice[1] [2]. While the conflict has been largely confined to the eastern DRC over the last few years, in North Kivu in particular, the situation remains volatile [3]. In discussions, Vinck noted that conflicts in Congo are often described as ethnic conflicts, despite a lack of formal study to assess this description. So our paper want to look into the evolvement of conflicts and see how it relates with ethnic relations.

One approach to understand what conflicts have caused and how it evolves on the way of peacebuilding is through population's attitudes and perceptions. For example, Vinck and Pham examined populations attitudes towards peace and justice in Uganda, revealing remained violence under conflicts between Ugandan government forces and Lord's Resistance Army [4]. Not only informative in terms of examining the conflicts, perception and attitudes can also provide guidance

on peace-building process. A study on attitudes in Israel played a crucial role in the policy making process[5]. A cross-sectional study on attitudes and perceptions towards health was conducted in Croatia, and served as a guide for developing a new public health plan [6].

In D.R.C., perceptions and attitudes towards security, justice and livelihood were collected and studied cross-sectionally. At 2008, the Human Rights Center (HRC) at the University of California, Berkeley, the Payson Center at Tulane University, and the International Center for Transitional Justice (ICTJ), conducted a survey of people most affected by the conflict in the DRC. In 2014, same researchers (now at Harvard Humanitarian Initiative (HHI)) conducted another survey for the most affected regions, and examined difference of attitudes and perceptions across regions[7]. From 2015, they conducted a series of polls following up the survey in 2008 and 2014. After each poll was conducted, researchers prepared an immediate cross sectional analysis [8]. Specifically, researchers examined the difference between gender and across regions to assess overall tendencies as well as to identify extreme behavior in certain regions. Relationships between different indicators are also of interest. For example, the presence of security actors might be positively associated with perception of security, while the experience of attack negatively associated with it.

Now with 10 surveys from 2015 to 2017, we want to use the element of time to enhance our understanding towards perceptions, especially about security and ethnic relations, and their relationship. Formally, there are two objectives for this paper: to model the changes in population's perceptions about security and ethnic relations, and to assess the relationship between these two perceptions when taking time effect into account.

One thing to clarify is that it requires casual analysis to claim whether conflicts are ethnic conflicts, so the relationship between perceptions about security and ethnic relations is still not sufficient evidence to make such claim. However, one need to be aware that the setting for this data set is not a trail, in that respondents come from different background, and unexpected events could happen that affect these perceptions. So before diving into the casual analysis, we want to first have a primary assessment for the relationship between perception about security and ethnic relations, with time information taken into account.

2 The survey and data

2.1 Sampling process and studying unit

The data is the responses to surveys conducted in the Congo. Respondents were selected by a multi-stage sampling process (procedure shown in Figure 1). At every stage, researchers sampled at the level of a smaller unit of region, from provinces to territories, groupements and then villages. Then for each survey, by design, researchers visited the villages and randomly selected approximately 8 respondents per village.The first three stages (territories, groupements, villages) are generally retained, but a new sample of individuals is formed every time. This is because following same individuals each time would potentially cause security issues to respondents and would lead to the more cost for collecting data.

In the practice of sampling, some adjustments were made to the above described process. First, even though the first three stages (territories, groupements, villages) are traceable, in practice, not all of the villages are visited for every survey. They visited most urban villages every 3 months and rural villages every 6 months. As a result, territories and groupements are also not visited for every survey. Second, sometimes villages were skipped or replaced for logistical reasons, including if security concerns limited access to a region. Third, in later surveys, new villages are added, requested by the UN, to increase coverage of some areas, called concentration areas. This analysis does not address the concentration areas, and focuses on the original sample, replacement that are a part of that schema.

With this traceable geographic structure of sample to study the change of perceptions, we have the choice of on which level, such as population level or village level, to model the change. We decide to go beyond population level, that is the change of mean perceptions, because mean perceptions cannot incorporate the region information of the sample. But here the perceptions are about security and ethic relations, and the change behavior of these perceptions is expected to differ across region. Thus, instead of studying the change of population mean perceptions, we model the change of perceptions on a region unit. In our case, the unit is groupement, because we currently don't have information about villages, and the number of territories is rather small.

2.2 Survey content and pre-process

Questions in the survey covers three main topics: security, justice and livelihood. See Appendix A for exact wording of questions for topics in our interest. For the questions that directly assess the

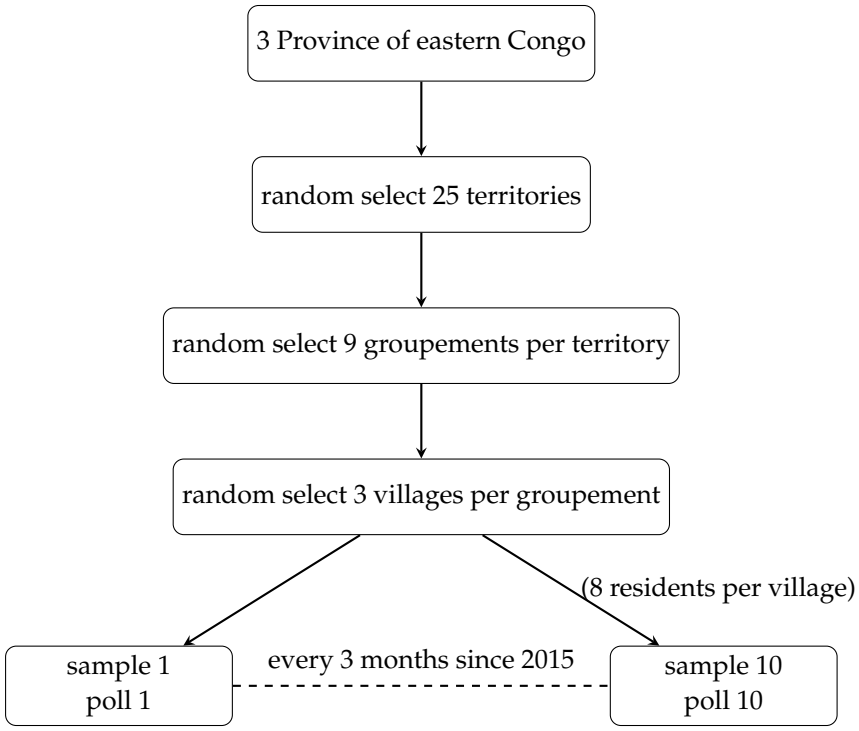


Figure 1: Multi-stage sampling processat every stage, researchers sampled at the level of a smaller unit of region, from provinces to territories, groupements and then villages.

Table 1: Items about perception of security in 4 aspects

Aspects	Items			
Daily activity	driving	walking alone	going to the nearest town	going to the nearest market
Night-time activity	sleeping at night	walking at night		
Interaction with people	meeting strangers	meeting people from other ethnic groups	meeting police officer	
Freedom of speech	talking openly about conflict experience	complaining to authority when you are a victim of crime		

perception of security, there are 12 items corresponding to 12 situations such as meeting strangers or walking alone at night. These 12 items address different aspects of the question of perception of security. One of them that asks about the perception towards armed groups and FARDC soldiers splits into two items at the 4th poll (see section 2.2 for detail descriptions). So we currently consider the other 11 items, and by description, they roughly measure 4 aspects of security (Table 1). As for perception about ethnic relations, one question in the topic of social cohesion asks about the relationship with people from other ethnic groups, which can be considered as a measurement for ethnic relations. Aside from questions about perception of security and ethnic relations, questions about exposure to violence and crimes are also examined when interpreting the change of perceptions.

Answers for every question are ordered categorical variables and are converted to integers for analysis. Specifically, for security and ethnic relations questions, the categories: “very bad”, “bad”, “medium”, “good”, “very good” are converted to 1 to 5 correspondingly. Some questions also provide choices like “without opinion” and “refuse to answer”, which are treated as missing values. Considering that there are significant amount of missing values and to make best use of data available, missing value are imputed by multiple imputation. This procedure predicts the value of missing entry for every respondent based on answers of other items and the demographic information such as ethnicity of this respondent, since for people of different background, missing value might correspond to different perceptions.

2.3 EDA

2.3.1 Sample size

1. Individual level:
   1547 respondents were interviewed for the first poll. For each of the other polls, around 4000 respondents were interviewed. Due to confidentiality reasons, identification of individuals are not available, which means it's not clear whether or how many individuals are repeated across polls. This affects whether the assumption can hold that data on groupement level are independent across polls, but for now, samples are considered to be independent across polls.

2. Groupement level:
   Since data is analyzed on groupement level to take advantage of time information, how the sample distributed on groupement level is also important. There are 261 groupements in total from 3 provinces, Ituri, North Kivu and South Kivu. Specifically, 64 of them are from Ituri, 98 of them are from North Kivu, and 94 of them are from South Kivu. For the first poll, 50 groupements were visited, and for every of the other polls, around 140 groupements were visited. Most groupements had around 24 respondents per poll. While the number of respondents per groupement per poll ranges from 1 to 236, the interquartile range (IQR) is from 23 to 31. Not all of the groupements were visited every time, because rural villages were visited every other poll. For most groupements (62% groupements), they were visited for 4 to 6 times. Note that 14 groupements are added later during this series of survey as a request from the UN as mentioned in Section 2.1, so this analysis focuses on the other 247 groupements.

2.3.2 Demographic information

Table 2 shows the demographic information of respondents (percentage are out of a single poll, and standard deviations are computed across polls). Some of the demographic information originally had multiple categories, but in this analysis, categories were combined to make it more easy to use. Appendix B presents the overall distributions for every demographic item as well as its variation across polls and on groupement level, and also gives brief reasons of combining rules.

Apart from the demographic information that's been for us, several measurements were also generated for every individual about assets, exposure to violence. Table 3 shows the basic information about these measurements. So far, the demographics and measurements assessed are all on indi-

Table 2: Demographics summary

	Mean	SD
Categorical		
Gender		
Male	49.71%	0.50%
Female	50.28%	0.50%
Income		
$150 per month or less	74.11%	3.48%
Higher than 150$ per month	9.07%	2.67%
NA	16.81%	3.72%
Religion		
Catholicism	45.79%	3.57%
Protestantism	38.72%	2.84%
other	15.18%	2.26%
NA	0.30%	0.14%
Ethnicity		
Nande	17.87%	4.68%
Shi	15.72%	6.19%
Other, to be specified	12.81%	2.86%
Other, specified	53.60%	6.13%
NA	0.00%	0.00%
Education		
Primary complete or less	43.76%	2.99%
Secondary incomplete or higher	55.91%	3.00%
NA	0.33%	0.15%
Job		
Agriculture	38.74%	5.99%
other	60.84%	6.14%
NA	4.22%	2.12%
Marital		
With partner(s)	72.54%	3.45%
Without partner	27.39%	3.45%
NA	0.06%	0.05%
Assets		
sum	4.56	2.34
index	0.00	1.98

Table 3: Demographic indexes

	Mean	SD overall	SD across polls
Witness exposure to violence			
Sum index	0.45	1.12	0.28
Binary index	0.19	0.39	0.11
Direct exposure to violence			
Sum index	0.20	0.63	0.13
Binary index	0.12	0.33	0.08
Exposure to crimes			
Sum index	0.66	1.06	0.20
Binary index	0.37	0.48	0.08
Displacement and separation			
Sum index	0.13	0.40	0.06
Binary index	0.10	0.30	0.04
Coercion			
Sum index	0.11	0.51	0.06
Binary index	0.07	0.25	0.04

vidual level, but since analysis mainly focus on groupement level, a measurement to characterize the features of grouepements, ethnic diversity is also generated. 247 groupemens in this analysis have median ethnic diversity of 0.17, with IQR from 0.02 to 0.50 See Appendix C for the definition for every measurements.

2.3.3 Questions of interest

This analysis mainly focuses on 11 questions about perception of security and one about perception of ethnic relations as mentioned in Section 2.2. Appendix D shows the overall distributions of answers for each questions. Out of the security questions, four questions about daytime activity seem to have a higher degree of security than the others when summarizing over all the samples across all polls. When it comes to security about freedom of speech, there are more people an-

swering "without opinion". The difference in the distribution of answers for different security questions indicates that we might want to generate more than one index for perception of security. As for ethnic relations, over 3/4 respondents think the ethnic relations are good or very good.

The histograms by poll for each question were also examined, to better see the effect of time. Data from first poll seems to have a relatively different pattern compared to the other polls, which might be a result of change of behavior over time, or relatively small sample size (roughly half individuals of other polls, see Section 2.3.1 for sample size information). Starting from the second poll, the data began to show consistent pattern over time.

To intuitively understand change pattern of perception of security and ethnic relations over time, the change of median score for each question on individual level are plotted (see Appendix D). It seems that many of the questions don't have change, possibly because median is taken over a heterogeneous sample, which motivates us to take into account the difference across samples (in our case, across groupements) when modeling the change.

To have a general idea about relationship between perception of security and ethnic relations, correlation between questions about perception of security and ethnic relations was assessed (see Appendix E for correlation table). Correlations for any of the 10 polls is less than 0.5, even though correlation with security level when meeting people from other ethnic groups is generally higher than other perception of security questions. These relatively low correlations indicate to some extend that perception of security item have little overlapping information with ethnic relations item according to correlation values, even if it's asking about security level when engaging with people from other ethnic groups.

3 Methods

On the way to our two objectives: model changes in perceptions about security and about ethnic relations, and assess relationship between these perceptions, there are three main steps:

1. Create indexes: before modeling the changes, indexes need to be defined about how to measure perception of security.

2. Assess change over time: to make use of time information when studying the relationship, the change of index for perception of security over time as well as the change of ethnic relation over time need to be analyzed.

3. Assess relationships: assess the relationship between change pattern of perception of security and ethnic relations. (eg. Increase in ethnic relation could be related with increase in perception of security.)

Specifically, indexes is created by assessing the overall dimensionality of all the items. To understand the change pattern with groupement difference taken into account, Group-Based Trajectory Modeling (GBTM) [9] was used for modeling the change, which identifies clusters of groupements based on the change pattern over time. When it comes to assess the relationship between two indexes, an extension of GBTM method was used to simultaneously study two indexes [10], and presented the relationship by showing the probability distribution of one index after observing the trajectory of the other index.

One of the fundamental assumptions for all of the above study is that, the answering criterion is consistent across different population. However, this assumption doesn't necessarily hold, especially for sensitive questions related to security. For example, when respondents are asked if they feel safe to walk in the night, it's possible that people who select answer "safe" might have very different descriptions of what "safe" means across different subpopulations such as female and male. Thus, aside from the above primary objectives, the consistency of answering criterion across subpopulations was also checked. In most cases, this analysis is done before huge amount of data is collected in order to adjust the design of questions. However, in this paper, answers were treated as a consistent measurement of perceptions across different subpopulations, but still were examined if consistency assumption holds, to give advice for further data collection.

3.1 Generating index

To generate the index for perception of security, there are two problems need to be addressed: 1. decide which ones of the questions form the index; 2. decide the weights for each question. Briefly, questions to form index was chosen by factor analysis, and the reliability and consistency for questions inside the index were checked. Then for each index, we use equal weight for questions inside the index. Appendix F shows the detailed procedure and justification of our choice of methods.

3.2 A model for change over time

For each of the three perceptions (personal security, freedom of speech security, and ethnic relations), its change over time is modeled by Group-Based Trajectory Modeling (GBTM)[9]. This

algorithm adopts the mixture model framework and models the change over time by regression on time points. By this mixture model framework, it can identify distinct classes of change pattern and classifies the population according to the classes of change pattern.

GBTM is suitable in our setting based on two observations from the data. First, the change of perception differs much across groupements (see Figure). GBTM can take this difference into account, and identify different classes of groupements according to the change pattern (see Figure). It then allows us to study the characteristics of different classes, which might reveal the connection between the characteristics and the change of perception. Second, perception is not recorded at same time points for all the groupements. By design, urban groupements should have records every three months, while rural groupements every six months. In practice, at some time points, some groupements were skipped or replaced. Such data issues, different time periods across groupements and different spans between recording time points, can be accommodated by GBTM.

The framework of GBTM is similar to mixture model. Specifically, suppose groupement i have n_i recorded perception $Y_i = \{Y_{i1}, \cdots, Y_{in_i}\}$ at time $\{t_1, \cdots, t_{n_i}\}$. The probability for observing Y_i is constructed through a mixture model of N classes:

$$P(Y_i) = \sum_{j}^{N} P(Y_i|Class_j)P(Class_j).$$

Based on this framework, GBTM models the change over time by making the model for each class $P(Y_i|Class_j)$ a regression model on the recording time points. That is, for each class j, the perception is regressed on time points by generalized linear model (GLM),

$$Y_{ik}^j \sim g(\beta_0^j + \beta_1^j t_k + \cdots + \beta_d^j t_k^d), \quad k = 1, \cdots, n_i,$$

where usually degree d is less or equal to 3 and the choice for link functions g of GLM is dependent on the observed variable. This regression model then provides the expression of $P(Y_i|Class_j)$ in the mixture model framework.

When fitting GBTM, three kinds of parameters need to be estimated: prior probabilitiy for each class $P(Class_j)$, coefficients in regression model β, and the number of classes N. $P(Class_j), \beta_j$ can be estimated using MLE. For the number of classes, when there is no prior information, multiple models with different number of classes are fitted, and compared according to BIC to find the best model.

One limitation when using GBTM lies in the fact that we treat the averaged perception from a groupement as a single sample, making the variance inside groupement not counted. In the future, we might want to adjust the method to take into account the variance inside groupement.

3.3 Assessing relationships

To study the relationships between trajectories of two variables, dual trajectory modeling is introduced [10], which is an extension of GBTM. The key outputs of dual model are: 1.trajectory classes for both variables; 2.the probability of membership in each class; 3. link probability: the probabilities linking membership across variables. The improvement lies in the third output. Traditional analysis for relationships between two variables is a correlation coefficient for each time point, which use longitude data inefficiently and view the population as a single group. However,the dual model take into account the effect of time explicitly by studying the relationship between trajectories. Also, by presenting the probabilities linking every class combinations for two variables, it prevents relationship of different trajectory groups from being cancel out, which might happen in the case where only the averaged relationship is extracted. Link probability can be represented by conditional probability $\pi_{k|j}$ or joint probability π_{kj}. In this analysis, $\pi_{k|j}$ can tell us the possibility of observing a certain perception of security trajectory when having observed a type of ethnic relation trajectory. For example, a possible conclusion would be groupements with increasing ethnic relations are more likely to have increasing perception of security.

The probabilistic model for dual model is as follows. Denote the observation of two variables as y_1,y_2. Assume that conditional on j and k, Y1 and Y2 are independently distributed, $P_{jk}(y_1, y_2) = h^j(y_1)l^k(y_2)$. The overall likelihood for two variables is given by

$$P(y_1, y_2) = \sum_j \pi_j h^j(y_1)(\sum_k \pi_{k|j} l^k(y_2))$$

3.4 Understanding item responses

Item response theory (IRT) was applied to model the response with respect to certain level of perception and check consistency of responses across different subpopulations. IRT specifies a mathematical function (characteristic curve) relating the probability of a respondent's response on a test item to an underlying ability [11]. In our case, the underlying ability is perception of security or of ethnic relations.

For a simple dichotomously scored item, the probability of "correct" response to an item is modeled as a function of respondent's ability level θ using logistic regression [12]. The resulting curve is called characteristic curve. The parameters characterize the features of this item.

$$P(x = 1|\theta) = c + (1 - c)\frac{1}{1 + e^{a(\theta - b)}},$$

where

- a is discrimination parameter, which describes how well an item can differentiate between respondents having abilities below the item difficulty and those having abilities above the item difficulty. The greater the value is, the better if can differentiate.
- b is difficulty parameter, which describes where the item functions along the ability scale, in other words, how hard is the item for the population. The greater the value is, the more difficult the item is.
- c is guessing parameter, it's the probability of getting the item "correct" by guessing alone. Note that it's assumed to not vary as a function of ability.

Appendix G introduces the extension of the above simple model for ordered multiple choice item, and diagnostic statistics.

The method to test if the relationship between answers and ability is different across populations is called differential item functioning (DIF) and differential test functioning (DTF) if we are examining over a test of multiple items. Specifically, we learn models for every subpopulation, and test if the item parameter is the same.

4 Results

4.1 Generating indexes

To measure the perception of security, three indexes were generated by first assessing overall dimensionality and then forming indexes based on dimensional structure.

4.1.1 Overall dimensionality

To decide which ones of items form the index(es), the overall dimensionality of all the items was explored, and items that fall into the dimension of perception of security were selected. We also checked the reliability of dimension structure and internal consistency for the candidate items.

The overall dimensionality was explored by exploratory factor analysis (EFA) on data from second poll. The reason for choosing the second poll is that EDA (Section 2.3.3) suggested that the data on first poll seems to have a relatively different pattern compared to the behavior of other polls, so data from second poll was used for EFA as it is the start of polls that seem to have similar behavior patterns. As a result, items about perception of security fall into two factors. One factor with 9 items can be interpreted as measurement for personal experience, and the other with 2 items can

be interpreted as freedom of speech regarding conflicts. For factor analysis result of all the items, see Appendix H.

To check reliability, that is to see whether this overall dimensionality holds for other polls, confirmatory factor analysis (CFA) was conducted on data from every single poll except for poll 2, and goodness of fit for confirmatory factor analysis was evaluated to assess the reliability. Overall, the dimension structure holds fairly well for every poll (see Appendix I for detailed results). Another thing to check is internally consistency of items in index, which means items in index should be strongly interrelated, so that the index generated can be representative of what we want to measure in every poll. The relatively high value of both Cronbach's alpha and ω_t for every poll indicates that items about perception of security are internally consistent (see Appendix I for detailed result).

To summarize, exactly 11 items that directly measure the perception of security fall into the dimension of perception of security and form two factors: personal experience security, and freedom of speech security. This dimension structure holds relatively good for all the polls, and the factors are representative of what we want to measure.

4.1.2 Forming indexes

Since the two factors are measuring different aspects of perception of security, we decided to create two indexes, one for each factor. However, one concern is that, there might be overlapping information between personal experience security factor and ethnic relations item. This is because, in that factor, one item asks about security level when meeting with people from other ethnic groups. However, by assessing the correlations between perception of security items and ethnic relations item (Table 12), the overall the correlations with item about meeting with people from other ethnic groups is not large: most are below 0.35, which indicating not much overlap. Still, two versions of personal experience security index were created, a long version and a short version. The long index have 9 items which are explored by factor analysis, and the short index have 6 items, in which we exclude 3 items about interaction with others, so that the possible overlapping with ethnic relations can be avoided.

In the end, three indexes for perception of security were created: personal experience security (long version), personal experience security (short version), freedom of speech. And for ethnic relations, the index is the answer from item that asking about relationship with people from other ethnic groups.

Table 4: Security and ethnic relations score summary

	Mean	SD	Missing (%)
Personal experience security (long)	3.44	0.70	0.89
Personal experience security (short)	3.50	0.73	0.53
Freedom of speech security	3.10	0.97	6.15
Ethnic relations	3.88	0.68	6.77

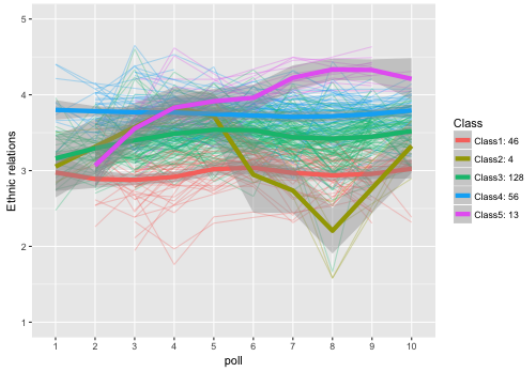
As one of the standard scores for factor analysis procedure, each index score is calculated by assigning equal weights to questions in that index, and then integragated to groupement level. Specifically, perception of security index scores for every groupement is the mean score for people within one groupement for a certain poll. Ethnic relations index score is the the median instead of mean, since the raw score for individuals is discrete. Table 4 shows the summary of four index scores overtime.

4.2 Modeling the change overtime

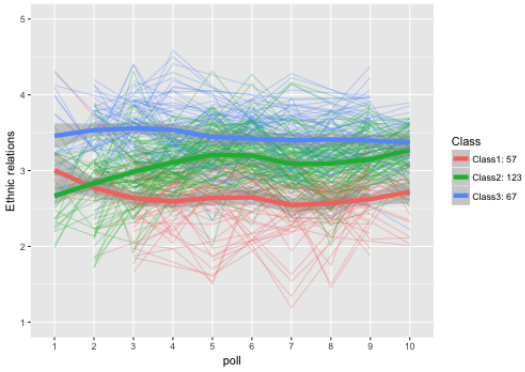
With three indexes about preception of security, and one about perception of ethnic relations, the change over time of these four indexes were modeled with groupement difference taken into account by GBTM. For each index, we compared the models with between 2 to 6 classes (for ethnic relations, we also tried 7 classes), and a model with local optimal BIC was chosen. Aside from unsatisfying BIC, when the number of groups continue to increase from the model we chose, the trajectories of different groups starts to mix together, which counter the goal of GBTM, to classify trajectories. Figure 2 and the later subsections present the result of classification and features extracted for each class. We decided to use long index for personal experience security, because the classification result for short index is not stable before and after applying the dual analysis (see Appendix J for detailed result and reasoning).

4.2.1 Security level about personal experience (long)

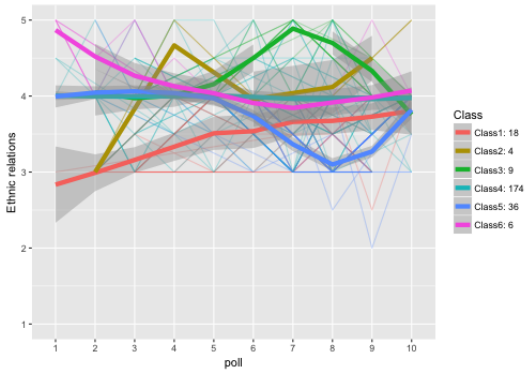
The personal experience security index (long version) with 9 items describes the security of some daily life experience. Trajectory model with 5 classes (Figrue 2a) was chosen by comparing BIC



(a) Trajectory class for personal experience security score (long index)



(b) Trajectory class for freedom of speech security



(c) Trajectory class for ethnic relations score

Figure 2: Trajectory classification for perception of security and of ethnic relations indexes

(see Appendix K for BIC of different models). As shown in the plot, class 2 has a very distinctive fluctuating security change pattern, but this class is not emphasized due to the small number of groupements, so this analysis won't much emphasize class 2. Groupements in class 1, class 3 and class 4 has relatively stable security, and the main difference between classes is overal security level. Security level for groupements in class 5 is consistently increasing overtime. In general, class 1 to 5 have roughly increasing level of security.

With five classes of groupements, the demographic information in each class was extracted (Table 5). There are apparent difference for ethnicity distribution across classes, and the exposure to violence indexes, which decrease as level of security increases. In Appendix K, the geographical information for each class was also extracted. With this information, we might be able to explore the security level and variance in different administrative regions in the future.

4.2.2 Security level about freedom of speech

The freedom of speech security index with two items asks security level when talking openly about conflict experience and when complaining to authority when you are a victim of crime. Trajectory model with 3 classes (Figure 2b) was chosen by comparing BIC (see Appendix L for BIC of different models). As shown in the plot, security level for three classes are all relatively stable, with difference overall value and the number of groupements in every class is rather balanced.

With three classes of groupements, the demographic information in each class was extracted (Table 6). The apparent difference across classes still lies in ethnicity distribution and the exposure to violence indexes, which tend to decrease as level of security increases. In Appendix L, the geographic information was also extracted.

4.2.3 Ethnic relations

One question in social cohesion topic formed the ethnic relations index (see Section 4.1.2 for details). Trajectory model with 6 classes (Figure 2c) was chosen by comparing BIC(see Appendix M for BIC of different models). Among six classes, class 2, class 3, and class 6 have less than 10 groupements each, so analysis was focused on the other three classes. More than half of the groupements belong to class 4, whose ethnic relations remains fairly good over all 10 surveys. Ethnic relations for class 1 is constantly increasing, but still not good overall. One interesting observation is that class 3 and class 5 have opposite change pattern during 5th to 9th survey, and the turning points in these two change pattern is also worth looking into. However, in the scope

Table 5: Group demographic info for personal experience security (long)

			Overall	Class1	Class2	Class3	Class4	Class5
		Number of groupements	247	46	4	128	56	13
Type	Demographic	Category						
Personal	Age	Mean age	37.20	36.80	39.00	37.14	37.43	37.68
	Gender	Female	51	52	50	50	50	50
	Income	Low income	76	74	79	75	78	86
	Assets	Weighted index	0.26	0.24	0.67	0.19	0.45	0.10
	Religion	Catholic	47	49	44	44	51	62
		Protestant	37	38	36	39	35	27
		Other religion	15	13	20	16	13	10
	Education	Low education level	36	36	56	35	35	40
	Job	Agricultural	44	47	61	39	49	62
	Marital	With partner	74	70	73	73	77	80
	Ethnicity	Nande	23	56	13	22	4	0
		Shi	14	1	0	12	25	26
		Other, to be specified	11	8	6	11	10	31
		Other, specified	52	35	81	55	60	43
	Ethnic diversity		0.31	0.17	0.32	0.37	0.28	0.24
	Witness exposure	Experienced	20	30	30	20	15	7
		number	0.49	0.80	0.74	0.49	0.32	0.11
	Direct exposure	Experienced	13	22	15	13	8	6
		number	0.22	0.36	0.23	0.21	0.14	0.11
	Crime	Experienced	37	42	46	35	36	43
		number	0.65	0.76	0.97	0.60	0.61	0.81
	Displacement	Experienced	12	19	15	11	10	4
		number	0.15	0.24	0.19	0.13	0.12	0.05
	Coercion	Experienced	7	9	13	7	7	3
		number	0.12	0.16	0.19	0.11	0.12	0.05
Groupement	Province	Ituri	55 (0.22)	6 (0.13)	0 (0.00)	26 (0.20)	18 (0.32)	5 (0.38)
		NorthKivu	98 (0.40)	29 (0.63)	4 (1.00)	50 (0.39)	15 (0.27)	0 (0.00)
		SouthKivu	94 (0.38)	11 (0.24)	0 (0.00)	52 (0.41)	23 (0.41)	8 (0.61)

Table 6: Group demographic info for freedom of speech security
(For personal demographics other than age, the number is the percentage)

			Overall	Class1	Class2	Class3
		Number of groupements	247	57	123	67
Type	Demographic	Category				
Personal	Age	Mean age	37.20	37.47	37.04	37.29
	Gender	Female	51	50	51	49
	Income	Low income	76	74	76	79
	Assets	Weighted index	0.26	0.24	0.22	0.35
		Number	4.27	4.33	4.30	4.16
	Religion	Catholic	47	51	43	52
		Protestant	37	36	40	34
		Other religion	15	13	16	14
	Education	Low education level	36	41	33	36
	Job	Agricultural	44	51	38	50
	Marital	With partner	74	71	73	78
	Ethnicity	Nande	23	59	17	4
		Shi	14	1	13	25
		Other, to be specified	11	5	13	13
		Other, specified	52	34	57	59
	Ethnic diversity		0.31	0.13	0.40	0.28
	Witness exposure	Experienced	20	30	19	14
		Number	0.49	0.79	0.45	0.31
	Direct exposure	Experienced	13	22	12	8
		Number	0.22	0.33	0.20	0.15
	Crime	Experienced	37	40	35	38
		Number	0.65	0.70	0.61	0.68
	Displacement	Experienced	12	17	10	11
		Number	0.15	0.22	0.12	0.13
	Coercion	Experienced	7	9	7	7
		Number	0.12	0.15	0.10	0.12
Groupement	Province	Ituri	55(0.22)	5 (0.08)	28 (0.22)	22 (0.33)
		NorthKivu	98(0.40)	41 (0.72)	43 (0.34)	14 (0.21)
		SouthKivu	94(0.38)	11 (0.19)	52 (0.42)	31 (0.46)

of this analysis, time varying features for classes was not included, so little can be reveal for the turning points.

With six classes of groupements, the demographic information in each classes was extracted(Table 7). The apparent difference across classes still lies in ethnicity distribution. And the decreasing trend for exposure to violence indexes still hold for higher level trajectories (i.e. class 2, class 3, class 4, class 6). In Appendix M, the geographic information was also extracted.

4.3 Assessing relationships

With the several trajectory shapes for each index, dual GBTM (see Section 3.3) was applied to assess the relationship between each of the two perception of security indexes and perception of ethnic relations index.

4.3.1 Personal experience security (long index) VS ethnic relations

This section shows the dual GBTM result for personal experience security (long index) and ethnic relations. Note that when we apply dual GBTM, the memberships for groupements are not guaranteed to be same as GBTM for a single index. So before looking at link probabiltiy, the membership change before and after the applying the dual GBTM was examined, and as a result, the classification for ethnic relations changed a bit (see Appendix N for detailed results). Specifically, some of the groupements that are originally in Class 4 separate out as a new class, which in this case is labeled as Class 2. So when looking at the link probability, one should keep in mind that Class 2 now is different from what's being discovered before, just sharing the same name.

Relationship (link probability)

Table 8 shows the conditional probability for ethnic relations membership, conditioning on membership for personal experience security (long index). The percentage in the bracket under each ethnic relations trajectory class is the marginal distribution. Conclusions are drawn by comparing ethnic relations membership difference for different conditions, that is, assuming different personal experience security trajectory type. For the personal experience security class with most groupements (Class 3), the conditional distribution for ethnic relations classes is similar as marginal distribution. In other words, the conditional distribution of ethnic relations classes for groupements belonging to Class 3 dominant the marginal distribution. While the 100% for security class 2 and 5 seems interesting, the number of groupements are small, so analysis is not focused on these two cases. For high security level class (class 4), a groupement's ethnic relations is very

Table 7: Group demographic info for ethnic relations

(For personal demographics other than age, the number is the percentage)

			Overall	Class1	Class2	Class3	Class4	Class5	Class6
Number of groupements			247	18	4	9	174	36	6
Type	Demographic	Category							
Personal	Age	Mean age	37.20	35.84	36.38	37.25	37.38	37.39	36.16
	Gender	Female	51	51	63	50	50	50	50
	Income	Low income	76	77	86	84	76	76	66
	Assets	Weighted index	0.26	0.89	1.35	-0.21	0.14	0.61	-0.36
		Number	4.27	3.56	2.87	4.77	4.41	3.87	4.94
	Religion	Catholic	47	38	76	61	48	44	50
		Protestant	37	41	18	28	38	39	34
		Other religion	15	21	6	11	14	17	16
	Education	Low education level	36	43	62	34	32	48	35
	Job	Agricultural	44	58	43	52	42	52	27
	Marital	With partner	74	75	81	79	73	76	71
	Ethnicity	Nande	23	22	0	1	22	33	7
		Shi	14	7	74	33	13	9	15
		Other, to be specified	11	3	25	31	12	3	18
		Other, specified	52	68	1	35	52	54	59
	Ethnic diversity		0.31	0.16	0.26	0.26	0.33	0.26	0.50
	Witness exposure	Experienced	20	35	7	10	19	22	13
		number	0.49	0.98	0.12	0.26	0.46	0.55	0.28
	Direct exposure	Experienced	13	24	6	6	13	13	7
		number	0.22	0.37	0.13	0.11	0.22	0.20	0.09
	Crime	Experienced	37	55	23	51	34	41	32
		number	0.65	0.89	0.40	1.04	0.60	0.71	0.56
	Displacement	Experienced	12	26	3	5	10	14	9
		number	0.15	0.35	0.03	0.06	0.13	0.17	0.11
	Coercion	Experienced	7	11	3	4	7	8	4
		number	0.12	0.16	0.07	0.09	0.12	0.12	0.07
Groupement	Province	Ituri	55(0.22)	0 (0.00)	1 (0.25)	2 (0.22)	51 (0.29)	0 (0.00)	1 (0.17)
		NorthKivu	98(0.40)	6 (0.33)	0 (0.00)	0 (0.00)	62 (0.36)	26 (0.72)	4 (0.66)
		SouthKivu	94(0.38)	12 (0.67)	3 (0.75)	7 (0.78)	61 (0.35)	10 (0.28)	1 (0.17)

Table 8: Link probability for ethnic relations membership given personal experience security (long index) membership

P(ethnic relations given personal experience) (%)		Ethnic relations classes					
		Class 1: bad but increasing (7.29)	Class 2: good and stable (11.34)	Class 3: good, hill shaped (3.64)	Class 4: good and stable (61.54)	Class 5: bow shaped (14.57)	Class 6: decreasing then stable (2.43)
Personal experience classes	Class 1: low, stable	13.82	61.22	0.00	0.00	24.96	0.00
	Class 2: fluctuating	0.00	0.00	0.00	0.00	100.00	0.00
	Class 3: increasing then stable	9.85	11.08	0.00	64.22	13.80	1.05
	Class 4: good and stable	0.00	0.00	0.00	83.80	1.00	15.19
	Class 5: increasing	0.00	100.00	0.00	0.00	0.00	0.00

likely to be also fairly good, when personal experience security is high and stable over time, which fits intuition. However, the situation for low security level class (class 1) is more complicated. By comparing with the marginal distribution, what makes intuitive sense is that, the ethnic relations is more likely to not be good (ethnic relations class 1 and class 5). But surprisingly, it's also more likely to have good and stable ethnic relations (ethnic relation class 2), comparing to marginal.

Demographics

To better understand what kind of grouepments are in these two-way class, demographic information are extracted for large size classes (with at lease 5% of the groupements). Table 9 shows the extracted demographic information and in the notation of classes, "Class1-4" stands for the groupements that belong to Class 1 of personal experience security, and Class 4 of ethnic relations.

One interesting finding from the demographic information is some possible explanation of Class1-2, which is counter intuitive because low security level is related with good ethnic relations. Specifically, as shown in the table, for Class1-2, the ethnicity diversity is very low, which could lead to relatively high ethnic relations. Also, the indexes about exposure to violence are high comparing to other classes, which could lead to low level of security feelings, especially when it's about personal experience security.

4.3.2 Freedom of speech security VS ethnic relations

This section shows the dual GBTM result for freedom of speech security and ethnic relations. Similarly as previous section, before looking at link probability, the membership change before

Table 9: Group demographic info for personal experience security VS ethnic relations

			Overall	Class1-2 [a]	Class3-4	Class3-5	Class4-4
		Number of groupements	247	28	91	18	59
Type	Demographic	Category					
Personal	Age	Mean age	37.20	37.15	37.36	36.97	37.51
	Gender	Female	51	50	50	50	50
	Income	Low income	76	73	74	78	70
	Assets	Weighted index	0.26	-0.10	0.00	0.68	0.44
	Religion	Catholic	47	51	44	45	53
		Protestant	37	38	39	40	35
		Other religion	15	11	16	15	12
	Ethnicity	Nande	23	63	22	29	5
		Shi	14	1	13	12	21
		To be specified	11	11	13	2	10
		Other ethnic	52	25	52	57	63
	Ethnic diversity		0.31	0.18	0.40	0.30	0.29
	Education	Low education level	36	32	30	50	34
	Job	Agricultural	44	43	34	49	51
	Marital	With partner	74	68	72	76	77
	Witness exposure	Experienced	20	31	19	17	14
		number	0.49	0.83	0.45	0.38	0.30
	Direct exposure	Experienced	13	25	12	10	8
		number	0.22	0.42	0.21	0.16	0.14
	Crime	Experienced	37	36	33	34	36
		number	0.65	0.66	0.59	0.52	0.60
	Displacement	Experienced	12	18	8	12	10
		number	0.15	0.24	0.10	0.15	0.12
	Coercion	Experienced	7	9	7	6	7
		number	0.12	0.17	0.10	0.08	0.13
Groupement	Province	Ituri	55 (0.22)	6 (0.21)	23 (0.25)	0 (0.00)	23 (0.39)
		NorthKivu	98 (0.40)	20 (0.71)	29 (0.32)	14 (0.78)	14 (0.24)
		SouthKivu	94 (0.38)	2 (0.07)	39 (0.43)	4 (0.22)	22 (0.37)

[a] In the notation of classes, "Class1-4" stands for the groupements that belong to Class 1 of personal experience security, and Class 4 of ethnic relations.

Table 10: Link probability for ethnic relations membership given freedom of speech security membership

P(ethnic relations given freedom of speech) (%)		Ethnic relations classes					
		Class 1: bad but increasing (7.29)	Class 2: good and stable (11.34)	Class 3: good, hill shaped (3.64)	Class 4: good and stable (61.54)	Class 5: bad, bow shaped (14.57)	Class 6: decreasing then stable (2.43)
Freedom of speech classes	Class 1: low, stable	23.65	0.00	0.00	38.32	33.78	4.25
	Class 2: increasing	0.00	0.00	0.00	92.77	7.23	0.00
	Class 3: good, stable	0.00	7.46	20.44	61.84	1.44	8.82

and after applying dual GTBM is examined and not much change was found. (see Appendix O for detailed results).

Relationship (link probability)

Table 10 shows the conditional probability for ethnic relations membership, conditioning on membership for freedom of speech security. The percentage in the bracket under each ethnic relations trajectory class is the marginal distribution. Consistent with findings from relationship for personal experience security, bad ethnic relations corresponds to low security level of freedom, and, good corresponds to high level.

Demographics

Similarly, to better understand what kind of groupements are in these two-way class, demographic information are extracted for large size classes (Table 11). When comparing across classes, the variation for ethnic diversity appear to be larger than for exposure to violence indexes. This make sense because here the security is about freedom of speech, which is more likely to affected by ethnicity of oneself and surrounded with.

4.4 Understanding items and their answers

One important assumption when we performed all the above analysis is that the answering criterion is consistent across different population. To check this assumption, the answering pattern of 9 items about personal experience security is modeled by multidimensional graded response model (see Section 3.4 for description of model), because there are 4 aspects being measured by parallel analysis. Similarly as the procedure of factor analysis, multidimensional IRT consists of

Table 11: Group demographic info for freedom of speech security VS ethnic relations

			Overall	Class1-1	Class1-4 [a]	Class1-5	Class2-4	Class3-4
		Number of groupements	247	16	29	26	118	27
Type	Demographic	Category						
Personal	Age	Mean age	37.20	35.44	37.51	37.61	37.30	37.16
	Gender	Female	51	51	50	50	50	50
	Income	Low income	76	77	75	74	75	81
	Assets	Weighted index	0.26	0.92	-0.25	0.66	0.16	0.56
	Religion	Catholic	47	40	57	47	43	54
		Protestant	37	39	33	36	41	35
		Other religion	15	21	10	17	16	11
	Ethnicity	Nande	23	25	77	48	14	2
		Shi	14	7	1	2	13	30
		To be specified	11	3	8	2	14	6
		Other ethnic	52	65	14	47	59	62
	Ethnic diversity		0.31	0.15	0.11	0.19	0.40	0.23
	Education	Low education level	36	43	33	47	31	36
	Job	Agricultural	44	58	41	55	39	53
	Marital	With partner	74	74	78	75	73	78
	Witness exposure	Experienced	20	36	28	24	19	16
		number	0.49	1.04	0.74	0.60	0.44	0.32
	Direct exposure	Experienced	13	26	22	15	11	10
		number	0.22	0.40	0.36	0.23	0.20	0.17
	Crime	Experienced	37	57	33	43	32	37
		number	0.65	0.92	0.57	0.75	0.59	0.62
	Displacement	Experienced	12	27	14	16	9	13
		number	0.15	0.37	0.18	0.19	0.11	0.16
	Coercion	Experienced	7	12	8	9	6	10
		number	0.12	0.14	0.15	0.12	0.10	0.17
Groupement	Province	Ituri	55 (0.22)	0 (0.00)	5 (0.17)	0 (0.00)	33 (0.28)	11 (0.41)
		NorthKivu	98 (0.40)	6 (0.38)	24 (0.83)	20 (0.77)	33 (0.28)	5 (0.19)
		SouthKivu	94 (0.38)	10 (0.62)	0 (0.00)	6 (0.23)	52 (0.44)	11 (0.41)

[a] In the notation of classes, "Class1-4" stands for the groupements that belong to Class 1 of freedom of speech security, and Class 4 of ethnic relations.

exploratory analysis and confirmatory analysis. Till the writing of this paper, exploratory analysis for 9 items based on data from second poll.

Since multidimensional model with more than 2 latent trait didn't converge, the model in the following analysis assumes 2 latent trait. However, the diagnostics for this model indicates a not good fit for the data. Though, by G^2 statistics, the fit is good overall (p-value = 1), it's not good for every single item according to chi-square testing (p-value = 0). It's also not a good fit for over 60% of the individuals according to Z_h statistics ($Z_h < 0$ indicates worse fit than expected). Nevertheless, the result is presented here, as a tentative analysis for item response pattern.

Figure 3 shows the characteristic curves for each item. The five curves in each item represent the characteristic function for each of the 5 answer options. As shown, one of the main difference between items is the direction of the curve, which indicates that some items are more focused on measuring one latent trait than the other. Specifically, items about night time activities ("walking at night" and "sleeping") and the item about meeting police are more focused on the first latent trait. Another thing to note is that some items (eg. going to town, going to market) don't have very distinguishable pattern for different answers. For these items, one suggestion is to cut down the answer options in the future study.

The assumption that different subpopulations have consistent answering criterion was tentatively checked by DIF result for unidimensional model because the DIF model with 2 latent traits didn't converge. Difference was tested in terms of gender, ethnicity, income, province (see Appendix P for corresponding p-values). By ethnicity, or by province information, or by gender, the difference between subpopulations is significant for every item. By income, the difference for items "walking alone", "walking at night", "going to town" are not significant (p-value > 0.05). For other items, the difference for income subpopulations is still significant.

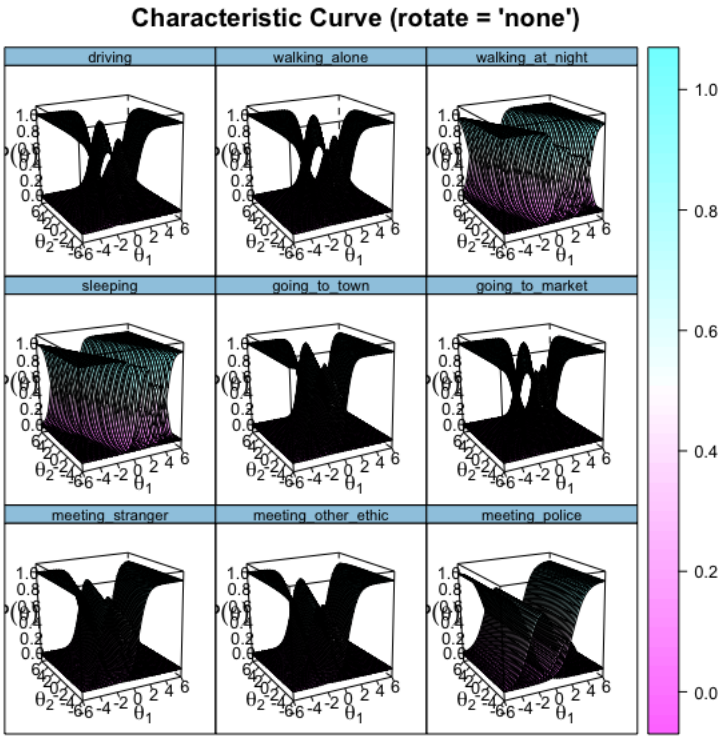


Figure 3: Characteristic curves for 9 items about personal experience security

5 Discussion

To summarize, the change pattern for perception of security are different across groupements, and the difference mainly lies in security level than trajectory shape. For both perception of security and of ethnic relations, the extend of exposure to violence have much variation for different change pattern, which motivates us, in the future work, to include exposure to violence as time varying covariates when modeling the change pattern. Another factor to be considered for modeling is geographic information, since intuitively, groupements near each other might have similar perceptions. Also, recall that some turning points were discovered for perception of ethnic relations, to better understand them, one-time events will be included in the model.

The relationships between perception of security and of ethnic relations are generally positively correlated, with some exceptions that could possibly be explained by exposure to violence and ethnic diversity. To better understand how the conflicts evolve and affect population, future work could move forward to causal analysis for perception of security, perception of ethnic relations and exposure to violence.

Appendix

A Question list

Here we present the exact wording of questions for topics that are most interest to us.

- Perception of security: what's your level of security in the following situations?
  1. Conduct your daily activities such as driving to work
  2. Walk alone at daytime in your district/village
  3. Walk alone at night in your district/village
  4. Sleep at night
  5. Go to the nearest village/city
  6. Go to the nearest market
  7. Meet people you don't know
  8. Meet people from another ethnic group
  9. Meet FARDC solders
  10. Meet armed groups
  11. Meet police
  12. Talk openly about your experience during the conflict
  13. Complain to authorities when you are a victim of a crime (infraction)
- Social cohesion: how do you judge your relations with the following persons or groups?
  1. Your relations with your parents, children, spouses
  2. Your relations with your neighbors
  3. Your relations with people of your district, village
  4. Your relations with people of your ethnic group
  5. Your relations with members of any other ethnic group
- Witness exposure to violence
  1. Have you ever been witness of fights in the last 12 months
  2. Have you been witness of pillages by armed or FARDC groups in the last 12 months
  3. Have you been witness of people being attacked or beaten by armed or FARDC groups in the last 12 months

4. Have you been witness of people being killed by armed or FARDC groups in the last 12 months
5. Have you been witness of people being sexually abused by armed or FARDC groups in the last 12 months

- Direct exposure to violence and threats
  1. Have you been physically attacked, beaten, tortured due to conflicts in the last 12 months
  2. Have you been taken in the middle of a battle in the last 12 months
  3. Have you been threatened to death in the last 12 months
  4. Have you thought that you are going to die because of conflicts in the last 12 months
- Exposure to crimes: during the last 12 months, have you personally experienced the following events?
  1. Fight or cambriolage
  2. Physical violence without weapon
  3. Physical violence with weapon
  4. Victim of sorcery
  5. Victim of extortion or corruption
- Displacement
  1. Are you currently moved
  2. Have you been separated from members of your household due to conflict in the last 12 months
- Coercion
  1. Have you been attacked, prisoned by an armed or FARDC group in the last 12 months
  2. Have you been removed by an armed or FARDC group in the last 12 months (S17a)
  3. Were you forced to work as a carrier or otherwise by an armed or FARDC group in the last 12 months
  4. Were you forced to pillage/participate in an armed or FARDC group pillage in the last 12 months
  5. Have you been forced to beat someone by an armed or FARDC group in the last 12 months

6. Have you been forced to kill someone by an armed or FARDC group in the last 12 months

B Demographic information

Here we present the overall distribution for demographic information (Figure 4), and brief reasons about combining rules.

1. Gender: The gender ratio for respondents is approximately 1:1 and the ratio is consistent for every poll and in most of the groupements.

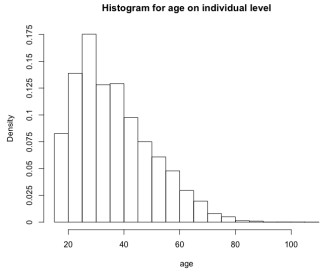
2. Age: on individual level, age has a skewed distribution (Figure a) with mean age 37.15, maximum age 106, and minimum age 18 because respondents are required to be adults. There is not much variation across polls.

3. Income: income information are originally divided into 9 categories: no income, $<$ \$15, \$16 $-$ \$30, \$31 $-$ \$45, \$46 $-$ \$60, \$61 $-$ \$150, \$151 $-$ \$300, \$300 $-$ \$600, $>$ \$600. By histogram on individual level (Figure b), there is a drop at \$150. So we would like to denote income less or equal to \$150 as low income and more than \$150 as high income. There is not much variation across polls. The distribution of percentage of individual with low income in every groupements doesn't vary much across polls either.

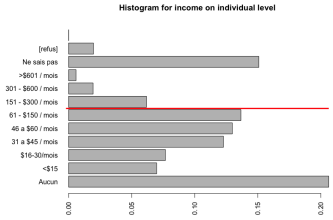
4. Religion: there are 8 options for religion: "Catholic", "Protestant", "Adventist", "animist", "Jehovahs Witness", "Kimbanguiste", "Muslim", "other". Most of the individuals are either Catholic or Protestant (Figure c). We would like to assess the difference in the answers for individuals with either of these two dominant religions and individuals with other religions. There is not much variation across polls. The distribution of percentage of Catholic or Protestant in every groupements doesn't vary much across polls either.

5. Ethnicity: There are 22 options for ethnic group questions. According to histogram, there are three main ethnic groups, which are coded as 13, 15, 19 (Figure d) (we have requested the codebook for this item and expect to get name of ethnicity soon). For each of these three ethnic groups, we would like to look at the percentage of people belonging to that ethnic group. For each of these three ethnic groups, the distribution of percentage in every groupement doesn't vary much across polls, and are centered around 75%, which indicates that most groupement have one dominant ethnic group.

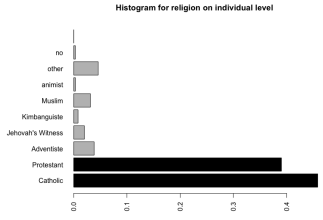
6. Education: there are 7 options for education level: “none”, “primary incomplete”, “primary complete”, “secondary incomplete”, “secondary complete”, “technical / professional school”, “university”. Figure e shows the histogram of education level. Generally, in region that education resource is hard to access, we consider education level lower or equal to “primary complete” as low education level, and the rest as high education level. The distribution of percentage of individual with low income in every groupements doesn’t vary much across polls, but the percentages spread from 10% to 90%.
7. Job: there are 13 options for job: “agriculture”, “breeding”, “daily work”, “household”, “hunting”, “miner”, “NGO”, “official”, “outside assistant”, “small business”, “student”, “trade”, “other”. The job with most individuals is “agriculture” (Figure f). We would like to assess the difference in the answers for individuals living on agriculture and individuals with other jobs. There is not much variation across polls. But the distribution of percentage of respondents living on agriculture in every groupements is not centered around percentage for all respondents. It’s spread and have two peaks, of which one is less than 10% and the other is about 40%. This means for some of the groupements, many people (40%) live on agriculture, while for another large amount of groupements, relatively small proportion of people (10%) live on agriculture.
8. Marital status: there are 5 options for marital status: “single”, “one partner”, “multiple partner”, “divorce”, and “widow”. The dominant answer is “one partner” (Figure g). Considering that people with partners might have similar experience, we would like to assess the difference in answers between individuals with one or multiple partners and individuals with other marital status. There is not much variation across polls. The percentage of respondents with partner(s) in every groupement centered around 70% (similar to the percentage for all the individual).



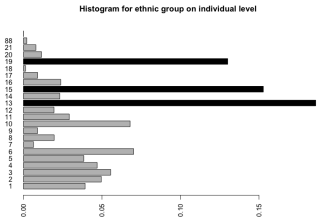
(a) Histogram for age on individual level



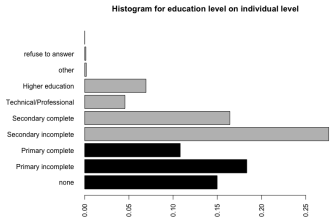
(b) Histogram for income on individual level



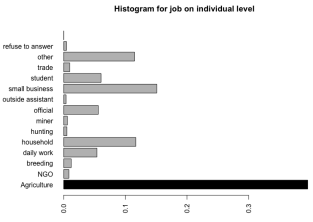
(c) Histogram for religion on individual level



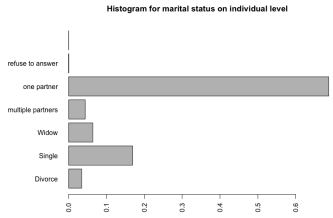
(d) Histogram for ethnicity on individual level



(e) Histogram for education level on individual level



(f) Histogram for job on individual level



(g) Histogram for marital status on individual level

Figure 4: Histograms for demographic information on individual level

C Measurements

Here we present the definition of measurements about assets, exposure to violence, and ethnicity diversity.

1. Assets index: there are 12 items asking about assets possession, in which two of them had no record after 4th survey. So we used the data from the other 10 items, each of which asks whether and how many the respondent possess a certain type of asset such as television. Based on a note discussing approaches to form wealth index [13], we developed the asset index is the first component score by apply PCA on the 10 items. Note that it's a component score, so it's not necessary true that higher score corresponding to more possession.
2. Exposure to violence: there are 5 aspects being assessed for exposure to violence: witness exposure to violence, direct exposure to violence and threats, exposure to crimes, displacement and separation, and coercion. Each aspects have multiple items asking whether they have certain experience about violence in the last 12 months. For each aspect, we developed two measurements, one is the sum of number of experiences, the other is a binary measurement, indicating whether one have experienced any of the described situations in that aspect. As you can see from table **??**, for every aspect, the mean value for sum index is higher than that for binary index, which indicates that the respondents exposed to violence tend to experience multiple violence events.
3. Ethnicity diversity: defined as the Simpson Diversity for 6 ethnic groups, each of which represents at least 5% of the population. This diversity measure the probability that two individuals in a given groupement would belong to different ethnic groups. We didn't take all the ethnic groups into consideration, because there are more than 20 kinds of ethnicities being recorded, while most of them only have a very small proportion in the population.

D EDA on item of interest

Figure 5 shows the histogram for 11 security items and the ethnic relations item on individual level. Figure 6 shows how median score of the related items change on individual level.

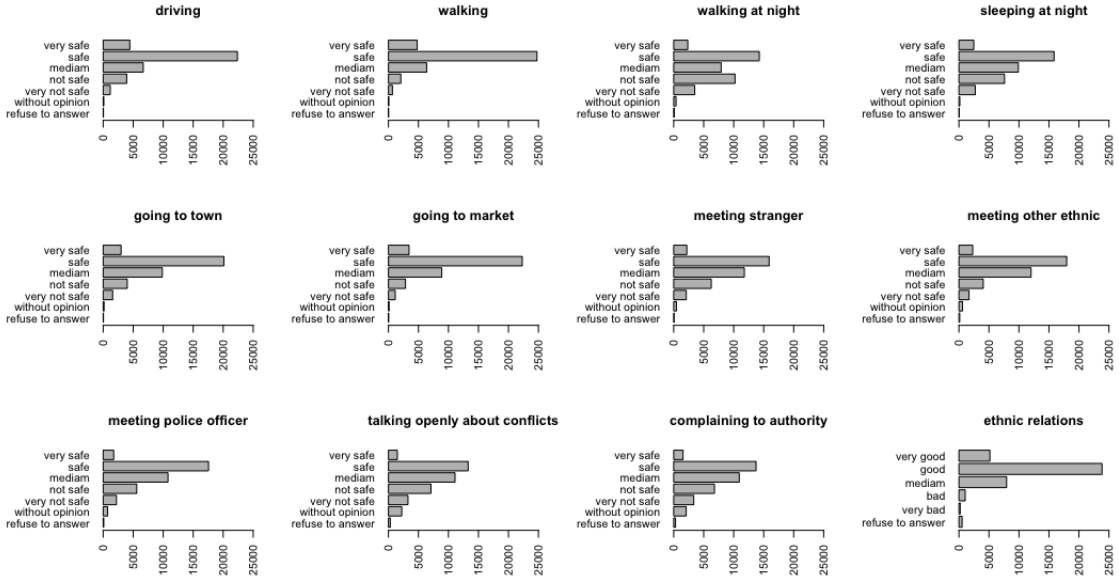


Figure 5: Histogram for 11 perception of security items and ethnic relations

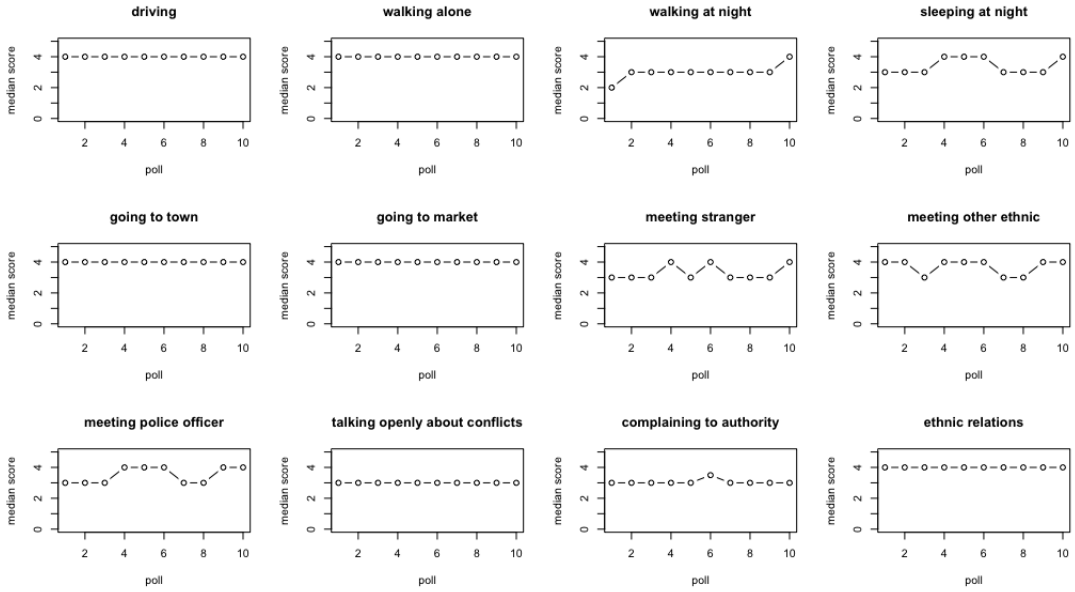


Figure 6: Change pattern for 11 perception of security items and ethnic relations item (median score for every poll)

E EDA on relationship

Table 12 shows the correlation between ethnic relations item and perception of security items for 10 polls.

Table 12: correlation between ethnic relations item and perception of security items for 10 polls

	driving	walking alone	walking at night	sleeping at night	going to town	going to market	meeting stranger	meeting other ethnic
poll1	0.11	0.15	0.10	0.14	0.11	0.14	0.22	0.26
poll2	0.19	0.20	0.13	0.13	0.19	0.18	0.23	0.30
poll3	0.19	0.19	0.21	0.17	0.23	0.23	0.29	0.33
poll4	0.18	0.22	0.16	0.12	0.16	0.18	0.24	0.29
poll5	0.28	0.32	0.21	0.22	0.21	0.22	0.32	0.34
poll6	0.27	0.29	0.07	0.11	0.27	0.28	0.30	0.36
poll7	0.37	0.43	0.29	0.31	0.37	0.37	0.41	0.42
poll8	0.26	0.27	0.17	0.16	0.23	0.24	0.27	0.36
poll9	0.30	0.30	0.25	0.25	0.29	0.30	0.30	0.35
poll10	0.21	0.20	0.18	0.17	0.18	0.21	0.22	0.25

	meeting police officer	talking openly about conflicts	complaining to authority
poll1	0.17	0.18	0.17
poll2	0.10	0.21	0.19
poll3	0.13	0.22	0.21
poll4	0.11	0.20	0.17
poll5	0.17	0.24	0.24
poll6	0.15	0.23	0.25
poll7	0.18	0.27	0.28
poll8	0.16	0.23	0.22
poll9	0.23	0.27	0.27
poll10	0.13	0.22	0.21

F Method for generating indexes of perception of security

Items that are going to form index of perception of security should be items that measure the perception security. Though it is clear that 12 items are designed to directly measure the perception of security, other items such as perception of security actors are also related to the perception of security. Thus, it's necessary to assess the overall underlying dimensionality of all the items in the survey and find the items that falls into the dimensionality of perception of security. Since what we want is an index for underlying variable (eg. perception of security, or social cohesion) that affect the answers to related items rather than pure dimension reduction, the model of factor analysis (FA) might fit the case better than principle component analysis (PCA) [14]. Specifically, we did exploratory factor analysis (EFA) on the data from second poll. But if the items in the dimension of perception of security are going to form the index, this index is going to be used for data of every single poll. So we need to make sure that the same set of items fall into dimension of perception of security at every poll, which is called as the reliability of dimensionality across polls. To check reliability, that is to see whether the overall dimensionality holds for other polls, confirmatory factor analysis (CFA) was conducted on data from every single poll except for poll 2. However, before deciding which items fall into the dimension of perception of security and should then form the index, there is another property to be confirmed: internal consistency. Because we are using the same index across every poll to examine the change of this index, we need to make sure that index measures the same thing over all the polls. Internal consistency assesses if items in index is strongly interrelated in every poll so that the index generated can be representative of what we want to measure over all the polls. Specifically, internal consistency was assessed by Cronbach's alpha [15] and ω_t, the proportion of test variance accounted by all common factors [16]. After checking internal consistency, items for generating the index can be decided.

In the process of assessing reliability by CFA, the goodness of fit for confirmatory factor analysis was evaluated. There are many measurements for goodness of fit, such as chi-square test, the root mean square error of approximation (RMSEA), the standardized root mean square residual (SRMR), the comparative fit index (CFI) and Tucker-Lewis Index (TLI) [17]. Chi-square measurement and SRMR are absolute fit indices. That is, they assess the model fit at an absolute level without taking into account other aspects such as fit in relation to more restricted model. The null hypothesis of Chi-square test is that the model specified is perfect for the data. It is often rejected for large sample size even there is only trivial difference between model specified and perfect model. SRMR can be viewed as the average discrepancy between the correlations observed in the input data and the correlations predicted by the model. It doesn't appear to perform well for

categorical data. RMSEA [18] adds a penalty for poor model parsimony on absolute fit indices. It measures the extent to which model fits reasonably well (as opposed to testing whether the model holds exactly like the chi-square test). It's sensitive to the factor loadings, which means it's sensitive to the structure of items. Generally, RMSEA under 0.05 indicates a good fit. But for categorical data, RMSEA under 0.06 is enough to be view as a sign of good fit. CFI and TLI are comparative fit. They measure the improvement of specified model against a solution positing no relationships among variables. By simulation study, CFI performs better than TLI, and a value close or above 0.95 indicates a good fit [18]. In our case, based on the large sample size, the chi-square test is very likely to be rejected, so it might provide little information. Therefore, the measurements that we focused on were RMSEA and CFI.

After we have introduced the method to decide which ones of the items to use to form indexes, we need to decide the weights for each item. According to W. Lawrence and Karen [19], items should be weighted equally unless you have a good theoretical reason for assigning different weights. While Earl agrees with this principle, he also suggests that weight should be related to the balance of items [20]. For example, let's say that items chosen to construct index reflect two aspects A and B. If there are more items reflecting aspect A than aspect B, then it might be more reasonable to assign more weights on items reflecting aspect B. The weights can also come from statistical technique such as factor analysis. But when what is interesting is relationship between variables, weighted and un-weighted index often give similar results. So we first assessed the methods to assign different weights. If they don't have very sound reason, we would then switch to equal weights as suggested.

If we are going to determine weights using FA result with all items available, we need to first find the factor score for every factor that items chosen for index belonging into. Christine, Min and Diana provide an overview of different methods to generate factor score [21]. There are mainly two kinds of methods: non-refined methods and refined methods. Weights from non-refined method tend to be more stable across samples. Considering that we have different samples for 10 time points, non-refined methods might be more appropriate. Within non-refined methods, aside from assigning equal weights, one method is to use factor loadings as weights. However, authors also noted that factor loadings may not be an accurate representation of the differences among factors due to a researchers choice of extraction model and/or rotation method, which means weights based on factor loadings might not result in a significant improvement over equal weights. Also, in our case, based on relatively small difference in most of the factor loadings within one factor, we chose to use equal weights to generate factor scores.

After we have the factor scores, we could combine factors that fall into the dimension of perception of security. However, it's not necessary. We could use multiple indexes to measure different aspect of perception of security during the study about whether conflicts in Congo are ethnic conflicts, one for each factor, especially if factor scores don't have same trend over time. In result section 4.1.2, we give more detailed reason for using multiple indexes for perception of security.

G IRT model for Understanding items

In Section 3.4, we introduced a basic item response model for dichotomously scored item. For ordered multiple choice item, there are many different ways of modeling such as the graded response model, rating scale modeling and the partial credit model, most of which are extension to the above logistic model [11]. The model we use are graded response model, because it allow for the assumption that items are measuring multiple latent traits. Even if we restrict our analysis on items about security, there might be different aspect of security, so the latent traits might be multiple. The graded response model models the probability of answers less or equal to a certain value as a logistic function.

$$P(x \leq k|\theta) = \frac{1}{1 + e^{a(\theta - b_k)}}$$

Note that we could also allow for guessing parameter in this model.

When a item is designed, we are interested in estimating the value of ability for a respondent. However, not respondents of all kinds of level of ability could be equally precisely measured by one item. For example, consider a simple dichotomously scored item. It's hard to distinguish respondents with ability value more than 3, if for this item $P(x = 1|\theta) \geq 0.9, \forall\theta > 3$. Information function, a function of ability θ, tells us how well each ability level can be estimated according to a certain item, that is, the precision with which a respondents ability is estimated depends upon where the respondent's ability is located on the ability scale [12].

Though the model for relationship between answers and ability for a single item is constructed, when what we have is answers for many items and we don't have exact value of respondent's ability, estimation is not a trivial work. A process called Birnbaum paradigm [12] states how to estimate the parameters for multiple items and also the respondent's ability in a metric for the underlying latent trait. It's similar to EM algorithm to estimate item parameters and respondent's ability alternatively. And when optimizing over item parameters, we optimize over one item at a time and rotate.

After a model is fitted to data, we need to assess whether this model is a good fit. There are three level of diagnostics: test level, assessing the global fitness; item level, checking how well each item fits within the test, and whether there are residual inter-dependencies between items; and person level, similarly as item level, checking how well each respondents fits within the test. For test level, one common global fitness statistics is G^2 statistics, and by chi-square type fit testing, we can know whether the model is a good fit in general. However, even if globally the model is a good fit, it's still necessary to look at fitness on item level and person level. Local dependence statistics (χ^2) is designed to test fitness on item level. Z_h statistics is designed to test fitness on person level, where $Z_h < 0$ indicates a worse fit than expected.

H Overall dimensionality

To explore the overall dimensionality, we conducted exploratory factor analysis (EFA) on data from second poll. Table 13 and Table 14 show the items and corresponding loadings of exploratory factor analysis on the data from second poll. Suggested by parallel analysis (a standard method to find the number of factors [22]), there are 18 underlying factors. As shown in the table, for each factor, items with factor loading bigger than 0.4 are presented. Items about perception of security fall into two factors. One factor with 9 items can be interpreted as measurement for personal experience, and the other with 2 items can be interpreted as freedom of speech regarding conflicts.

The rest of the questions aren't essential to our indexes, but we review key findings here. Items about social cohesion fall into one factor. For items about perception of security actors, the relationships are complicated. There is one factor mixing perception of FARDC and MONUSCO and 3 factors mixing items about perception of police and perception of FARDC. For exposure to violence, the items about whether a victim of witchcraft separates out from the rest and forms one factor on its own. The other four items form one factor. Items on crime fall into one factor.

Table 13: Exploratory factor analysis on data from second poll (first part)

Topic	#{items} in the factor	Items and corresponding loadings				
Perception of security	factor with 9 items	go to the nearest town/village 0.8	go to nearest market 0.8	walk alone 0.7	driving 0.7	sleep at night 0.7
		meet strangers 0.7	meet people from other ethnic group 0.6	walk at night 0.6	meet police officer 0.5	
	factor with 2 items	talk openly about conflict experience 0.6	complain to authority when you are a victim of a crime 0.5			
Social cohesion	factor with 5 items	relationship with people in your neighborhood, village 0.9	relationship with neighbors 0.8	relationship with people in your ethnic group 0.7	relationship with people in other ethnic group 0.7	relationship with relatives 0.5
Perception of police	factor with 4 items	trust 0.8	contribution 0.7	protect or do nothing or hurt 0.7	access 0.6	
	factor with 2 items	encouragement must be paid for police to work on a complaint 1	possible to avoid being arrested if pay police 0.6			
	factor with 1 item	treat all ethnic group same 0.5				
Mixed factor: Perception of police and FARDC	factor with 2 police item and 2 FARDC items	assisted by police 0.5	assisted by FARDC 0.5	a victim of bad behavior by FARDC 0.4	a victim of bad behavior by police 0.4	
	factor with 1 police item and 1 FARDC item	FARDC unpunished 0.7	police officer are unpunished 0.6			
	factor with 1 police item and 1 FARDC item	Victim of crime committed by FARDC can file complaint 0.9	Victim of crime committed by police can file complaint 0.7			
Perception of FARDC	factor with 4 items	trust FARDC 0.8	protect or do nothing or hurt 0.7	contribution 0.7	FARDC accountability efforts to avoid crimes are underway 0.4	

Table 14: Exploratory factor analysis on data from second poll (second part)

Topic	#{items} in the factor	Items and corresponding loadings				
Mixed factor: Perception of FARDC and MONUSCO	factor with 2 FARDC items and 2 MONUSCO items	is there deployment of FARDC 0.7	is there deployment of MONUSCO 0.7	how often do you see FARDC 0.6	how often do you see MONUSCO 0.5	
Perception of MONUSCO	factor with 5 items	contribution 0.8	general opinion 0.8	trust 0.8	protect or do nothing or hurt 0.8	assisted by MONUSCO 0.6
	factor with 1 item	a victim of bad behavior by MONUSCO 0.9				
Exposure to violence	factor with 4 items	theft or burglary 0.8	physical violence without weapon 0.7	physical violence with weapon 0.7	victim of extortion 0.6	
	factor with 1 item	victim of witchcraft 0.8				
Crime	factor with 12 items	witness of fight 0.8	witness of pillages 0.8	witness of being underway 0.8	witness of being killed 0.8	witness of sexually abused 0.8
		have things stolen, destroyed or burned by conflict 0.7	separated from members of household due to conflict 0.7	physically attacked by conflict 0.6	taken in the middle of a battle 0.6	been threatened of death 0.6
		have thought that would live during conflicts 0.6	had members of household killed by conflicts 0.6			

I Reliability and internal consistency

To check reliability, that is to see whether the overall dimensionality holds for other polls, confirmatory factor analysis (CFA) was conducted on data from every single poll except for poll 2, and goodness of fit for confirmatory factor analysis was evaluated to assess the reliability. Table 15 shows RMSEA and CFI, which are two goodness-of-fit measurements of CFA, on the data from every single poll except poll 2. As the table shows, the RMSEA result indicates that the structure holds for every poll except for poll 1. This might due to that for poll 1 nearly half of the data is missing for questions like exposure to violence and crimes. Also, there is literature suggesting model with RMSEA less than 0.06 can be viewed as a good fit [18]. So by the value of RMSEA on poll 1, the dimension structure still holds to some extent. Note that CFI is not large enough for any polls (greater than 0.95 indicates good fit), which indicates that the improvement against model that assume every item is independent is not much. This means that either the model we assume doesn't correctly reflect much of the relationships among items or the relationships among items is weak in nature. Note that the correlation based on data from every single poll is not very large even for items within the same factor. This might be part of the reason about why CFI is low. Overall, the dimension structure holds fairly well for every poll.

Internal consistency is also evaluagted. Table 16 shows the Cronbach's alpha and ω_t for perception of security items for every poll. The relatively high value of both Cronbach's alpha and ω_t for every poll indicates that items about perception of security are internally consistent.

Table 15: Goodness-of-fit indexes for overall dimensionality

poll		1	3	4	5	6
RMSEA	value	0.053	0.049	0.046	0.048	0.049
	p-value (RMSEA<=0.05)	0.000	0.944	1	1	0.999
CFI		0.791	0.827	0.830	0.830	0.829

poll		7	8	9	10	
RMSEA	value	0.049	0.047	0.047	0.046	
	p-value (RMSEA<=0.05)	0.967	1	1	1	
CFI		0.835	0.848	0.836	0.822	

Table 16: Internal consistency of perception of security items (measured by Cronbach's alpha and ω_t)

Poll	1	2	3	4	5
Cronbach's alpha	0.89	0.91	0.94	0.93	0.93
Omega Total	0.94	0.95	0.97	0.97	0.97
Poll	6	7	8	9	10
Cronbach's alpha	0.93	0.93	0.94	0.95	0.93
Omega Total	0.97	0.97	0.97	0.97	0.96

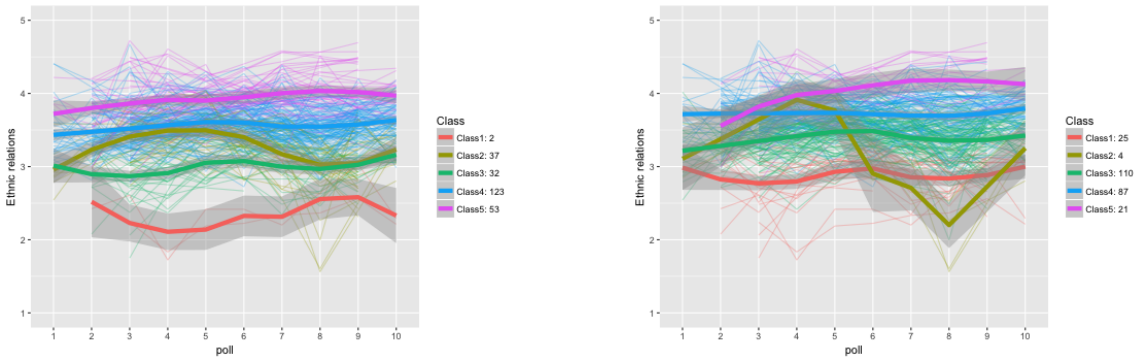
J Trajectory model for personal experience security (short)

The personal experience security index (short version) consists of 6 items. To best avoid possible overlapping information with ethnic relations item, it excludes 3 items about iteractions with people compared with the long version of personal experience security. By comparing BIC (Table 17), we chose the model with 5 classes of trajectory (Figrue 7a). As shown in the plot, the trajectory shape for each class is very different from what's been found in long index for personal experience security.

Dual GBTM was also applied to personal experience security (short index) and ethnic relations and figure 7b shows the trajectory classes after dual GBTM. As shown in the plot, some trajectory shapes after dual GBTM is very different from that before dual analysis (such as class 2 and class 5), and the membership shifted quite a bit. 158 out of 247 groupements changed their classes (Table 18). To summarize, after the dual analysis, the model decides to separate out a very fluctuating trajectory from previous Class 2, and an increasing trajectory from previous Class 5, which resembles the classification result for long index (Section 4.2.1). In this sense, the classification result for long index seems to be more stable before and after applying the dual analysis.

Table 17: Personal experience security (short) models for different number of groups

number of groups	BIC	group description					
		group 1	group 2	group 3	group4	group 5	group 6
2	-701.6	high, flat	low, fluctuating				
		73.4%	22.6%				
3	-660.06	high, flat	low, flat	increasing then flat			
		27.3%	17.8%	54.9%			
4	-656.90	high,flat	low, flat	increasing then flat	fluctuating		
		21.1%	10.1%	48.9%	19.9%		
5	-640.46	mildly increasing	low, flat	flat	fluctuating	very low, flat	
		22.0%	13.3%	51.8%	46.9%	0.9%	
6	-665.72	high, flat	low, flat	increasing then flat	fluctuating	flat	flat, (same trajectory)
		15.6%	10.4%	31.3%	19.6%	14.2%	8.8%



(a) Trajectory class for personal experience security (short index)

(b) Trajectory class after dual GBTM analysis

Figure 7: Trajectory class for personal experience security (short index)

Table 18: Membership shift for personal experience security (short index)

BeforeAfter	Class 1 (25)	Class 2 (4)	Class 3 (110))	Class 4 (87)	Class 5 (21)
Class 1 (2)	0	0	0	0	0
Class 2 (37)	2	0	31	0	0
Class 3 (32)	21	0	0	0	0
Class 4 (123)	0	0	68	0	2
Class 5 (53)	0	0	0	34	0

K Trajectory model for personal experience security

The personal experience security index (long version) consists of 9 items that fall into one factor in EFA result. These 9 factors are describing the security of some daily life experience. By comparing BIC (Table 19), we chose the model with 5 classes of trajectory.

Apart from the extracted demographic information in Section 4.2.1, we also extracted the geographical information for each classes. Table 20 shows the number of groupements in each territory for each class.

Table 19: Personal experience security (long) models for different number of groups

number of groups	BIC	group description					
		group 1	group 2	group 3	group4	group 5	group 6
2	-647.02	high, flat	low, flat				
		72.5%	27.5%				
3	-619.28	high, flat	low, flat	increasing then flat			
		18.5%	22.3%	59.2%			
4	-612.82	high,flat	low, flat	increasing then flat	fluctuating		
		15.8%	13.2%	53.7%	17.3%		
5	-603.26	high, flat	low, flat	increasing then flat	fluctuating	high, increasing	
		22.7%	18.9%	51.8%	17%	4.8%	
6	-613.71	high, flat	low, flat	increasing then flat	fluctuating	higher, flat	very low, fluctuating
		21.3%	24.10%	42.9%	17%	12.8%	10%

Table 20: Geographic info for personal experience security long index (number of groupements)

Province	Territory	Class1	Class2	Class3	Class4	Class5
NorthKivu Total: 98	Ville de Goma	1	0	10	0	0
	Ville de Beni	10	0	1	0	0
	Ville de Butembo	8	0	10	0	0
	Beni	3	0	7	1	0
	Lubero	5	0	5	0	0
	Masisi	0	0	4	5	0
	Nyiragongo	0	0	7	0	0
	Rutshuru	2	4	3	3	0
	Walikale	0	0	3	6	0
SouthKivu Total: 94	Ville de Bukavu	0	0	7	4	0
	Fizi	3	0	6	0	0
	Idjwi	0	0	0	0	5
	Kabare	0	0	5	4	0
	Kalehe	0	0	4	5	0
	Mwenga	2	0	7	2	0
	Shabunda	5	0	4	0	0
	Uvira	1	0	8	1	0
	Walungu	0	0	1	6	3
	Ville d'Uvira	0	0	10	1	0
Ituri Total: 55	Ville de Bunia	0	0	10	0	0
	Aru	3	0	3	1	2
	Djugu	0	0	4	5	0
	Irumu	3	0	4	3	0
	Mahagi	0	0	0	5	3
	Mambasa	0	0	5	4	0

L Trajectory model for freedom of speech security

The freedom of speech index has two items, they ask security level when talking openly about conflict experience and when complaining to authority when you are a victim of crime. By comparing BIC (Table 21), we chose the model with 3 classes of trajectory.

Apart from the extracted demographic information in Section 4.2.2, we also extracted the geographical information for each classes. Table 22 shows the number of groupements in each territory for each class.

Table 21: Freedom of speech security models for different number of groups

Number of groups	BIC	Class description				
		Class1	Class2	Class3	Class4	Class5
2	-964.86	increasing 69.1%	low, flat 30.9%			
3	-949.64	increasing 44.5%	low, flat 23.4%	high, flat 32.1%		
4	-953.36	increasing 28.0%	low, flat 24.18%	high,flat 13.0%	slightly fluctuating 34.2%	
5	-955.60	increasing 26.9%	low, flat 23.2%	high, flat 12.5%	slightly fluctuating 33.0%	low, fluctuating 4.4%

Table 22: Geographic info for freedom of speech security (number of groupements)

Province	Territory	Class1	Class2	Class3
NorthKivu Total: 98	Ville de Goma	0	9	2
	Ville de Beni	8	3	0
	Ville de Butembo	13	5	0
	Beni	4	6	1
	Lubero	9	1	0
	Masisi	0	2	7
	Nyiragongo	0	6	1
	Rutshuru	7	3	2
	Walikale	0	8	1
SouthKivu Total: 94	Ville de Bukavu	0	6	5
	Fizi	0	9	0
	Idjwi	0	1	4
	Kabare	0	5	4
	Kalehe	3	3	3
	Mwenga	0	6	5
	Shabunda	8	1	0
	Uvira	0	10	0
	Walungu	0	1	9
	Ville d'Uvira	0	10	1
Ituri Total: 55	Ville de Bunia	0	9	1
	Aru	3	5	1
	Djugu	0	3	6
	Irumu	2	6	2
	Mahagi	0	0	8
	Mambasa	0	5	4

M Trajectory model for ethnic relations

We use answer to one item that asks about relationship with people from other ethnic groups as the ethnic relations index. By comparing BIC (Table 23), we chose the model with 6 classes of trajectory.

Apart from the extracted demographic information in Section 4.2.3, we also extracted the geographical information for each classes. Table 24 shows the number of groupements in each territory for each class.

Table 23: Ethnic relations models for different number of groups

Number of groups	BIC	Class description						
		Class1	Class2	Class3	Class4	Class5	Class 6	Class 7
2	-554.02	flat 88.2%	fluctuating 17.8%					
3	-556.98	flat 79.4%	bow shaped 17.6%	decreasing then flat 3.0%				
4	-516.38	flat 73.6%	bow shaped 14.4%	decreasing then flat 3.9%	low, increasing 8.1%			
5	-503.92	flat 70.1%	bow shaped 14.4%	decreasing then flat 4.0%	low, increasing 7.2%	high, hill shaped 4.3%		
6	-476.27	flat 67.6%	bow shaped 14.7%	decreasing then flat 4.0%	low, increasing 8.0%	high, hill shaped 4.1%	high, fluctuating 17%	
7	-481.94	flat 67.0%	bow shaped 14.6%	decreasing then flat 4.0%	low, increasing 7.3%	high, hill shaped 4.1%	high, fluctuating 17%	slightly fluctuating 13%

Table 24: Geographic info for ethnic relations (number of groupements)

Province	Territory	Class1	Class2	Class3	Class4	Class5	Class6
NorthKivu Total: 98	Ville de Goma	2	0	0	7	0	2
	Ville de Beni	0	0	0	11	0	0
	Ville de Butembo	0	0	0	17	1	0
	Beni	1	0	0	6	4	0
	Lubero	2	0	0	2	6	0
	Masisi	0	0	0	8	1	0
	Nyiragongo	0	0	0	0	7	0
	Rutshuru	1	0	0	4	5	2
	Walikale	0	0	0	7	2	0
SouthKivu Total: 94	Ville de Bukavu	0	0	1	8	1	1
	Fizi	0	0	0	8	1	0
	Idjwi	0	0	4	1	0	0
	Kabare	0	0	2	5	2	0
	Kalehe	4	0	0	3	2	0
	Mwenga	1	0	0	10	0	0
	Shabunda	5	0	0	0	4	0
	Uvira	2	0	0	8	0	0
	Walungu	0	3	0	7	0	0
	Ville d'Uvira	0	0	0	11	0	0
Ituri Total: 55	Ville de Bunia	0	0	0	10	0	0
	Aru	0	0	0	9	0	0
	Djugu	0	0	0	9	0	0
	Irumu	0	1	0	8	0	1
	Mahagi	0	0	2	6	0	0
	Mambasa	0	0	0	9	0	0

N Dual analysis: personal experience security VS ethnic relations

N.1 Membership change in personal experience security (long index)

Note that when we fit the dual trajectory model, the membership for groupements are not guaranteed to be same as GBTM for a single index. So before we look at link probabiltiy, we examined how membership changed when we are fitting the dual model.

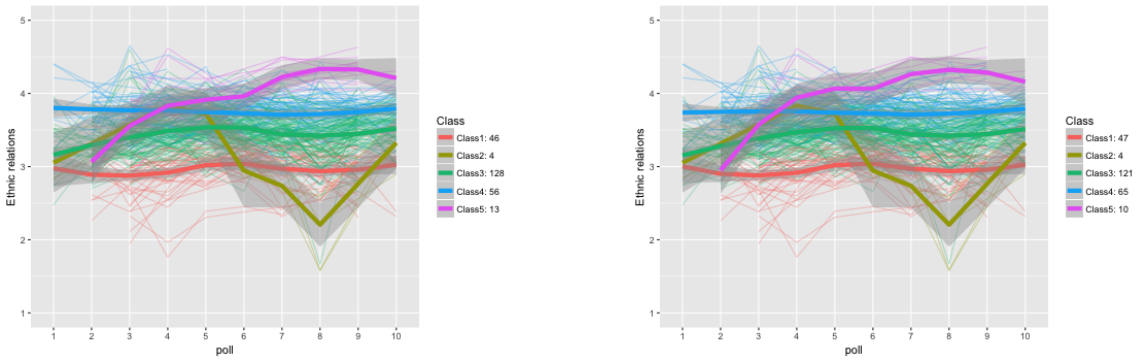
Figures show the trajectory classes for personal experience security (long index) in single GBTM model (Figure 8a) and in dual model (Figure 8b). There is not much change in terms of the shape of trajectory classes. As shown in Table 25, the number of groupements in each class also didn't change much. In all, fitting the dual model have little influence on the membership and the trajectory classes for personal experience security (long index).

N.2 Membership change in ethnic relations

Figures show the trajectory classes for ethnic relations index in single GBTM model (Figure 9a) and in dual model (Figure 9b). Class 2 (yellow line) and Class 3 (green line) have a rather apparent change in the shape of trajectory. When looking at the number of groupements in each class (Table 26), we can see that some of the groupements that are originally in Class 4 separate out as a new class, which in our case labeled as Class 2. Its trajectory has little difference with Class 4's trajectory. For Class 3, its trajectory looks like a combination of trajectories for original Class 2 and Class 3. So when looking at the link probability, we should keep in mind that Class 2 now is different from what we discovered before, just sharing the same name.

Table 25: Membership change for personal experience security (long index)

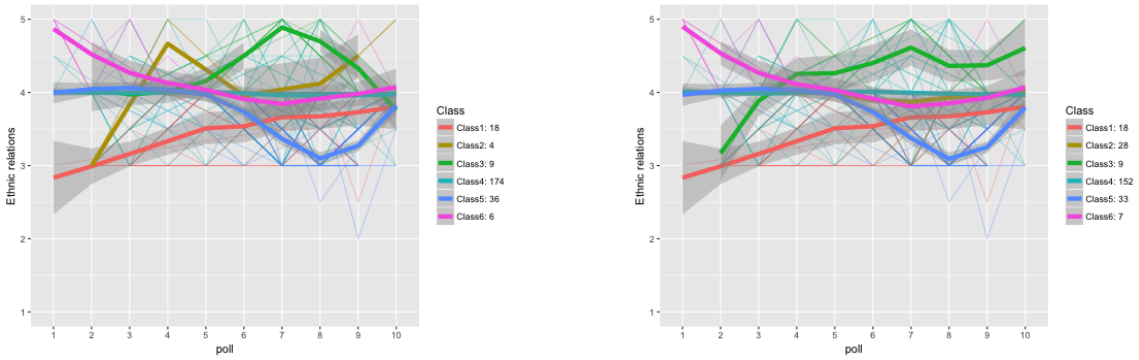
Class	Shape	Single	Dual
1	low, flat	46	47
2	fluctuating	4	4
3	increasing then flat	128	121
4	high and flat	56	65
5	high and increasing	13	10



(a) Trajectory classes by single GBTM

(b) Trajectory classes by dual model

Figure 8: Trajectory classes change for personal experience security (long index)



(a) Trajectory classes by single GBTM

(b) Trajectory classes by dual model

Figure 9: Trajectory classes change for ethnic relations

Table 26: Membership change for ethnic relations

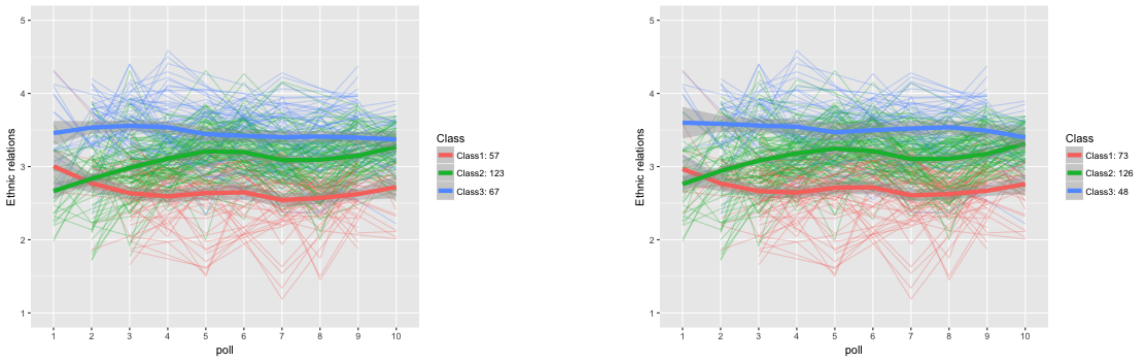
Class	Shape	Single	Dual
1	low but increasing	18	18
2	increasing and fluctuating	4	28
3	high and hill shaped	9	9
4	high and flat	174	152
5	bow shaped	36	33
6	decreasing, then flat	6	7

Table 27: Link probability for personal experience security (long index) membership given ethnic relations membership

P(personal experience given ethnic relations) (%)		personal experience classes				
		Class 1: low, flat (18.26)	Class 2: fluctuating (1.62)	Class 3: increasing then flat (51.82)	Class 4: high and flat (22.67)	Class 5: increasing (5.26)
Ethnic relations classes	Class 1: low, increasing	35.0	0.0	65.0	0.0	0.0
	Class 2: high, flat	68.0	0.0	32.0	0.0	0.0
	Class 3: high, hill shaped	0.0	0.0	0.0	0.0	100.0
	Class 4: high, flat	0.0	0.0	59.2	40.8	0.0
	Class 5: bow shaped	34.7	13.4	50.0	1.9	0.0
	Class 6: decreasing then flat	0.0	0.0	11.6	88.4	0.0

N.3 Relationship: personal experience security distribution conditioning on ethnic relations

Here we show the flipped conditional probability, that is the conditional probability for personal experience security (long index) membership, conditioning on membership for ethnic relations (Table 27. The percentage in the bracket under each personal experience security trajectory class is the marginal distribution. Since the number of groupements for Class 3, and Class 6 are relatively small, we won't read too much into them. When a groupement have low but increasing ethnic relations (Class 1) or a bow shaped trajectory for ethnic relations (Class 5), it's more likely to have low and stable personal experience security level; when a groupement have high and stable ethnic relations (Class 4), it's more likely (40.8%) to have also high and stable personal experience security. An observation we didn't expect is at the second row: for groupements that are classified into Class 2 of ethnic relations (high and stable ethnic relations), it's more likely (68.0%) to have a low and stable personal experience security.



(a) Trajectory classes by single GBTM

(b) Trajectory classes by dual model

Figure 10: Trajectory classes change for freedom of speech security

Table 28: Membership change for freedom of speech security

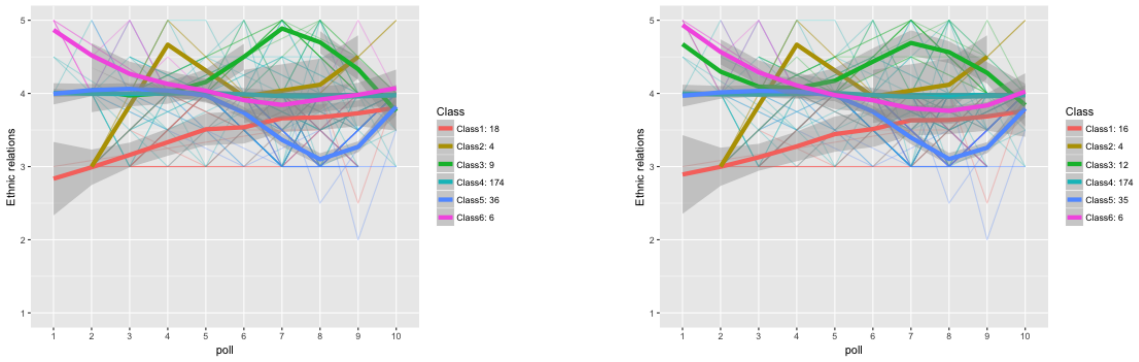
Class	Shape	Single	Dual
1	low, flat	57	73
2	increasing	123	126
3	high, flat	67	48

O Dual analysis: freedom of speech security VS ethnic relations

O.1 Membership change in freedom of speech security

Note that when we fit the dual trajectory model, the membership for groupements are not guaranteed to be same as GBTM for a single index. So before we look at link probabiltiy, we examined how membership changed when we are fitting the dual model.

Figures show the trajectory classes for freedom of speech security in single GBTM model (Figure 10a) and in dual model (Figure 10b). There is not much change in terms of the shape of trajectory classes. As shown in Table 28, the number of groupements in each class has a little shifting. In all, fitting the dual model have little influence on the membership and the trajectory classes for freedom of speech security.



(a) Trajectory classes by single GBTM

(b) Trajectory classes by dual model

Figure 11: Trajectory classes change for ethnic relations

Table 29: Membership change for ethnic relations

Class	Shape	Single	Dual
1	low but increasing	18	16
2	increasing and fluctuating	4	4
3	high and hill shaped	9	12
4	high and flat	174	174
5	bow shaped	36	35
6	decreasing, then flat	6	6

O.2 Membership change in ethnic relations

Figures show the trajectory classes for ethnic relations index in single GBTM model (Figure 11a) and in dual model (Figure 11b). Either in terms of trajectory shapes or in terms of the number of groupements in every class (Table 29), there is not much change.

O.3 Relationship: freedom of speech security distribution conditioning on ethnic relations

Here we also show the flipped conditional probability, that is the conditional probability for freedom of speech security membership, conditioning on membership for ethnic relations (Table 30. Since the number of groupements for Class 3, and Class 6 are relatively small, we won't read too much into them. For ethnic relations class with most groupements (Class 4), the conditional distribution for freedom of speech security classes is similar as marginal distribution. In other words,

Table 30: Link probability for freedom of speech security membership given ethnic relations membership

P(freedom of speech given ethnic relations) (%)		freedom of speech classes		
		Class 1: low, flat (23.07)	Class 2: increasing (49.80)	Class 3: high, flat (27.13)
Ethnic relations classes	Class 1: low, increasing	100.0	0.0	0.0
	Class 2: high, flat	0.0	0.0	100.0
	Class 3: high, hill shaped	0.0	0.0	100.0
	Class 4: high, flat	15.5	64.7	19.8
	Class 5: bow shaped	71.3	26.3	2.4
	Class 6: decreasing then flat	37.9	0.0	62.1

the conditional distribution of freedom of speech security classes for groupements belonging to Class 4 dominants the marginal distribution. When a groupement have low but increasing ethnic relations (Class 1) or a bow shaped trajectory for ethnic relations (Class 5), it's very likely to have low and stable personal experience security level. For groupements that are classified into Class 2 of ethnic relations (high and stable ethnic relations), it's very likely (100.0%) to have high and stable personal experience security.

P DIF results for different kinds of subpopulations

Here we present the DIF results for different kinds of subpopulations. Table 31 shows the p-values of each item for every type of subpopulations.

Table 31: DIF for 9 items about personal experience security for different types of subpopulations (p-values)

Item	By ethnicity	By province	By gender	By income
Driving	0	0	0.01	0.001
Walking alone	0	0	0.01	0.145
Walking at night	0	0	0	0.158
Sleeping at night	0	0	0	0.006
Going to town	0	0	0	0.14
Going to market	0	0	0	0.008
Meeting strangers	0	0	0	0
Meeting people from other ethnic groups	0	0	0	0
Meeting police officer	0	0	0	0

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