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What is This?

Making Predictions: Computing Populations

Christine Holmberg[1], Christine Bischof[2], and Susanne Bauer[3]

Abstract

Statistics constitute the social universe of which they are gathered. The foundation necessary to develop quantified knowledge about society is the population. If quantified knowledge changes society, the question arises on how individuals become to be represented as population. The population has to be extracted from individuals in a process that we call "populationisation." This encompasses the development of the individual into a segment of a population through the compilation of individual data into population data and its analysis. To describe the process of populationisation, we follow a statistical risk assessment tool, the German Diabetes Risk Score, from its inception in a cohort study to its entry into the public sphere of German society. The population is extracted from individuals that function as research subjects through an identification number. Preprocessed information is entered into a dynamic database that enables its rearrangement according to main aggregates. Through populationisation, a

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signified is enacted that can be sliced up and that is equal in all its parts. Now predictions can be computed and fed back to society as tools of moral judgment. The acting individual and "society" are—numerically and literally!—entangled in the production and enactment of risk knowledge.

Keywords
archiving and collecting practices, politics, power, governance, epistemology, methodologies, methods, representation, accounting practices

Introduction

In February 2007, an article on the calculation of the absolute risk to develop diabetes in the German population was published in an important scientific journal on diabetes with considerable resonance in the regular media. The article described a statistical model that predicted an individual's risk to develop diabetes in the next five years. The same day of the publication the tool was made available through the Internet (www.dife.drs.de). Individuals could calculate their five-year-diabetes risk and were given tips on what they needed to change in their habits in order to lower their risk. The tool was called the "Deutscher Diabetes Risiko Score" (German Diabetes Risk Score), in short DRS. Soon after the publication, the DRS became available as a pen and paper version. The launch of the DRS, especially its paper version, was marketed through German tabloids, newspapers, and health insurance journals. Individual usage of the software tool enacted cascades of categorizations by age, gender, and habits of their "lifestyle." Once calculated the particular risk of an individual was compared to the risk of their specific subgroup. This was possible, because "ideal" risk values were created along the age continuum in which all modifiable risk factors were set at their minimum value to show the maximum risk reduction the individual may achieve if he or she changed his or her behavior.

The online tool became another gadget to quantify one's potential future. It became a successful tool with which people play to calculate their risk of developing diabetes (Holmberg et al. 2011). The sociologists Beck, Giddens, and Lash (1996) argue that modernity functions in a reflexive mode that has led to the development of a "second modernity" in which we live today. They argue that in modernity knowledge is reflexive because of a feedback loop between society and knowledge creation. Both, knowledge creation and society in their interactions shape and reshape

society. The argument is that the statistics that are gathered about a social universe are fed back into the social universe through which it is transformed. Thus, statistics constitute the social universe of which they are gathered. Knowledge creation about a society shapes society through venues such as policies and lay education (Giddens 1990). Feminist scholars and historians of science have moved the argument forward by showing that the way knowledge is created is embedded in the communities it comes from (Haraway 1991; Harding 1991, 1993, 1998). Thus, technologies of data collection are inherently social and political (Porter 1996) and the knowledge they create is always particular to a specific situation. This can best be illustrated by methods of quantification and their success in the last 300 years. Current societal, political, and economic institutions require modes and formats of knowledge that enable the knowledge to travel outside the context of its creation. Knowledge has to adhere to ideals of mobility and convertibility. Numbers seem to best provide these characteristics as ''technologies of distance'' (Porter 1996) that are seen as faithfully representing reality (Gigerenzer et al. 1989; Desrosières 1998). Porter (1996) calls quantitative techniques ''strategies of communication'' that can be transferred across time and place. They receive their legitimacy through ''mechanic objectivity'' (Daston and Galison 2010), that relies on rules that determine the way knowledge is collected and processed. This means that the validity of knowledge relies on its methods of gathering and processing rather than on a precise understanding of any one given phenomena within a context. Thus, it is the data collection strategies and their statistical transformation that make knowledge transferable and suitable for current social, economic, and political circumstances.

Quantification

The development of technologies to create knowledge and the socioeconomic and political circumstances under which they are established influence each other. For example, for quantification to become a successful technology, societal structures had to be rearranged. The establishment of specific bureaucratic institutions and the organization of power structures accordingly were necessary to gather the ''population'' information necessary for modern governments. The success story of quantification over the last 300 years is as much a story of mathematics as it is a story of society's flexibility. Not only was the bureaucracy of the social universe restructured but statistical categories today form the basis for individual and collective

identity (Porter 1996; Gigerenzer et al. 1989; Hacking 1986). Thus, quantification has changed the world it set out to resemble.

Numerical characteristics of a population represent the basis for political, economic, and social decisions. Quantification becomes both a means of planning and of prediction (Asad 2002). It represents and directs the phenomenon studied. This suggests that knowledge creation through quantification has two important features: (1) Its transportability across time and space—a feature more important in the scientific endeavor than to describe some "reality" in depth and in its complexity (Latour 1987) and (2) Quantified knowledge changes reality by its feedback loop to society (Beck, Giddens, and Lash 1996).

Changing Society through Quantification

In other words, quantitative information gathered from society does not necessarily reflect the local context but it will change that context once the information gathered from it has been transformed into quantified knowledge. The question arises of how people come to be represented in numbers and how they acquire the information that was extracted from them in a feedback loop? What Beck, Giddens, and Lash (1996) describe are political strategies and decisions. However, studies on the effects of health messages on individuals have shown how entrenching the feedback loop is deep into each individual's embodiment (Beck, Kehl, and Niewöhner 2008; Greene 2007). This makes it particularly interesting to look at knowledge creation in the medical sciences. How is the knowledge acquired that is then distributed throughout society? How do the feedback loops work that remake society? Research has focused on showing how "objectivity" is constructed, but the interaction and engagement of the individual and the population with each other has thus far not been the focus of research.

In what follows we will elaborate on what we call "populationisation," a process that encompasses the enrollment of the individual into a segment of a population through the compilation and transformation of individual data into population data. To describe the process of populationisation, we follow the DRS from its inception in a large cohort study to its calculation and entry into the public and private sphere of German society. The DRS is a risk assessment tool that determines the likelihood to develop diabetes in the next five years based on a set of characteristics of an individual, such as eating habits and physical activity (Schulze et al. 2007). As such it is part of a larger trend in epidemiology and the medical sciences to develop tools that quantify the possibilities of disease onset for an

individual. Such a trend proves to be ethically challenging as the predictions are based on populations not individuals (Holmberg and Parascandola 2010). At the same time, it is this entanglement of individual–population–individual that makes risk assessment tools a case in point to study the production of populations and their entanglement with individuals.

The Population and the Individual

In this article, we show that to understand the mechanisms through which quantification reshapes the world it represents, one has to study "the population" and its creation. In what ways do the population and the individual relate to each other—how does one become a part of the other? The foundation necessary to develop quantitative knowledge about society is "the population." The population first has to be prepared accordingly to make possible quantified knowledge production. This is similar to the recreations in the laboratory and the incessant experimental practices, tinkering, and optimizing the experimental set up by controlled variation (Rheinberger 1997; Latour 1987; Latour and Woolgar 1986).

A prominent set of literature has dealt with the problematic of using population-calculated data for individualized medicine (Rockhill 2005) and of using population data at the bedside (Goodman 1999). Further, there is research into the production and deployment of statistics and their resilience effects in public health and social policy (Desrosières 1998; Bauer 2009; Bischof 2010; Waidzunas 2012). However, the literature is sparse when it comes to the mechanisms that create populations in epidemiology and how the population and the individual relate to each other. In what follows, we will show the transformation of an individual into a research subject through epidemiological infrastructures. We will then turn to the development of the database of the research study and to the epidemiological computations through which populations come into being. Finally, we will trace the risk assessment tool in its reentry into society. We will show how the population becomes the organizing principle in epidemiological processing and what population signifies. This will clarify the relationship of an individual to a population and illustrate how society is restructured and reorganized.

Calculating Risk

There are several risk scores such as the DRS used in diabetes campaigns across Germany and Europe. These other risk scores are contested in their

ability to predict accurately diabetes risk in the German population as they were developed in other regions (Rathmann et al. 2005). For the purpose of this article, the risk assessments can be used interchangeably as we are interested in their use rather than their statistical qualities. From the user's point of view, all of these risk assessments work similarly. The difference the users recognize lies in the factors the risk models assess. These are dependent on the factors that are available in the data sets used to create the risk model (Holmberg and Parascandola 2010). This highlights some of the characteristics risk assessments show that are not apparent for users such as the meaning of "risk factors." Risk assessment models do not necessarily include all or even the most important causal factors that lead to a disease (Holmberg and Parascandola 2010). Risk factors in risk modeling may merely be factors that appear often in association with the disease but they do not have to have a causal relationship with the disease (Rockhill et al. 2002). To understand this phenomena, we look at how the DRS was developed and what factors play into its development.

The Tool (DRS) and the Underlying Epidemiological Study

The DRS is based on data from the European Investigation into Cancer and Nutrition (EPIC). This study was implemented with the support of the European Commission in the early 1990s. EPIC was designed to investigate the relationships between diet, nutritional status, lifestyle, and environmental factors and the incidence of cancer and other chronic diseases (www.epic.iarc.fr). The study comprised of ten European countries: Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and the United Kingdom. The central coordination of the European project was through the International Agency for Research on Cancer in Lyon, France. EPIC is a large cohort study of diet and health that has recruited over half a million (520,000) people.

Cohort studies are epidemiological, observational studies designed to find "risk factors" for disease. They recruit people who are healthy and assess factors the people interact with or are exposed to. With time people become ill, after that the diseases are then connected to the exposures assessed earlier to establish a link between certain factors and certain diseases. In the case of EPIC, all inhabitants of Europe (close to the study centers) were suitable for the study if they did not have any cancers (Boeing, Korfmann, and Bergmann 1999).

To recruit such a large study population, the local research institutes of EPIC used different paths of public relations, such as advertising on their homepages, ads in local newspapers, radio stations, or television. A common and successful way of recruitment was to contact the registration office in regions of the major research centers and to choose citizens at random taking into account the study's most general study inclusion criteria, age, and gender. The selected citizens were then contacted by mail. The mailing letter included (1) a cover letter with the proposed examination date and time for a visit at the research institute, (2) an information flyer about the aims of the EPIC study and the duties for participants, (3) a response form, and (4) a response envelope (Boeing, Korfmann, and Bergmann 1999).

Those who contacted a research institute about participating in EPIC were first given information and for those that agreed to be examined (including taking blood pressure, anthropometrical measurements, and a blood sample) received lifestyle and food frequency questionnaires ten days prior to the exam as well as "24-hour recalls" on dietary intake of one day (Boeing, Korfmann, and Bergmann 1999). They were then asked to sign an agreement on the study participation (informed consent). Among other things, the agreement included a guarantee of protection of personal data, confidentiality, and the anonymity of data in accordance with respective laws and regulations on data protection in the countries. Once the legal forms were signed, the person received an identification number (ID) which remained the specific identification of the individual as long as data were saved. It was the number not the name that was connected to the collected data. The ID was on the first page of the questionnaires on the top left. In addition to the identifying code, all data collecting waves, every action and each substudy was assigned a second code, linked to the ID.

The Research Subject

Once individuals were provided with an ID, they officially became research subjects with specific tasks, including donations of samples and information in the mode defined by the study. Being assigned with an ID number organized the information and enacted participants as research subjects. Participants' tasks included a baseline examination and regular provision of information through questionnaire assessment. In the beginning of the study, sociodemographic questions on marital status, education, employment status, and the size of the household were assessed from every research subject. Throughout the study, research subjects needed to answer

questions about dietary habits, alcohol consumption, physical activity, smoking, and medical history such as hospital visits, diseases, or medications. Some of the questions were asked only from the female research subject such as pregnancies, contraceptive pills, menopause, cancer screening, and gynecological operations.

The first data collection on a research subject was done at the time of its entry into the study. After that research subjects received ''follow-up'' questionnaires at specific time intervals, for example, participants in Germany received them twice a year by mail. Questionnaires included repetitions and similarities between baseline and follow-up questionnaires to assess changes over time and consequences thereof for the state of health. Since the focus of the study was to see who with what type of lifestyle develops what type of disease, data collection on incident (the appearance of) disease was of particular importance. Thus, at each follow-up, participants had to check a list with the following diseases: tumors, cancer, cardiovascular diseases, circulatory disorders, chronic infections, and diabetes. If a participant checked a disease, she or he had to include the exact diagnosis and the name and address of the diagnosing physician or hospital. This included items on previous illnesses and illness in the family.

In each follow-up round, special questions were included in addition to the routine questions. Depending on research projects, these could include topics like dental health or illnesses in the family.

The Database

The questionnaires were filled out by the research subjects and were marked with their ID. They were then returned to the research centers and automatically scanned and entered into the database with the help of a computer program developed for the study. The organizing principle of the data base was the ''individual'' through its ID number which meant that all information given under one ID number was collected under the specific ID and thus traceable.

After the first entry step, the information went through a series of verification procedures, including the search for mistakes in the data set through checks against background databases and classifications, such as the International Classification of Diseases, as well as plausibility checks for all data fields and search for outliers, for example, blood pressure measurements. Verification procedures are key in ensuring the validity of a data set. It is through them that one assures comparability and transferability across time and space. Thus, verifying data and making them conform to

international standards is one of the most important tasks in data collection (Bowker 1996; Bowker and Star 1999)

The staff of the follow-up observation used computer programs to check the questionnaires visually and semantically to ensure their plausibility. The program also compared newly entered data with information stored under the ID to check the consistency of information given. All of the procedures were detailed in an international protocol to which all research centers adhered. It is through these rules that ''mechanic objectivity'' (Daston and Galison 2010) of the empirical records is achieved and that makes the data transferable and comparable across research centers and enables the analytic processing of the data.

Because the assessment of appearance of disease was the major goal of the study, specific researcher–physicians were hired into the follow-up team to verify newly reported diseases by the research subject with the diagnosing physician and hospitals. In the case of death of a research subject, the cause was determined through local registration offices. Once the information had passed all checks, it was entered into the core database where it was permanently stored.

The verification procedures are of utmost importance to allow for the data to become used in epidemiological risk calculation. From the very beginning of an epidemiological study, the focus is on objectification through plausible and transferable information, not on the individual's perspective. The subjective information given by an individual person is transformed into objective data. It is removed from the experiences of the individual by making it plausible toward the mean of a population, in the sense of statistical frequency distributions.

After objectifying the data and summarizing it under a specific ID number, the data were further processed. In order to perform calculations using the data, the information from the questionnaires needed to be numerically coded in a standardized fashion. For example, diseases were coded according to the IDC-10 or IDC-11 key. This implied a standardization of the localization of a tumor when the code number entered the data base.

During the phase of baseline data collection—and later during follow-up—the database was regularly updated with new codes, for example, regular follow-up questionnaires and health information, as the data came in. The database and its content were dynamic and under continual development as long as follow-up was ongoing. Such a development over a long period of time requires complex update logistics and careful data management. Tools to manage those logistics include controlled maintenance of separate compartments of the database; of which each has different

functions: for instance, a platform needed to be provided for managing contact with the individual participants for follow-up (i.e., contact for queries, mailing out questionnaires); second the database needed to allow generations of anonymized files to be provided to researchers for analyses. This architecture was required to store data, validate them, and enable the creation of subsets from the database. The actual analyses files were anonymized and partial subsets were retrieved by the researchers for specific analyses. While files for analyses had to be anonymized, other procedures in the database such as follow-up needed to link up to the individual information—via the ID to the person behind an observation in the data set—this was the case for additional data collecting activities in which further variables were to be linked to the core database.

Processing of Data—Creation of the Population

Once the information was part of the database, it had been transformed from local information in a local setting to comparable information that was standardized according to international rules and that could be compared to similar information from other EPIC centers and, potentially, anywhere else. Now the data could be compiled beyond the ID number to give general characterizations of a population. For example, in a series of descriptive analyses conducted for the EPIC data (all twenty-three centers), the following main aggregations were carried out: tabulations by center population and physical activity (Haftenberger et al. 2002a), alcohol consumption (Sieri et al. 2002), or age and obesity (Haftenberger et al. 2002b). In these analyses, descriptive overviews were presented. Nutritional differences in the cohorts were described, for example, with respect to meat consumption or fruit and vegetables consumption, and so on; the cohorts were grouped and made comparable by center, country, and adjustments by age, season, day of the week.

Thus, at the stage of analysis, instead of an ID number as organizing principle, variables of interest at aggregate levels become the organizing principle of the data. For each step of the analyses, the data and variables of interest had to be selected. In the first descriptive presentations of a population, it is often demographic or organizational categories that serve as the organizing grid. The tabulation practices themselves bring about a reorganization and reclassification of the database. In this process, individual data are transformed into patterns that describe distributions of a variable within or between study groups.

Cohort Studies and Data Collection

Baseline examination and questionnaires are especially important in cohort studies as they represent the backdrop upon which analysis is conducted. Cohort studies are designed to identify risk factors for disease. This implies that the risk factors have to be present/recorded before the disease process begins. Thus, baseline data gathering is about gathering information on issues that have been identified in the health literature as possibly influencing disease development and the goal is to assess the "exposure" of these issues as best as possible to use in future epidemiological risk computations for the identification of some of these as "risk factors."

Questionnaires are as detailed as possible in order to ensure accurate exposure data. For example, EPIC research subjects who indicated on the questionnaire that they were smokers or that they drank alcoholic beverages had to give more detailed information about their consumption. They had to name the beverages, the average frequency, and the average of the amount. To do so, the questionnaires included a list of different kinds of alcoholic beverages, like beer, white wine, red wine, champagne, liqueur, sherry, or wodka. Likewise the amount was differentiated into the following portions, 0.5L bottle, a 0.25L glass, a 0.1L glass, or a glass with 0.8 cl.

It is well known that the collection of dietary habits is a difficult task and many different methods have been utilized to receive the most accurate information, like the "24-hour recall" of food intake. Data collection procedure developments rest on the assumption that there exists true, objectifiable information that needs to be assessed as best as possible in order to develop the best risk models. All questionnaires are developed and tested under this assumption. The expectation of epidemiological studies is to make statements about an objective world existing out there. The understanding of this life is a particular, prestructured life that can be captured through questionnaire data, statistically evaluated and compared to each other (Gigerenzer et al. 1989). However, this claim can only be upheld according to the scientific rules if all efforts are made to accurately capture the data. Accurately capturing the data does not mean that it is as close as possible to "reality" it means that the measurements all assess the same thing (Porter 1996). Thus as mentioned before, both the questionnaire development and the questionnaire data are crucially important as they shall assure the sameness of things in data collection.

The numerical codes are the encrypted information that makes up the database and that are the prerequisite for further epidemiological

Table 1. Example of a 2 × 2 Contingency Table

	Disease Present	Disease Absent
Exposure present	++	+−
Exposure absent	−+	−−

calculations and for the populationisation. While linkages of the data to the individual were possible and part of active follow-up procedures in EPIC, the data set was otherwise only of interest in the sense of "population health" (as opposed to individual health) in which the organizing principle of the data were set around predefined characteristics. In fact, only population health and not individual health can be calculated from the data set with epidemiological procedures (Rockhill 2005). In this sense, population health is something that can always only be assessed by preexisting notions and knowledge on risk factors. Nothing new can be found as the population can only be described by something that has been collected in the manner described.

Populationisation

For the tabulations, the coded data of each ID number were compiled together with information from other ID numbers on the same variables. In contingency tables (Table 1), individual data were grouped and sorted by exposure and disease categories. Once these were analyzed and computed they were part of the population that can be sliced up through computations in various ways.

Tabulations depend on the goal of a study, its theoretical and conceptual assumptions as well as the hypotheses they set out to investigate, for example, nutrition, lifestyle, and cancer. For analysis, the data set at this stage remains detached from the individual level and is, as a numerical representation and resource, interrogated for the investigation of "population health," its patterns, determinants, and etiologies. Thus, through the compilation of individual data that are processed for a data base that is used for epidemiological computation and populationisation, a population is created for which predictions can take place. It is these predictions through which the information originally gathered from individuals is fed back to society and individuals (Asad 2002).

The characteristics of the population health have been transformed out of the complex nature of human life and individual habits. They have been

created to identify relationships between people's ways of life and diseases. The characteristics epidemiological procedures of data collecting and organizing bring about are signifiers of individuals' life and health. A signifier is a word or a sound image through which a signified is brought into being (Saussure 1998; Lenoir 1998). In this case, it is quite difficult to discern what the signified is as there seems to be two potential signified: the "ought to be" and the one that is brought into being: the signified that is brought into being through the described characteristics is a "mass" that can be sliced and that is equal in all its parts. The signified enacted in these tables are societal beings/individuals that live a calculable life according to these characteristics. This is the base assumption of the entire process of epidemiological risk calculations—the ability to predict an event. However, because the processes that are necessary to create categories that are statistically acceptable to reflect the real life out there are very complex and, because they can only represent populations rather than smaller entities, the individuals out of whom the signifier has been created are not palpable anymore. The parts that can be cut out of the population cannot represent the individual that has provided his or her information for the study. This begs the question as to what are the signifiers meant to be representing? Are they free floating, or what is the signified supposed to be? The signifier and the signified as the lived life of an individual do not resemble each other. It is an ambiguous and multilayered signified. The signifier then influences the individual life that it is supposed to represent as it returns in form of risk information and coshapes the social spheres of the individual. Indeed, the mere study of what Hacking (1995) calls "human kind" is dependent on social ideas that decide on what type of knowledge is needed for specific populations (Aronowitz 2008). This in turn changes the members of said population in their behaviors and assumptions which in turn will then influence knowledge creation again (Hacking 1995). Hence, the signified and the signifier are necessarily fluid.

Deutscher Diabetes Risiko Score (DRS)

Let us turn back to the risk assessment that became publicly available in 2007, the DRS and the ways in which its inception was possible.

The development of a risk score is done *retrospectively;* in the case of the DRS, the EPIC database was used to identify those who have diabetes and who did not have diabetes at the beginning of EPIC. Thus, the data of the variables that were included in the DRS were collected *prospectively*

before the persons were diagnosed with diabetes. The assumption was that the factors, if shown to be *statistically significantly associated with diabetes,* may have a link to diabetes development. The risk score developed can then be used *prospectively* to predict the risk for other people to develop diabetes in the future but only if the DRS showed its *validity* in other databases other than the one it was created of.

In its initiation prior to its validation, regression modeling (Cox regression) was used to "find" all appropriate risk factors.

The statistical method of regression modeling assumes that each variable is unrelated to the others. Then for each factor, the amount it contributes to diabetes development is calculated. In the case of the DRS, the factors that were checked to see how much they contribute to diabetes risk were age, sex, weight, height, body mass index, waist circumference, history of hypertension, alcohol consumption, physical activity, education, smoking, red meat intake, processed meat intake, the intake of whole-grain bread, fruits, vegetables, and coffee. All of these factors had already been related to diabetes risk by other studies. To calculate which of these factors were most important in predicting the occurrence of diabetes, all incident diabetes cases (diabetes that developed only after the individual participated in EPIC) were identified. This number of diabetes cases became the "outcome" or "dependent" variable of the statistical model. In simplified terms, all the information from the people with and without diabetes in the cohort was lumped together. Those risk factors that were presented most often in the diabetes group got the highest weight and the risk factor that was only present in very few cases of the diabetes group got the lowest weight and so on. The calculation established how much each factor contributed *independently* to the disease.[1] If the increase in risk passed the threshold of the statistical tests used (which means that many of the diabetes cases showed these characteristics), it was concluded that the association between the risk factor and the disease was not due to chance but could help predict the onset of diabetes (incidence or risk).[2] From the variables that were tested in the modeling, the following ones passed the statistical threshold (meaning that the association was seen to be not by chance) and were included in the DRS: age, height, waist circumference, history of hypertension, alcohol consumption, physical activity, smoking, red meat intake, whole-grain bread, and coffee consumption (Schulze et al. 2007a). In lay terms, the fact that these factors ended up in the risk assessment meant that of those in the EPIC database that had diabetes, the above factors were (most) often present. When the DRS was calculated, each factor was weighted according to its calculated influence on disease incidence. This is

the first step in developing a general model. However, in a second step this model has to be validated in other databases to ensure that it does not only fit its own data set.

To prove that the model predicted diabetes well, the model had to be tested and verified against other epidemiological databases. These other databases had to have the variables collected that are part of the risk model to be tested. So a data set had to be found that had collected diabetes incidence, age, height, waist circumference, history of hypertension, alcohol consumption, physical activity, smoking, red meat intake, whole-grain bread, and coffee consumption. This was found at another site of the EPIC. Such validation procedures are another reason why standardized measures of data collection are so valuable. On one hand, it enables the connection of different data sets to larger samples and the larger a sample the more likely it is that one finds statistically valid associations. On the other hand, it allows for the verification of other studies within another data set. This is another important part of legitimizing quantitative research findings as valid representations of reality.

To validate the DRS, the data on the risk factor from the new database were all entered into the DRS with which the expected diabetes incidence in the "new" population was calculated based on the distribution of the risk factors in the population. This was compared with the actual diabetes cases reported and it was checked if indeed those who had a higher risk scores were also those who had diabetes. The DRS proved to predict very well in other German populations (Schulze et al. 2007a).

Thus, the development of a risk assessment is dependent on different factors: (1) databases are needed that have incident cases of the disease, (2) they need to have collected the same risk factors as the database of which the score was developed, and (3) they have to be large enough to find statistically significant associations between factors and disease. When all of the tests were found to be statistically satisfying, the DRS could be published in a high-profile diabetes journal.

From there on, the information that was originally gathered from individuals living in specific parts of Germany and transformed into quantitative information comparable to individuals from anywhere else in the world returned back to the individuals it came from as a tool to predict the risk of an individual to be diagnosed with diabetes in the next five years. Based on the assessment, interventions could be suggested or initiated and the individual with higher risk scores could become a legitimate part of the health care system to get appropriate treatment (Schulze et al. 2007b).

The feedback loop (Beck, Giddens, and Lash 1996) and the looping effect (Hacking 1995) had begun.

The Entry of the Population into the Social World of the Individual

The computated information entered society through different mechanisms. The initial entry point was the first scientific publication to which reports in the popular press followed. The risk assessments in journals such as the pharmacists' journal and the health insurance members' journal focused on *intervention* and produce new population segments: those at risk of diabetes. In each age group, there existed qualitatively defined cut points (Holmberg and Parascandola 2010) that gave hints as to who should work to lower their risk (Schulze et al. 2007b). The tasks of the risk assessments were to guide an individual's behavior toward some statistical optimum.

The DRS not only shall reshape the individual's behavior, it already reshaped the characterization of the German population and the ways the health of the population in Germany is studied. The DRS questions shall be assessed in health surveys the Robert-Koch-Institute, a federal institution responsible for disease control and prevention, undertakes in regular intervals to monitor the population health so that the calculation of the rate of Germans with increased risk of diabetes is now possible. Such an assessment will allow for the calculation of diabetes risk levels across the German population. In recent years, media and scientific arguments frequently discussed the threat of a diabetes epidemic due to the increase of body weight in the population. The DRS will now allow quantifying the risk of a potential diabetes epidemic through risk strata for the German population. A characterization of society became possible that was not possible before. This in turn made it possible to argue for further intervention programs. This is a classic example of the ways in which the feedback loop of reflexive modernity changes the society we live in.

But it is not only the DRS that moves from the scientific field where it was developed into other fields in which it takes on tasks to shape society in particular ways. The DRS also changed the scientific field in that it enabled new connections and different associations between factors. For example, in one paper that used the DRS a relationship was established between a high risk score and myocardial infarction, stroke, and higher overall mortality (Heidemann et al. 2009). The DRS in the publication became more than a simple tool to predict diabetes risk; it was used to give hints to overall mortality. The score could now be used beyond risk prediction to identify

serious complications of diabetes such as mortality. The range in which the DRS became the right tool (Clarke and Fujimura 1992) was significantly increased by the newly established association that supported efforts to use the DRS as screening tool for the public in general. The argument had been bolstered that the score not only identifies high risk individuals but also undetected diabetes cases which in turn can delay premature death.

The most important part of this message was that these so identified individuals had to undertake diet and lifestyle changes and perhaps needed to take medications. Risk models are not merely quantifying an individual's risk that was present before they mark the alleged necessity of change. Thus, they do not just make visible what was there before, but they create what is in specific ways as "risk" that necessitates an intervention (Holmberg and Parascandola 2010; Fosket 2004). Risk modeling is not only a presentation of what is, it is a moral judgment which indeed is the reason to visualize and quantify risk information (Hacking 1995).

Consequences of the Populationisation of Individuals

The populationisation of individuals that enables slicing the population up in ways of interest to epidemiologists then creates segments of populations. These segments have been established to intervene and change similar to the looping effects described by Hacking (1995). Human kinds are established as populations through which at the end stands an individual who becomes responsible to change her or his life (Fosket 2004). Such a health message also became possible because the statistical methods used to create the risk score assumed the independence of the risk factors in the model. Thus, the change of any of these risk factors reduces the risk of diabetes (statistically). Such a statistical assumption/calculation is transferred to an individual's life. It is then assumed that (1) In principle anyone can change risk factors independent of each other; (2) The induced change will not only change the statistical but also the factual risk of an individual to develop diabetes. Such assumptions fit well into the dominant Western cosmology (Douglas 1987; Fosket 2004; Rockhill 2005). In that sense, the individual actively performs adjustments to his or her life, according to the collective experience of a population she or he is made to be part of by statistical group calculations. It is in this sense that the acting individual and "society" are—numerically and literally!—entangled in the production and enactment of risk knowledge.

Conclusion

In this article, we showed the iterative process of how the feedback loop described by Beck, Giddens, and Lash (1996) is deeply embedded in the practices of social institutions and how literally societies and individuals are shaped and reshaped through looping effects (Hacking 1995). In the case of the DRS, a compilation of signifiers has taken place that together shall signify an individual's chances of getting diabetes. This "signified"—a statistical risk estimate coproduced by data collecting, processing, and modelling techniques—is transferred into the lives of men and women and into societal institutions, who were conceived of as the signifiers out of whom the signified was discerned. The score, the construed signified, "knows" and enacts individuals through the aggregate mode in the database.

Statistical procedures produce profiles and computable, knowable, calculable, and "independent" entities within these profiles. It is in the database that the individual is transformed into a part of a study population. In the database population, subgroupings are created and processes of populationisation take place. This literal entanglement of acting individuals in the production of risk knowledge shows the deep embeddedness of epidemiological risk production and society.

The results of these processes of populationisation are published in scientific journals, government reports, or project reports. Once the publications enter the public sphere such as the political field or the mass media the information enters the social sphere of the individual.

A statistical model, the DRS, has moved from its "birth place" in epidemiology into other forms of knowledge production. From a statistical tool, it developed into a political and social tool: once population level risks have been calculated, these can be used to argue for research support on diabetes prevention and for the development of populations that need intervention. Thus, the DRS has moved into the political realm and has become a disciplining tool of power. The DRS becomes an economic tool as new intervention groups have been defined for which treatments may be developed and marketed for. Finally, by its use in popular journals and newspapers, the information that was originally given to research by "average Germans" is transformed and reenters the public sphere of said users in Germany and moralizes their body statures. As the score enters not only scientific fields but also broader political and social domains, society and individuals are being reshaped. The score calls for iterative individual risk management by adjusting oneself to a "populationalized optimum." In this way, numerical estimates, derived through complex collection mechanisms from

individuals, circulate through society and travel back to the individual. The DRS, a tool developed by "objective" science, intended to provide "objective information" about reality is a political, economic, and social technology of power that travels through different fields and changes them accordingly.

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Notes

1. The difference between a 2×2 contingency table and regression modeling is that in a 2×2 table, one only considers a single factor and its relationship to a disease whereas in regression modeling multiple risk factors (at different scales and allowing for changes over time) can be statistically tested simultaneously and their contribution to the overall risk estimated independent of each other.
2. If factors influence each other, interaction terms have to be introduced into the model. For example, in the DRS sex, height, and waist circumference were assumed to be related to each other and an interaction term of these factors was included in the model that was tested.

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