Modelleren voor Pandemische Paraatheid: een oproep tot innovatie en kennisontwikkeling SA 2023

Grant application

1. General information

1.1 General information	
Record ID:	17678291
File number: **(added after submission)**	
Programme:	Kennisprogramma Pandemische Paraatheid
Funding round:	Modelleren voor Pandemische Paraatheid: een oproep tot innovatie en kennisontwikkeling
Main applicant:	Danielle Timmermans

1.2 General project details

Project title:
Provide a descriptive title that identifies the type of research, project, and/or topic. The title contains, if applicable: research design/project setup, objects/elements of the research/project, intervention(s), diversity/gender.

Project type:
Which phase of the knowledge chain does your project focus on?
More information and examples about the ZonMw knowledge chain can be found in the document ZonMw knowledge chain.

- **Fundamental research: Research designed to expand knowledge of basic mechanisms and principles of health and care problems. This is generally longer-term research with broad applicability.**
- **Strategic research: Research geared to practical application. This can also involve more generally formulated practical problems derived from everyday clinical or social practice. This is generally medium-term research.**
- **One important type of strategic research is translational research, i.e. research on the borderline between basic and clinical research. Research questions can derive from both clinical practice and laboratory work.**
- **Applied research: Research focused on a question arising from a specific, tangible problem, with the aim of applying the resulting knowledge products in the particular practice. Applied research generally takes place in the shorter term.**
- **Development projects: Development projects aim to provide practical action perspectives. They focus primarily on developing improvements in the particular practice and disseminating and implementing innovations or changes that are of proven value in everyday practice.**
- **Implementation projects: Implementation projects focus on facilitating the use of knowledge products with a view to the legitimate and effective solution of social problems and issues. Implementation research projects are designed to demonstrate the effectiveness of implementation projects or to contribute to knowledge of effective implementation in some other way.**
- **Other: Projects that do not fit into any of the above categories.**

Project title in Dutch:	Het modelleren van vaccinatie keuze profielen van burgers voor doelgerichtere interventies
Project title in English:	Modelling Individuals' Vaccination Decision Profiles to Target Interventions
Planned start date:	01 september 2024
Planned duration (in months):	15
Project type:	Toegepast onderzoek
Is this a continuation of a project previously funded by ZonMw?	Nee
Has this or a comparable grant application previously been submitted to ZonMw?	Nee
Has this application also been submitted to an organisation other than ZonMw?	Nee

1.3 Required project members

You are required to add the following three project members:

- **Main applicant: this is the person who has final responsibility for the grant application. During the grant awarding process, the main applicant is the contact person with whom ZonMw communicates about the application.**
- **Project leader and secretary: this is the person responsible for the content and day-to-day management of the project. If the application is granted, the project leader and secretary is the contact person with whom ZonMw corresponds regarding the progress of the project.**
- **Administrative representative: this is the person authorised to represent the organisation on the basis of its articles of association.**

Please note:

- **For ZonMw, the person submitting the application is, by definition, the main applicant. You cannot submit an application on behalf of a colleague. If someone other than yourself is the main applicant for this application, that person must create their own account at Mijn ZonMw and submit the application from that account.**
- **An account is created with a personal (work)email address. General email addresses to which people other than yourself have access to, such as an info account, are not allowed.**
- **the main applicant and the administrative representative must be employed by the same organisation. If this is not the case, a collaboration agreement with respect to the implementation of the application for the grant in question must be concluded.**
- **Please enter the address of the organisation where the project group members are employed, never their private addresses.**

Main Applicant **Complete or update your personal data. Please add a '.' (dot) after your initials.**			
Title (academic):	prof. dr.	**Initials:**	D.R.M.
First name:	Danielle	**Prefix to the last name (e.g. de, van der)**	
Last name:	Timmermans	**Suffix:**	PhD
Phone number:	+31621871189	**Mobile phone number:**	0621871189
Email:	drm.timmermans@amsterdamumc.nl	**Gender:**	Vrouw
Position:	HGL = hoogleraar (professor)		
Name, department and address of the organisation:			
Organisation:	Amsterdam UMC, VU	**Department:**	Public and Occupational Health
Street and house number:	Van der Boechorststraat 7	**Postcode:**	1081BT
City:	Amsterdam		
Project leader/correspondent			
Is the main applicant also the project leader?	Ja		
Administrative representative			
Title (academic):	drs.	**Initials:**	S.B.
First name:	Sanne	**Prefix to the last name (e.g. de, van der)**	
Last name:	Heerens	**Suffix:**	
Email	s.b.heerens@amsterdamumc.nl	**Gender:**	Vrouw
The name of the department and the correspondence address of the administrative responsible person.			
Organisation:	Amsterdam UMC	**Department:**	Division 10
Street and house number:	Van der Boechorststraat 7	**Postcode:**	1081BT

City:	Amsterdam	

1.4 Additional project members

Does your research require additional project group members?	Ja

2. Additional project group members

2.1 Additional project members

Please note! **Please note! Remember to click +Save after entering a project member. The project member will not be added if you do not use the +Save button.**

Please also mention other people who will play a substantial role in the proposed project.

On the financial data tab, you can mention organisations that contribute actively to the project as collaborating parties. You can enter employees of these collaborating parties as project group members.

Title (academic):	Initials:	First name:	Prefix to the last name (e.g. de, van der):	Last name:	Suffix:	Gender:	Email:	Role in the project:	Organisation:	Department:
dr.	J.	Javier		Garcia-Bernardo	PhD	Man	j.garciabernardo@uu.nl	co-applicant	University Utrecht	Methodology & Statistics
prof. dr.	V	Vincent		Buskens	PhD	Man	v.buskens@uu.nl	co-applicant	University Utrecht	Sociology
dr.	P.	Peter		Lugtig	PhD	Man	p.lugtig@uu.nl	advisor	University Utrecht	Methodology & Statistics
prof. dr.	M.E.E.	Mirjam		Kretzschmar	PhD	Vrouw	m.e.e.kretzschmar@umcuntrecht.nl	advisor	Utrecht UMC	Julius Center
dr.	M.P.	Mirjam		Fransen	PhD	Vrouw	m.p.fransen@amsterdamumc.nl	advisor	Amsterdam UMC	Public and Occupational Health
dr.	O.C.	Olga		Damman	PhD	Vrouw	o.damman@amsterdamumc.nl	advisor	Amsterdam UMC	Public and Occupational Health

2.2 Check

We ask you to check if all project members have been saved correctly. This is the case if there is a red 'Delete' button next to each project member. Have all project members been saved correctly?	Ja

3. Summary

3.1 Public summary in Dutch

This summary is intended for a broadly interested audience with different backgrounds. Therefore, please use simple language in your summary.
Answer at least the following questions:
- **Why do you want to do this project?**
- **What results do you hope to achieve with this project?**
- **Why is this project important for patients/clients and their relatives?**
- **How will you carry out this project?**

(max 1,000 characters)

Public summary in Dutch:

Bij uitbraken van een virus met pandemisch potentieel zijn vaccins een effectieve manier om verspreiding van infecties te voorkomen. Burgers kiezen soms om niet te vaccineren door gebrek aan kennis, misvattingen, religieuze waarden, meningen in de sociale omgeving, en/of factoren zoals toegankelijkheid. Hoewel GGD's zich bewust zijn van deze verschillen en de noodzaak van een meer persoonlijke aanpak, kan een een beter begrip van verschillen in vaccinatie keuze factoren deze aanpak versterken. In dit project gebruiken wij data uit bevolkingsregisters (CBS) en een vragenlijst onderzoek, om een model te bouwen om vaccinatiegraad op populatie- en lokaal niveau te voorspellen. Dit model houdt rekening met de manier waarop overtuigingen en waarden vaccinatiekeuzes beïnvloeden, en hoe deze zich onder de bevolking verspreiden. We krijgen zo een beter begrip van hoe communicatie gerichter kan worden ingezet om vaccinatie keuzes te ondersteunen en vaccinatiegraad te optimaliseren.

3.2 Public summary in English

This summary is intended for a broadly interested audience with different backgrounds. Therefore, please use simple language in your summary.
Answer at least the following questions:
- **Why do you want to do this project?**
- **What results do you hope to achieve with this project?**
- **Why is this project important for patients/clients and their relatives?**
- **How will you carry out this project?**

(max 1,000 characters)

Public summary in English:

During outbreaks of a virus with pandemic potential, vaccines are a very effective way to prevent the spread of infections. However, citizens may decide not to vaccinate due to lack of knowledge, misbeliefs, religious values, being embedded in social networks of vaccination hesitancy and/or factors such as accessibility. Although GGDs are aware of these differences and that a more personal approach is needed, that approach requires understanding how vaccination decision factors differ across the population. In this project, we will integrate population-level registry (CBS) data and data from a survey on beliefs, values, and behavior to build a model to predict vaccination uptake on a population and local level. This model will take into account both how beliefs and values impact vaccination decisions, and how they spread in the population. This will lead to a better understanding of how to target communication and support decisions to optimize public support and vaccination uptake.

3.3 Comprehensive summary in Dutch

If applicable, please use the following headings:
- **Background and relevance**
- **Problem definition and objective(s)**
- **Plan of approach / research design**
- **Objects/units of the project (incl. inclusion/exclusion criteria, data sources). For example participants/participants, (test) animals, biological samples, documents, problems, events, studies, populations, subgroups, target locations (eg sports fields), etc. included in the research/project.**
- **Intervention(s) An intervention can be: an approach, facility, method of treatment, methodology, protocol, measure, instrument, strategy, etc. in practice and/or policy.**
- **Intended results**
- **Impact: How will the project contribute to knowledge utilisation: the use of the results of projects and programs in practice, policy, education and/or research?**
- **Innovation: How does the project contribute to innovation in modelling for Pandemic Preparedness?**

Also indicate whether the project focuses on one or more diversity aspects such as: sex, gender, age, ethnicity, socio-economic background, sexual orientation, (in)ability.

Comprehensive summary in Dutch:

ACHTERGROND EN RELEVANTIE
Vaccinatie is zeer belangrijk gebleken voor de volksgezondheid, maar is ook een betwist onderwerp. De Wereldgezondheidsorganisatie (WHO) heeft 'vaccine hesitancy' of twijfels over vaccinatie aangemerkt als een van de grootste bedreigingen voor de volksgezondheid[1]. Deze twijfels zijn vaccin-specifiek of generiek en geografisch geconcentreerd in bv. bepaalde buurten[2,3]. Ons project draagt bij aan de effectiviteit van het huidige GGD vaccinatiebeleid, gebaseerd op de TIP-aanpak van de WHO[4], door beter inzicht te krijgen in de manier waarop heersende opvattingen en waarden over vaccinatie in gemeenschappen individuele keuzes beïnvloeden.

PROBLEEMBESCHRIJVING EN DOELSTELLINGEN
Dube et al.[5] definiëren individuele besluitvorming als het kernconcept van vaccin twijfel. De heterogeniteit in vaccinatie keuze profielen (d.i. verschillen in besluitvorming) en de verdeling ervan in de Nederlandse bevolking belemmeren de implementatie van effectievere vaccinatiestrategieën. We adresseren dit probleem met de ontwikkeling en evaluatie van een nieuw data-gestuurd, persoonsgericht raamwerk om de vaccinatiegraad beter te voorspellen en betere interventies te ontwikkelen op lokaal niveau (vooral voor kwetsbare groepen), gebruik makend van SARS-CoV-2-vaccinatie data. Doelstellingen: (1) Identificeren en karakteriseren van vaccinatie keuze profielen in subpopulaties. (2) Modelleren van de verdeling van vaccinatie keuze profielen op lokaal niveau in de hele bevolking. (3) Modelleren van de vaccinatie bereidheid op basis van sociale netwerken en verschillende vaccinatie keuze profielen.

PLAN VAN AANPAK (zie bijgevoegde figuur)
Doelstelling 1: Data over individuele besluitvorming (overtuigingen, waarden, etc.) worden verzameld via het LISS-panel: een representatief panel dat kan worden gekoppeld aan CBS-gegevens (N = 5000). We gebruiken Latente Profiel Analyse [6] om subpopulaties met verschillende keuze profielen te identificeren en relaties tussen sociale (bv vertrouwen, sociale normen, religie), contextuele (bv toegankelijkheid) en demografische (bv leeftijd, etniciteit, opleiding) covariaten te berekenen; en ook de vaccinatiegraad in elk profiel.
Doelstelling 2: We koppelen de survey data aan CBS-microdata en modelleren profielen met sociodemografische covariaten van het CBS en schatten de verdeling van vaccinatie keuze profielen in de hele bevolking. We valideren het model door geschatte vaccinaties voor elk profiel te vergelijken met de CBS SARS-CoV-2-vaccinatie data.
Doelstelling 3: We modelleren de vaccinatiegraad op regionaal niveau op basis van de keuze profielen en de connectiviteit (met CBS/POPNET-netwerkgegevens) van de verschillende subgroepen om zo subpopulaties te identificeren voor een gerichtere interventie om individuele keuzes te ondersteunen en beïnvloeden, als ook de gemeenschap waar individuen deel van uit maken.

BEOOGDE RESULTATEN EN IMPACT
Ons project resulteert in een karakterisering van vaccinatie keuze profielen voor de hele bevolking, en vaccinatiedeelname. Door rekening te houden met individuele waarden, overtuigingen en netwerkrelaties draagt onze aanpak bij aan doelgerichtere interventies om de vaccinatiedeelname te optimaliseren. We zullen onze resultaten verspreiden via een interactieve website met vaccinatie keuze profielen en potentiële effecten van interventies.

INNOVATIE
We adresseren twee beperkingen in het huidige beleid. Er wordt geen rekening gehouden met (i) verschillen in overtuigingen en waarden, met het risico dat vaccinstrategieën botsen met overtuigingen van mensen, en vaccin twijfels kunnen toenemen; (ii) hoe vaccinatie keuzes zich verspreiden via sociale netwerken, terwijl onderzoek laat zien dat netwerken een cruciale rol spelen bij vaccin twijfels [2,3].

DIVERSITEIT
In ons project modelleren we de heterogeniteit van vaccinatie keuze profielen en de verdeling ervan in de bevolking, inclusief voor groepen van burgers met een migrantenachtergrond.

3.4 Comprehensive summary in English

If applicable, please use the following headings:
- **Background and relevance**
- **Problem definition and objective(s)**
- **Plan of approach / research design**
- **Objects/units of the project (incl. inclusion/exclusion criteria, data sources). For example participants/participants, (test) animals, biological samples, documents, problems, events, studies, populations, subgroups, target locations (eg sports fields), etc. included in the research/project.**
- **Intervention(s) An intervention can be: an approach, facility, method of treatment, methodology, protocol, measure, instrument, strategy, etc. in practice and/or policy.**
- **Intended results**
- **Impact: How will the project contribute to knowledge utilisation: the use of the results of projects and programs in practice, policy, education and/or research?**
- **Innovation: How does the project contribute to innovation in modelling for Pandemic Preparedness?**

Also indicate whether the project focuses on one or more diversity aspects such as: sex, gender, age, ethnicity, socio-economic background, sexual orientation, (in)ability.

Comprehensive summary in English:

BACKGROUND AND RELEVANCE
Vaccination has been a huge success for individual and population health, but has also become the subject of heated public debates. The World Health Organization (WHO) has identified vaccine hesitancy as one of the 10 major threats to public health[1]. Vaccine hesitancy is vaccine-specific or generic, and geographically concentrated, e.g. in specific urban areas[2,3]. Our project contributes to the effectiveness of the current GGD vaccination policy based on WHO's TIP approach[4], by gaining a better understanding of how prevailing beliefs and values about vaccination in communities affect individual decisions.

PROBLEM DESCRIPTION AND OBJECTIVES
Dube et al [5] define individual decision making as the core concept of vaccine hesitancy. The heterogeneity in vaccination decision profiles (i.e. differences in decision making) and the unequal distribution in the general Dutch population hampers implementation of more effective vaccination strategies. We address this problem by designing and evaluating a new data driven, person-centered framework, to better predict vaccination uptake and tailor interventions at a local level —especially for vulnerable groups, using data of SARS-CoV-2 vaccination. Objectives: (1) Identifying and characterizing vaccination decision profiles in subpopulations. (2) Modeling the distribution of vaccination decision profiles at the local level for the entire population. (3) Modeling vaccination preparedness based on social networks of different vaccination decision profiles.

PLAN OF APPROACH (see attached Figure)
Objective 1: Data on individual decision making (beliefs, values, etc.) will be collected through the LISS panel-—a representative survey directly linkable to CBS data (N = 5000). We will use Latent Profile Analysis[6]to identify subpopulations with different decision profiles—group-dependent relationships between social (e.g. trust, social norms, religion), contextual (e.g. accessibility) and demographic (e.g. age, ethnicity, education) covariates; and calculate the rate of vaccination uptake in each profile.
Objective 2: We will link the survey to CBS microdata, and model profiles using CBS sociodemographic covariates to estimate the distribution of vaccination decision profiles in the total population. We will validate the model comparing the expected vaccinations for each vaccination profile and the real SARS-CoV-2 vaccinations as recorded in CBS data.
Objective 3: We will model vaccination uptake at the regional level based on the decision profiles and the connectivity (using CBS/POPNET network data) of the different subgroups. This will enable us to identify the most promising subpopulations in which to test an intervention in terms of possibilities to change their decision as well as their potential to influence additional subpopulations.

INTENDED RESULTS AND IMPACT.
Our project will result in a characterization of vaccine decision profiles for the whole population, and their relationship with vaccination decisions. By taking into account individual values, beliefs and network relations, our approach will contribute to better target interventions to optimize uptake. We will distribute our results through an interactive website displaying the distribution of vaccination decision profiles and the potential effect of targeted interventions.

INNOVATION

We address 2 limitations that are currently not yet taken into account: (i) differences in beliefs and values, risking to focus on vaccine strategies that collide with people's belief systems increasing vaccine hesitancy. (ii) how vaccination decisions spread through social networks, although empirical results show that networks play a crucial role[2,3] .

DIVERSITY
In our project, we will explicitly model the heterogeneity of vaccination decision profiles and detail their distribution for the entire population, also communities with citizens with a migrant background and other hard-to-reach groups.

3.5 Keywords

Please specify no more than five key words for the project.

Keyword 1:	Vaccination decision profiles
Keyword 2:	Social networks
Keyword 3:	Data science
Keyword 4:	Targeted vaccination strategies
Keyword 5:	Optimizing vaccination uptake

4. Project information

4.1 Have you pre-registered your application?

For this grant call, a pre-registration of your application is required before January 22nd, 2024. Applications that are not pre-registered are not taken into consideration. The pre-registration link can be found in the grant call.

Explanation:

☑ Ja
☐ Nee

4.2 Population/Target group

Below you will see a number of selection lists that we use to organize your application. Multiple answers are possible. Please select only the most suitable and non-overlapping choices.

What population/target group do you reach with this project?	Populatiebreed

4.3 Scientific and/or professional association

Which scientific and/or professional association will be/are involved in this project?

The applicants are employed at the department of Public and Occupational Health at the Amsterdam UMC, the departments of Sociology and Methodology of Statistics at University Utrecht and the Julius Center of Utrecht UMC.
The project is strongly linked to work conducted in the BePrepared consortium with 13 organisations, in which 3 of the applicants and advisors (Timmermans, Lugtig, Buskens) lead tasks.
We will collaborate with ODISSEI Social Data Science group as one of the co-applicants (Garcia-Bernardo) is a member of this group. This group has extensive experience with using CBS data (including network data and COVID19 data), statistical models and open science.
We will install and advisory group with stakeholders, i.e. RIVM (Lambooij,Fransen), GGD Amsterdam (Woudenberg, Nielen) , GGD Rotterdam (Voeten), Pharos (expertise center health inequalities).

4.4 Main discipline

Main discipline: ***Please select your main discipline***	Other
Other sub-discipline:	Psychology
Extra Disciplines: ***Please select no more than four extra disciplines***	Communication science Mathematics Mathematics ==> Probability theory, statistics Sociology

4.5 Relevance

Please describe and substantiate:

- **relevance for the programme and the grant call;**
- **societal and scientific relevance;**
- **significance in relation to the problem definition;**
- **expected results or output innovative or pioneering character in terms of content or approach;**
- **no areas of overlap with ongoing or completed projects alignment with current developments or comparable projects;**
- **relevance and output for stakeholders/end users.**

Relevance:

RELEVANCE FOR THE PROGRAMME
By understanding the interlink between risk beliefs and values, networks and vaccine uptake, our models will help us prepare for a possible next pandemic by: (i) uncovering the barriers and beliefs related to vaccination for different vaccination decision profiles, which will reveal which factors are more important (and should be monitored) for designing impactful interventions; (ii) characterizing the distribution of those profiles at the regional level to find potential targets for interventions (e.g. specific vulnerable groups); (iii) revealing how the level of connectivity within and between vaccination decision

profiles impact vaccination uptake through the spread of vaccination decisions.

SOCIETAL AND SCIENTIFIC RELEVANCE
The WHO has identified vaccine hesitancy as one of the 10 major threats to public health [1]. During the COVID19 pandemic, vaccine hesitancy and inequalities in vaccination uptake, not only threatened public health and health care capacity, but also contributed to health inequity, polarization and mistrust. These controversies about vaccination are related to differences in (risk) beliefs and values [7]. In our project we will address both barriers to vaccination as well as differences in values, beliefs and social networks. This will allow public health professionals to adapt vaccination strategies to better align with citizens' vaccination beliefs and foster vaccination uptake in social networks. Scientifically, our project will contribute to the literature on person-centered approach to vaccination—which is in contrast to the more common variables-centered approach. This literature [8,9] has highlighted the importance of taking values, beliefs and values into consideration. By showing how survey and registry data can be integrated to create such a person-centered approach, we will pave the way to new studies on other diseases, and to quickly design a person-centered approach in future pandemics.

EXPECTED RESULTS AND INNOVATIVE CHARACTER
We will build a psychologically informed network-data model combining information about citizens' vaccination decisions and related beliefs, values and barriers with CBS microdata to get a better insight into the distribution of vaccination decision profiles. Most studies on vaccination decisions and uptake take a variable-centered approach assuming a homogeneous sample in which there are no interactions between variables and simplified assumptions on connectivity within and between subpopulations. We propose a person-centered approach by identifying clusters of individuals with similar vaccination decision profiles. With a better insight into vaccination decision profiles in specific communities and the connectivity within and between these communities, we expect targeted interventions on vaccination to be more effective.

OVERLAP AND COMPARABLE PROJECTS
In the ZonMw BePrepared consortium, two projects are currently ongoing that focus on vaccination behavior, one focusing on characteristics of social networks (Dukers-Muijers), and one on individual and environmental factors (Ruiter). Both projects have a variable-centered approach, modeling vaccination uptake for a homogeneous population. In contrast, our proposed project takes a person-centered approach acknowledging the diversity in vaccination decisions. Moreover, we will also examine the distribution of vaccination decision profiles at a local level.

RELEVANCE FOR STAKEHOLDERS
With a better insight into vaccination decision profiles on a local level, health professionals could better target vaccination strategies taking beliefs, values and barriers into consideration, leading to a greater public support for vaccination and a higher uptake. Furthermore, our data model will establish which beliefs and networks are more important for vaccine uptake. This could be used in future pandemics to quickly deploy surveys to determine risk beliefs and social networks.

4.6 Innovation

Elaborate on what makes your research proposal innovative.

Explanation:

Our approach addresses two key limitations of targeted vaccination approaches:
- they currently do not consider differences in beliefs and values. As a result, we risk focusing on vaccine strategies that collide with people's belief systems, which can increase vaccination hesitancy. By modeling the heterogeneity of vaccination decision profiles, we can better align (risk) communication with people's belief systems and local circumstances.
- they do not take into consideration how vaccination decisions spread through social networks, although empirical results show that networks play a crucial role in shaping attitudes and vaccination uptake [2,3,10]. The distribution of vaccination decision profiles can help us understand which vaccination strategies are required to increase the likelihood of vaccination while respecting individual's values and beliefs and maintaining public support. To predict how increases in the likelihood of vaccination spread to larger subpopulations, we need to take into consideration the connectivity between individuals. For example, individuals with more network members who are vaccine supporters are more likely to be vaccinated [11]. By including these networks in our models, we will be able to estimate the indirect effect of interventions, maximizing their impact.

This project contributes to Pandemic Preparedness by understanding and predicting where interventions can lead to a higher vaccination uptake while keeping public support high. Moreover, the vaccination decision profiles and estimated connectivity between groups could also be included in epidemiological models.

While incorporating behavioral data for understanding the epidemiology of infectious diseases and vaccination uptake is gaining more attention, our approach is unique in the sense that we focus on the variety of individual vaccination decisions and respecting citizens' values, beliefs and choices. In this project we will combine the complementary expertise and experience in behavioral decision research (Timmermans) with statistical modeling of social dynamics on social networks (Buskens, Garcia-Bernardo) and use of large-scale administrative data to study pandemics, including information on social networks (Garcia-Bernardo).

4.7 Problem definition and objective

Please describe what the project aims to achieve in a clear, concrete and concise manner.
Depending on the type of application involved (research, development or implementation), the objective is followed by a research question or hypothesis:

- **In research projects, the objective should result in a specific and testable research question.**
- **In a development or implementation project, the objective should lead to a specific and practically achievable result.**

Problem definition and objective:

During outbreaks of a virus with pandemic potential, it is crucial to contain the infection spread as effectively as possible. When available, vaccines are a very effective way to prevent further spread of infections. However, vaccination uptake varies among people and communities due to practical barriers but also to different attitudes, risk beliefs and values. Citizens may decide not to vaccinate due to lack of knowledge, misbeliefs, religious values, and/or due to contextual factors such as accessibility. If vaccination refusal is due to lack of knowledge, an information campaign could be useful. Alternatively, if vaccination refusal is related to values such as autonomy or belief systems, the conclusion might be that the deviant choices should be respected, and we need other measures to limit virus spread. Moreover, empirical sociological research on the spreading of vaccination attitudes and uptake [2,3, 10]

highlights the crucial role of social networks. Current vaccination plans do not take the heterogeneity in vaccination profiles and social networks into consideration.
We address this problem by designing and evaluating a new framework for targeted vaccination policies with the dual goal of maintaining high levels of public health and aligning vaccination strategies with beliefs and values of citizens. This will allow public health professionals to predict vaccination uptake and tailor preventive and educational interventions at a local level—especially for vulnerable groups– while taking into account citizens'(risk) beliefs and values. We do so by (i) identifying and characterizing vaccination decision profiles, (ii) modeling the distribution of vaccination decision profiles at the local level for the entire population, (iii) modeling vaccination uptake based on the social networks of the different vaccination decision profiles.

The specific research questions are:
- Which type of vaccination decision profiles are present in the Netherlands?
- How are these profiles distributed at the local level for the entire population?
- To what extent do the distribution of vaccination decision profiles and social networks between people determine vaccine uptake at the local level?

We will develop this framework for COVID 19 vaccination decisions using existing data. If our approach proves itself to be valid, the approach could also be applied to other vaccination decisions with a variable uptake among communities (e.g. measles, HPV).

4.8 Approach

The approach aligns with the objectives. Describe the chosen methods and analyses, including the theoretical and/or empirical foundation.

If your project involves model development, consider the following components:

- **What kind or type of model is being developed?**
- **What are the key structural assumptions in the model(s)? Provide both the rationale and the data supporting these assumptions.**
- **Indicate which data are available for the model parameters and for which there are no data available.**
- **Specify which data are used for model calibration and the potential impact of any limitations in this data on the model outcomes.**
- **How are uncertainty margins determined, and which sources of uncertainty are considered?**
- **Indicate whether data are used to validate the model outcomes, and demonstrate that this data is available (or will be).**
- **What is the time horizon of the model?**
- **What heterogeneity is considered, and why?**
- **What sensitivity analyses are applied?**
- **Who are the users of the model outcomes?**
- **Who are the potential users of the model?**
- **How can the model be implemented?**
- **How will the organization/research group ensure that knowledge about the developed model remains within the organization after the project is completed, so that the acquired knowledge can still be used in the event of a new pandemic?**
- **What is the plan to update the model if new insights become available after the project concludes?**

If your project/research involves other (knowledge) products for modeling, consider the following:

- **What kind of (knowledge) product is being developed?**
- **What contribution does this (knowledge) product make to modelling in the event of a new pandemic?**
- **What data are used to develop or validate the (knowledge) product? Demonstrate that this data is available.**
- **Who are the potential users?**
- **How can the (knowledge) product be implemented?**
- **How can the developed (knowledge) product be continuously updated after the project concludes?**
- **How will knowledge about the developed (knowledge) product be preserved within the organization/research group after the project is completed and be used in the event of a new pandemic?**

Approach:

OBJECTIVE 1: IDENTIFYING AND CHARACTERIZING VACCINATION DECISION PROFILES USING SURVEYS.

Brewer et al [12] distinguishes 3 main categories shown to be related to vaccination behavior: (1) how people feel and think, e.g. risk beliefs about disease and vaccine; (2) social processes e.g. social norms, social networks; (3) direct behavior change, e.g. reminders, reduce barriers. Vaccine hesitancy or a low motivation to vaccinate is influenced by many of these factors (for an overview of vaccine hesitancy [5,13]). Most studies assume homogeneity in how these factors relate to individuals' vaccination behavior, while it is clear that these factors do not have the same impact for every individual. That is why we rely on profiles of factors that influence behavior and assume heterogeneity, as can be analyzed using Latent Profile Analysis. In our approach we focus on the vaccination decisions of individuals and thus on identifying vaccination decision profiles that are embedded in and influenced by a social context. We aim to analyze the interaction between factors, such as how individual risk beliefs may spread in social networks and alternatively how social networks may affect people's risk beliefs. Research [8] showed that clusters of beliefs in a social network can via an opinion formation process lead to clusters of unvaccinated individuals thus increasing outbreak probability. Not vaccinating might not be a problem per se, the clustering of individuals with a negative attitude about vaccination might be.

The Brewer et al [12] overview relates to the Tailored Intervention Program (TIP) of the WHO [4], which is aimed at identifying barriers and drivers to vaccination in low coverage groups and using these insights to design tailored interventions. TIP is based on the COM-B model and individual and social processes related to vaccination uptake: Capabilities (e.g. skills), Opportunity (e.g. social norms) and Motivation (e.g. values, beliefs, trust) impacting Behavior. Our approach, if successful, will thus provide input for the TIP to be more effective. The social (and spatial) clustering of vaccine-refusing households could be leveraged to tailor communication strategies to improve vaccine acceptance and community perceptions of immunization programs.

As mentioned, the emergent literature about preventive behaviour and infectious diseases and vaccination behavior employs a variable-centered approach assuming sample homogeneousness with how variables are related to each other [14]. We propose a person-centered approach, acknowledging heterogeneity within the population with respect to vaccination decision making.

Data on individual citizens' decision making (beliefs, values, vaccination choice etc.) will be collected (N = 5000). Using data of (to be conducted) focus groups (N=4) with citizens and building on existing knowledge about citizens' vaccination decision making (see for an overview Brewer et al [12]), we will design a survey to measure citizens' risk beliefs, attitudes and values related to vaccination decisions, as well as barriers which hinder citizens to actually take the vaccination. The most important categories related to vaccination decisions are risk beliefs or risk perceptions, values, person variables and contextual variables. Risk perceptions (cognitive and affective) about: (1) the contagiousness and severity of the infectious disease to be vaccinated against; (2) adverse side effects of vaccination; (3) benefit beliefs or efficacy of vaccinating to prevent the disease. Relevant values for vaccination decisions are, e.g. autonomy, purity, responsibility and security [15,16]. Person variables: (1) demographic variables such as age, educational level, religion, ethnicity; (2) health literacy and numeracy [17]; (3) perceived knowledge. In addition contextual variables (e.g. accessibility of vaccination) as well as social variables (trust, social norms) will be measured. Risk beliefs as well as beliefs can be more or less shared between individuals in the same group [17]. We will use existing studies to design our questionnaire [e.g. 7, 18,19,20].

We will use Latent Profile Analysis [6] to identify subpopulations with different vaccination decision profiles. Latent profile analysis (LPA) is a categorical latent variable approach that focuses on identifying latent subpopulations within a population based on a certain set of variables. LPA thus assumes that people can be typed with varying degrees of probabilities into categories that have different configural profiles of personal and/or environmental attributes [21]. LPA is not often used for vaccination decision profiles, but see Rossen et al [18]. Rossen et al identified 3 vaccination decision profiles, which they named vaccine "accepters", "fence sitters", and "rejecters", each characterised by a distinct pattern of vaccination attitudes. LPA thus focuses on patterns of variables (also called LPA indicators). We will identify the number of different vaccination decision profiles as well as the prevalence. Profiles of individuals sharing similar patterns of variables are identified and compared with other profiles, both in terms of how the variables combine to form the profiles, and how those combinations are differentially related to predictors and outcomes.

We will then characterize these decision profiles using a variety of social (e.g. trust, social norms), contextual (e.g. accessibility) and demographic (e.g. age, ethnicity, religion, education) covariates [22]. We will then classify the profiles with different vaccination uptake according to the arguments that are most relevant for those profiles, to answer the question of which profiles have values related or perceived risk related arguments against vaccinations and which profiles seem to lack information and accessibility to vaccination. We will also determine which values and risk beliefs are most important for the different vaccination decision profiles to be able to survey these more quickly in a next pandemic.

We will make use of the LISS panel (Longitudinal Internet studies for the Social Sciences; lissdata.nl) which is based on a true probability sample of households, drawn from the population register by Statistics Netherlands. It consists of 5000 households, comprising approximately 7500 individuals of 16 years and older. Self-registration is not possible, participation is invite-based only. Households that could otherwise not participate are provided with a simple computer and Internet connection. With these measures, the LISS panel can control and guarantee the quality of the composition and representativeness of the panel. This distinguishes the LISS panel from other online panels where panel members often can register themselves and where non-internet users are absent, and makes this panel ideally suited for research where a correct representation of the Dutch population is of great importance. In addition, data can be used from the LISS core study. There are over 10.000 variables available per individual, with lots of detailed information about general values and beliefs, religiosity, health, social integration, etc.

OBJECTIVE 2: MODELING THE DISTRIBUTION OF VACCINATION DECISION PROFILES AT THE LOCAL LEVEL FOR THE ENTIRE POPULATION.

After determining which vaccination decision profiles exist, and which profile corresponds to each individual in the LISS panel, we will then link the LISS panel to CBS microdata, which is possible through a common identifier. We will then model vaccination decision profiles using the vast information in CBS microdata, including income and profession, household composition, geographical location, family and household networks, or demographic information. For example, we may find that being a university professor in a large city is highly correlated with a vaccination profile "highly receptive to vaccines". This model will allow us to extrapolate the distribution of the vaccination decision profiles for the entire population of the Netherlands at a regional level.

We will model the heterogeneity in vaccination profiles using a wide range of data-driven classification models, from multinomial logistic regression to histogram-based boosting methods such as LightGBM [23] —a widely used algorithm due to its good performance in a wide range of prediction tasks. We will train the model in 70% of the individuals in the LISS panel and evaluate its sensitivity and specificity in the remaining 30% of individuals. This extrapolation to the Dutch population will provide an estimate of the size, location and concentration of the different decision profiles in the country at a regional level (4-digit postcode, buurt, gemeente). This will enable us to identify the most promising subpopulations in which to test an intervention.

We will validate our model by comparing the expected SARS-CoV-2 vaccine uptake predicted by the distribution of vaccination profiles—each profile is linked to a rate of vaccination—to the real vaccine uptake, as recorded in CBS data. Uncertainty margins will be calculated analyzing the variance in model predictions across different regions by fitting the model 100 times, where the vaccination decision profile of each individual is sampled with a probability obtained from the latent profile analysis model of objective 1. By quantifying these sources of uncertainty, we will provide more robust estimates of vaccination decision profiles across the Netherlands.

We will make the results of the model publicly available through an interactive website showing the regional distribution of different distribution profiles. This can help public health officers and researchers to understand which vaccination profiles exist and how they relate to sociodemographic characteristics, and to understand the potential effect of vaccination strategies.

OBJECTIVE 3: MODELING VACCINATION PREPAREDNESS BASED ON THE SOCIAL NETWORKS OF THE DIFFERENT VACCINATION DECISION PROFILES.

The distribution of vaccination decision profiles can help us understand which vaccination strategies are required to increase the likelihood of vaccination while respecting individual's values and beliefs and maintaining public support. To predict how increases in the likelihood of vaccination can spread (or not) to larger subpopulations, we need to take into consideration the connectivity between individuals. Overall vaccination coverage is not only determined by individuals' beliefs and barriers, but also affected by the influence spreading in social networks [2]. For example, individuals embedded in networks of vaccine supporters are more likely to be vaccinated [11].

We will study the effect of networks in the spread of vaccination decisions in two steps. First, we will explore the role of different social contexts at the individual level. Then, we will explore how vaccination uptake at the regional level depends on the connectivity between vaccination decision profiles. For both analyses, we will combine population-wide data on SARS-CoV-2 vaccination uptake and the recently available POPNET data from Statistics Netherlands (CBS), which connects all Dutch residents through over 1 billion relationships [26, 27] in five social contexts: school, families, workplaces, households and closest neighbors.

Social contexts play a key role in vaccination decisions. For example, among participants with negative views on papillomavirus vaccination, 62.5% said their family and friends also held negative beliefs about vaccines, with families playing a central role [24]. Moreover, vaccine safety is influenced by family's perceptions [25], and perceiving family, and peers as vaccination supporters is associated with greater vaccination uptake [3]. We will analyze the effect of social contexts estimating, for each vaccination decision profile, the correlation between SARS-CoV-2 vaccine decisions and being connected through family, households, workplaces and neighborhoods. This will allow us to understand which social contexts are more important for influence spreading in the different vaccination decision profiles.

In the second step, we will formalize this approach by modeling the share of SARS-CoV-2 vaccine uptake in 2021 at the regional level (4-digit postcode, and neighborhood, municipality) based on the share of the population of each vaccination profile and the number of connections between and within the decision profiles in the region. The number of connections will be estimated using the number of connections according to POPNET data: nuclear family connections, extended family connections, non-family household connections, workplaces, and closest neighbors. While social contexts act as proxies for social networks, it is important to realize that carefully targeted campaigns on specific groups are more effective in terms of social influence impact even if the network information available is imperfect [29].
Similarly to the previous objective, we will fit different regression models in 70% of the regions and evaluate the performance on the remaining 30%. Uncertainty margins will be calculated by fitting the model 100 times, where the vaccination decision profile of each individual is sampled from the probabilistic model of objective 2.

This model will allow us to understand how an increase in vaccination uptake in one vaccination decision profile—targeted according to the beliefs, values and barriers found empirically in objective 1—can impact (positively or negatively) the likelihood of vaccination in other groups. We will make the results of the model available through the same interactive website. This can help public health officers and researchers to understand the potential effect of interventions, balancing impact, respect of values, and protection of vulnerable target groups.

We will pay special attention to Open Science practices, publishing all aggregated data at the regional level (to comply with CBS policies), data pipelines to work with the LISS panel and CBS, and the models of vaccination decision profiles (e.g. coefficients in a regression model). This will allow us and other researchers to quickly develop new results in a new pandemic, or for other diseases for which we have data (e.g. influenza or measles).

4.9 Feasibility

- **Please elaborate on the opportunities and challenges in carrying out the project.**
- **Please provide a timeline and explain why the project is feasible within the timeline.**

Feasibility:

OPPORTUNITIES

A major opportunity is to be able to approach the problem of vaccine hesitancy from a multidisciplinary perspective, i.e. the complementary expertise and experience in behavioral decision research (Timmermans) with statistical modeling of social dynamics on social networks (Buskens, Garcia-Bernardo, Kretzschmar) and the use of large scale administrative data to study pandemics, including information on social networks (Garcia-Bernardo,Lugtig). We are convinced that this complementary expertise will lead to new insights to better tailor interventions to people's risk beliefs and values, in order to optimize vaccination rates. We are very much looking forward to learning whether our approach is successful and working with health professionals to support their vaccination policies. After and as a result of the COVID19 pandemic, many GGDs have changed their vaccination strategy. The Municipal Health Service (GGD), responsible for administering most vaccines, has become even more aware of the importance of a more personal approach since the COVID-19 pandemic. The GGD Amsterdam uses the WHO's TIP approach to target interventions on groups with a low vaccination rate (see: https://www.ggdgezondheidinbeeld.nl/wp-content/uploads/2021/06/Actieplan-Verhogen- Vaccination Council - Amsterdam. pdf). We believe that our approach, if successful, will make this TIP approach more effective. Health professionals will gain a better understanding of how prevailing beliefs and values about vaccination in communities influence individual decisions. Because experience and knowledge of practitioners and health professionals are crucial to our approach, we plan to install a stakeholder advisory group.

CHALLENGES:

If the surveys provide a diffuse picture of where low vaccine uptake is located and no clear decision profiles emerge, it will be difficult to design subpopulation based intervention. However, as studies showed that vaccine uptake is considerably related to various demographic profiles, we are confident that we can link these subpopulations also to specific vaccination decision profiles. We will monitor if hard-to-reach groups (e.g. with migrant background) are sufficiently represented in the panel and take measures if needed. We will ensure the access to vaccination uptake micro-data on time, so we can think of alternatives if access is limited.
The network information available from CBS is certainly limited, which might also imply that the predictive power to understand regional decision profile distributions can be limited. Still, it is important to realize that even with modest predictive power and limited information on social networks, using this information as much as possible in information campaigns can still be expected to induce large improvements of more general information campaigns.

TIMELINE AND PERSONNEL

We intend to assign two postdocs to work on the project. One postdoc will do the data acquisition and analysis of the survey data about identifying vaccination decision profiles. Another postdoc will be involved in preparing and analyzing the CBS data, to extrapolate vaccination decision profiles to the Dutch society, and fit model to vaccination uptake per region, identify subpopulations with a suboptimal vaccination uptake.
Postdoc 1: Months: 1-4 running focus groups, designing the questionnaire and running the survey; Months: 5-7: data cleaning and analysis: vaccination profiles; Months 8-10: extrapolation to vaccination profiles at CBS (with postdoc 2). Months 10-12: Validation of model by comparing with vaccine uptake. Months 12-15: interactive website and impact
Postdoc 2: Months 1--3 data preparation at CBS; month 3-7: correlation vaccination uptake in social contexts; 8-10 connectivity between vaccination profiles; month 10-14: modeling at regional level; month 14-15: sensitivity analysis.

4.10 Expertise and experience

- **This question is relevant to the assessment of the project group or individual. The term 'expertise' refers to the expertise gained from substantive, practical or methodological experience that is essential to completing the project successfully. Familiarity with the specific field is also important.**

- **Please describe any previous activities and products as well as any relevant knowledge or skills of the project group or individual. The term 'products' may refer to publications, reports, guidelines, protocols, or interventions. You can also list here the number and nature of any previous grants as well as national and international contacts with colleagues and target groups. If the application involves a personal grant, we ask that you also attach a curriculum vitae.**

Expertise and experience:

In this project we will innovatively combine qualitative and quantitative social science methods and modeling. The research team members have complementary expertise in statistical modeling, data science, sociology, psychology, and public health. The main applicant Timmermans has extensive experience in qualitative and quantitative research on citizens' risk beliefs, values and decision making for a variety of health topics, including vaccination. Her research group is (inter)nationally prominent and collaborated(s) with many professional organizations such as the RIVM. Scientific expertise about statistical modeling of behavior in social contexts, calibrating of these models using microdata, and open science practices is provided by the UU Departments of Sociology (Buskens) and the ODISSEI Social Data Science team and UU Department of Methods and Statistics (Garcia-Bernardo). The project team will be advised by scientific advisors with expertise in infectious disease modeling (Kretzschmar, UU), diversity and health literacy (Fransen, AUMC) and (risk)communication (Damman, AUMC). and a methodologist with expertise in survey methodology and questionnaire design in panel surveys (Lugtig). We will collaborate with the BePrepared (BEhavioural and social sciences and pandemic PREPAREDness) consortium (P.I. De Bruin RU), in which Timmermans, Buskens and Lugtig are involved. We will also set up an advice board with stakeholders, i.e. Municipal Health Services (MHS) Amsterdam (Van Woudenberg, Nielen) and Rotterdam (Voeten) and RIVM (Lambooij, Fransen) and Pharos (expertise center health inequalities).

4.11 Publications

- **Please summarise the most relevant publications by the project members for this project.**

Publications:

Research on citizens' risk beliefs, values and decision making for a variety of health topics, including vaccination
•Timmermans DR, Henneman L, Hirasing RA, Van der Wal G. Attitudes and risk perception of parents of different ethnic backgrounds regarding meningococcal C vaccination. Vaccine. 2005 May 9;23(25):3329-35.
•Van der Weerd W, Timmermans DR, Beaujean DJ, Oudhoff J, Van Steenbergen JE. Monitoring the level of government trust, risk perception and intention of the general public to adopt protective measures during the influenza A (H1N1) pandemic in the Netherlands. BMC public health. 2011
•De Vries M, Claassen L, Te Wierik MJ, van den Hof S, Brabers AE, de Jong JD, Timmermans DR, Timen A. Dynamic public perceptions of the coronavirus disease crisis, the Netherlands, 2020. Emerging Infectious Diseases. 2021 Apr;27(4):1098.
•Lehmann BA, de Melker HE, Timmermans DR, Mollema L. Informed decision making in the context of childhood immunization. Patient education and counseling. 2017 Dec 1;100(12):2339-45.
•Claassen L, Bostrom A, Timmermans DR. Focal points for improving communications about electromagnetic fields and health: A mental models approach. Journal of Risk Research. 2016 Feb 7;19(2):246-69.
•Timmermans DR, Ockhuysen-Vermey CF, Henneman L. Presenting health risk information in different formats: the effect on participants' cognitive and emotional evaluation and decisions. Patient education and counseling. 2008 Dec 1;73(3):443-7.

Modelling diffusion of health related behavior or other behaviors through networks including vaccination behavior. Some articles also address how the network structure can be used to improve spread of behavior.
•Nunner, H., Buskens, V., Corten, R., Kaandorp, C., & Kretzschmar, M. (2023). Disease avoidance threatens social cohesion in a large-scale social networking experiment. Scientific Reports, 13(1), 22586.
•Nunner, H., van de Rijt, A., & Buskens, V. (2022). Prioritizing high-contact occupations raises effectiveness of vaccination campaigns. Scientific Reports, 12(1), 737.
•Ou, J., Buskens, V., Van De Rijt, A., & Panja, D. (2022). Influence maximization under limited network information: Seeding high-degree neighbors. Journal of Physics: Complexity, 3(4), 045004.
•Nunner, H., Buskens, V., & Kretzschmar, M. (2021). A model for the co-evolution of dynamic social networks and infectious disease dynamics. Computational Social Networks, 8(1), 1-33.

Using CBS/POPNET network data to predict SARS-CoV-2 infections and estimate the impact of different social contexts, showing the key role of families:
•Hedde-von Westernhagen, C., Garcia-Bernardo, J., & Bagheri, A. (2023). Predicting COVID-19 Infections Using Multi-layer Centrality Measures in Population-scale Networks. arXiv preprint arXiv:2310.14767.
•Garcia-Bernardo, J., Hedde-von Westernhagen, C., Emery T., and van Hoek, A.J (Forthcoming). Assessing COVID-19 Transmission Dynamics Among Students in Dutch Schools: The Impact of Distance, Social Ties, and Shared Environments.

On using Latent Class and Latent Profile analysis
•Lugtig, P. (2014). Panel attrition: Separating stayers, fast attriters, gradual attriters and lurkers. Sociological Methods and Research, 43, 699-723.

On data linkage
•Bostanci, I, Gootzen, Y. & Lugtig, P. (2023). Data Linkage to Validate and Calibrate Traffic Estimations on a Nationwide Scale: A Framework for Official Statistics. CBS discussion paper.

4.12 Literature and references

- **Please summarise the references that support your application. Avoid listing publications of the project group or individual project members.**
- **If it concerns literature references, please note author(s), title and year of publication.**
- **If it concerns other types of reference, please be as specific as possible.**

Literature and references:

1.WHO Increase in measles cases. UNICEF and WHO warn of perfect storm of conditions for measles outbreaks, affecting children. https://www.who.int/news/item/27-04-2022-
2.Ni, L. et al. (2021). Towards understanding socially influenced vaccination decision making: An integrated model of multiple criteria belief modelling and social network analysis. EJOR
3.Konstantinou, P. et al (2021). Transmission of vaccination attitudes and uptake based on social contagion theory: a scoping review. Vaccines
4.WHO TIP: tailoring immunization programmes 2019
5.Dubé et al.(2013) Vaccine hesitancy, Human Vaccines & Immunotherapeutics,
6.Oberski, D. (2016). Mixture models: Latent profile and latent class analysis. Modern statistical methods for HCI,
7.Petts J et al. Health risk communication and amplification: learning from the MMR vaccination controversy. Health, risk & society. 2004
8.Salathé M, et al. The effect of opinion clustering on disease outbreaks. J Royal Society Interface. 2008
9.Brewer NT et al. Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. HealthPsyc 2007
10.Nunner, H. et al. (2022). Prioritizing high-contact occupations raises effectiveness of vaccination campaigns. Scientific Reports,
11.Hernandez, E. et al. (2019). Social networks and the emergence of health inequalities following a medical advance: Examining prenatal H1N1 vaccination decisions. Social networks,
12.Brewer NT et al. Increasing vaccination: putting psychological science into action. Ps Science in the Public Interest. 2017
13.Larson HJ et al. Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: a systematic review of published literature, 2007–2012. Vaccine. 2014
14.Ong YX et al. Profile identification and characterization of risk perceptions and preventive behaviors during the COVID-19 pandemic: A latent profile analysis. Frontiers in Psych. 2023
15.Cataldi JR et al. Addressing personal parental values in decisions about childhood vaccination: measure development. Vaccine. 2019
16.Schwartz, S. H. et al. (2012). Refining the theory of basic individual values. JPSP
17.Buskens V et al. (eds) Advances in the Socioloy of Trust and Cooperation. 2020
18.Rossen I, et al. Accepters, fence sitters, or rejecters: Moral profiles of vaccination attitudes. SS&M. 2019
19.Timmermans DR, et al. Attitudes and risk perception of parents of different ethnic backgrounds regarding meningococcal C vaccination. Vaccine. 2005 .
20.De Vries M, et al. Dynamic public perceptions of the coronavirus disease crisis, the Netherlands, 2020. EmergInfec.Dis. 2021 .
21.Spurk D, et al. Latent profile analysis: A review and “how to” guide of its application within vocational behavior research. J Vocational Behav. 2020 .
22.Steinert JI, et al. COVID-19 vaccine hesitancy in eight European countries: Prevalence, determinants, and heterogeneity. Science advances. 2022 .
23.Ke, G., et al. (2017). Lightgbm: A highly efficient gradient boosting decision tree. Advances in neural information processing systems, 30.
24.Fu, L. Y. et al (2019). Social networks for human papillomavirus vaccine advice among African American parents. J Adolescent Health, .
25.Casillas, A. et al (2011). The impact of social communication on perceived HPV vaccine effectiveness in a low-income, minority population. Ethnicity & disease .
26.Bokányi, E., et al (2023). The anatomy of a population-scale social network. Scientific Reports, .
27.van der Laan, J. et al. (2022). A whole population network and its application for the social sciences. Eur.Soc.Rev.
28.Mascia, D., et al , A. (2020). The impact of school and after-school friendship networks on adolescent vaccination behavior. Vaccines,
29.Ou, J. et al (2022). Influence maximization under limited network information: Seeding high-degree neighbors. J Physics: Complexity

4.13 Knowledge transfer, implementation and consolidation

- **In the case of a research project, please mention the relevant groups with a stake in the potential outcomes of the research. In addition to those colleagues with whom you are familiar, for whom you write publications and present results at conferences, this mainly concerns users who are not from your immediate research environment but for whom your results or approach can be very useful in the context of another project or a possible follow-up project. Please identify these groups as precisely as possible and rank them by order of importance, if possible. Please also give a brief description of the proposed objectives in terms of transferring the knowledge derived from your project or of encouraging the use of your results by the indicated target groups. The planned activities aimed at achieving the knowledge transfer objective may vary according to the type of project.**
- **Please be sure also to indicate how you plan to inform the relevant groups about your project and the interim results at an early stage, as well as how you plan to involve them in the project itself and at what stage.**
- **Please define the activities, including the means and channels of communication to be used. Please also indicate the phase of the project in which you intend to carry this out and provide details of any other parties - aside from yourself - who could play an active role in this.**
- **Please clarify how knowledge about the newly developed product or model remains available within the organization or project group and will stay available in case of a pandemic.**
- **Please note: at the end of the project, a recommendation is required for future improvement/innovation of the developed models or products.**

Knowledge transfer, implementation and consolidation:

We will design and evaluate a new framework for targeted vaccination policies with the dual goal of maintaining high levels of public health as well as aligning vaccination strategies with vaccination decision profiles on a local level, and will thus be able to better understand vaccination decision making in subpopulations. This will allow health professionals of, e.g., Municipal Health Services to develop targeted and thus more effective interventions when vaccination uptake is too low. We will involve representatives of these organizations in our advisory board.

From a scientific point of view this is a novel approach integrating behavioral knowledge about citizens’ decision making with statistical modeling and use of large-scale administrative data. Our framework of a more person-centered approach of vaccination policies may also be applied to other public health topics where individual citizens have to make decisions (e.g. population cancer screening). In line with the open science approach and with the guidelines of the LISS survey, we will make all data collected in the project available to other researchers after being anonymized. All statistical models, code and pipelines to work with large administrative data will also be published in the Open Science Framework (OSF). Aggregated CBS data will also be made available in the Open Science Framework (OSF).

Our approach will address vaccine hesitancy, one of the 10 major threats to public health according to the WHO.[1] By taking into account individual values and beliefs and allowing for freedom of choice, our approach will contribute to a greater public support for vaccination and a higher uptake. By identifying vaccine decision profiles for subpopulations, we will be better able to design targeted interventions for suboptimal vaccination uptake, thereby fostering equity in health care. In developing our new vaccination approach using decision profiles in the Dutch society, we will explicitly take into account the diversity of views on vaccination of all stakeholders (e.g. policymakers, health professionals, citizen groups). Throughout the project, we will discuss our approach with stakeholders to reach shared views on vaccination for various infectious diseases in our society.

During the project, the team will regularly meet to discuss in detail project planning, interim results, and to reflect critically on how to translate results into practice and policy. All project team members, scientific advisors and stakeholders (e.g. citizens, RIVM, Municipal Health Service, policy makers) will participate. Based on the discussions, we will translate the findings of our project to guidelines for designing a personalized public health framework for vaccination and interventions. The guidelines and practical recommendations on the implementation of alternative vaccination policy will be finalized in an

invited symposium at the end of the project, to be organized with all stakeholders.

We will also develop an interactive website for external communication, where we will publish the distribution of all vaccination decision profiles, the potential effect of interventions based on our network-based model, and results and recommendations and communicate the progress of the project to the targeted audiences and the general public, e.g. via short public lectures and animations. Most likely, such a website will become part of the existing website of the BePrepared Consortium. Output of research projects of this consortium is coordinated by the pandemic preparedness team of RIVM to make all usable results (i.e. toolkit pandemic preparedness) available for professionals and the public.

4.14 Open science

If you plan to generate new data or reuse existing data (or other resources), you only need to submit a data management plan after your application has been approved. At this stage, you should already consider the data management requirements and what you need to deliver at the end of your project.

Please reply to the following questions in the data management section. Note that wherever "data" is mentioned, you should also provide information about other resources you plan to use for your research, such as collections of biological materials, software, image or sound material, etc.

- **Are you going to collect new data in your project? Yes / no, please explain.**
- **Are you going to use existing data in your project? Yes / no, please explain.**
- **Who is the data steward (data expert) involved in the planning and execution of the data management? Name and Institute. If more than one, name all.**
- **Are you aware of standards (e.g. terminologies or data models) that are common in your research domain? If so, which one(s) are you considering to use in your project? Please explain.**
- **Have you set aside sufficient budget for your project to make your data reusable and available?**
- **Did you take into account the requirement in the call for proposals that you must produce metadata-for-machines in your project? Yes / No. If no, please explain:In FAIR data and Data management you can find more information.**

Data management:

We will generate new data (about vaccination decision profiles) as well as we will use existing data, i.e. CBS micro data. In line with the open science approach and with the guidelines of the LISS survey, all anonymized survey data collected will be available to other researchers via the LISS panel website. We will publish the code to fit the statistical models (latent class analysis) and the results of the model in the Open Science Framework (OSF).

We will use administrative data from Statistics Netherlands (CBS). These data are not publicly available, but researchers can set up a project and get access. We will export aggregated data from CBS. To comply with CBS policy, the data will be aggregated at the numeric portion of the postcode and containing at least 10 people. Following FAIR principles, we will make the aggregated data available at the Open Science Framework (OSF), and publish the machine-readable metadata in the ODISSEI portal (https://odissei-data.nl/en/odissei-portal/). All statistical models, code and pipelines to work with large administrative data will also be published in the Open Science Framework (OSF).

We will also create an interactive website to facilitate exploration and reuse of the aggregated data, and analysis of the effect of interventions on vaccination uptake at the regional level. We have set aside sufficient budget for the development of the website, and the team has a strong expertise in data management and open science—see section 4.10. There will be a data steward at Amsterdam UMC for the survey data (I.e. Drs Wim Kraan, Amsterdam UMC) as well at the University of Utrecht for the aggregated data exported from CBS (Dr. Pascal Pas, Privacy Officer of the Faculty of Social Science at Utrecht University).

5. Financial data

5.1 Summary of the budget

We ask you to enter a summary of your budget by clicking on the link 'Add summary of the budget' below. You will be directed to a page with several tabs, where you can enter all the project costs. You can save each tab. Do you want to save in between? You can do so using the 'Close and temporarily save' button in the 'Overview' tab.

When you are finished and have filled in all the project costs on the various tabs, you must submit the summary definitively. You do this by clicking on the button 'Submit final budget' on the 'Overview' tab. The summary of your project budget can then no longer be changed.

Click here to enter the summary of your budget:		
Is this the total amount you request from ZonMw? Applied amount:		Ja

Kostenpost	Sub-kostenpost	Omschrijving	Financiële periode	Bedrag	Toelichting
1.1 Personele kosten		Twee postdocs voor een periode van 15 maanden	Tot. projectperiode/Tot. project period	€253.586,30	
1.2 Materiële kosten		Kosten gebruik CBS data en LISS panel	Tot. projectperiode/Tot. project period	€70.000,00	
1.4 Implementatiekosten		Website en symposium voor verspreiding kennis en interactie met doelgroep (i.c. professionals)	Tot. projectperiode/Tot. project period	€20.000,00	
1.5 Overige kosten		Kosten open access publicatie, reiskosten voor project, benchfee postdocs	Tot. projectperiode/Tot. project period	€16.250,00	
			Total	€359.836,30	

5.2 Budget

‘Below you can upload the specified project budget. It is mandatory to use the English DAEB form. Click here to download it.

Please upload your specified budget here (PDF format):	Timmermans_Budget_DAEB_ENG_202303_update-30102023___23022024.pdf

5.3 Are there collaborations with other parties?

ZonMw encourages collaborations between and participation of parties. However, a grant will not be awarded when the arrangements made in the various agreements lead or could lead to unlawful state aid. We ask you to provide information about the collaborating parties to determine which conditions must be applied to the grant. More information about this can be found on the ZonMw website .

A collaborating party is an organization that has an active role in executing the project. If you indicate that a collaborating party is entitled to part of the grant, please state the grant amount and briefly describe the project activity/activities. If you indicate that an organization is not entitled to part of the grant, ZonMw will assume that this organization participates at their own account and risk.

You are not required to mention sponsors (organizations that do not actively participate in the undertaking of the project and only contributes in cash or in kind).

Nee

5.4 Deze vraag is niet van toepassing.

5.5 Explanatory notes

- **Please justify each cost item in the contribution requested from ZonMw, with a brief explanation.**

Personnel: two postdocs: postdoc 1 for executing the survey using the LISS panel and analyses (objective 1); postdoc 2 for the modelling with CBS data (objectives 2 and 3).
Material: Use CBS data (20 k) and LISS Panel data collection (50k: that is 5.000 * 7.50 euros for incentives (standard rate) + 12k for time at LISS to programme questionnaire, etc.)
Knowledge dissemination: symposium for stakeholders end of project (10 k); interactive website for professional organisations (10k)
Other: benchfees postdocs, open access costs, travel costs.

5.6 Bank Details

This concerns bank details of the organization of the administrative representative. The IBAN name is also called the ascription.
Bank details are for internal use and will not be shown to reviewers and/or committee members.

IBAN account name:	Stichting Amsterdam UMC - location VUmc
IBAN:	NL75 INGB 0670 1697 30
BIC:	INGBNL2A

6. Annexes

6.1 Annexes

We kindly ask that you attach the requested documents below. Please bear in mind the permitted file size (max. 5 MB). The documents must not be password protected.
Please note: You can only add 1 attachment per requested document. Do you have multiple documents? Please merge them into 1 document first.

Figures en tables:	PROJECT_PLAN_Modelling_Vaccination_Decision_Profiles_MOVADECT.pdf
Collaboration agreement:	
Letter of commitment:	Letter-of-commitment_English_2022_1.1_Timmermans_Amsterdam_UMC-1_BuskensGarciaLugtig.pdf
Declaration of approval for submitting a grant application **The Declaration of approval for submitting a grant application must be signed by the administrative representative and the main applicant. The signed statement can be added here immediately or sent by e-mail to the relevant program secretariat no later than one week after submission.**	Verklaring-akkoord-indienen-uitgewerkte-subsidieaanvraag__TImmermans_23_02_2024.pdf

7. Declarations and signature of applicant

7.1 Permits

Please indicate the permits you need to implement the project. Please also indicate, for each required permit, whether it has been applied for or has already been granted.

- **Research governed by the Dutch Medical Research Involving Human Subjects Act (WMO; *Wet medisch-wetenschappelijke onderzoek met mensen*) must be reviewed beforehand by an accredited METC (Medical research ethics committee) or the CCMO (Central Committee on Research Involving Human Subjects**
- **Is an Animal Testing Project Permit CCD/DEC; Central Authority for Scientific Procedures on Animals) required?**
- **In certain cases, a permit is required to carry out population screening. This is laid down in the Dutch Population Screening Act Wbo; *Wet op het bevolkingsonderzoek*).**

	Status declaration
Positive opinion of an accredited METC or the CCMO	Niet van toepassing
Animal Testing Project Permit (CCD/DEC)	Niet van toepassing
Permit under the Wbo	Niet van toepassing

7.2 Declarations

I have completed this form truthfully.	☑ Yes
I agree that ZonMw will process my application and if applicable will make my data visible to committee members, reviewers and other parties for the purpose of assessing my application. See https://www.zonmw.nl/en/privacy .	☑ Yes
I will comply with the Biosecurity Code as well as all relevant codes of conduct and guidelines that apply in the profession. You can find more information at https://www.zonmw.nl/en/news-and-funding/funding/codes-of-conduct/.	☑ Yes