Numberstand
Personalized Number Explanations

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Graduation Thesis
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February 2013
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***Abstract*—In all sorts of media we encounter large numbers that are relatively hard to understand. New technologies broaden the possibilities to personally explain such numbers. This paper describes an experiment of presenting personalized number explanations by means of personal data collection. Several participants were interviewed to gain insights in their abilities to explain numbers and their opinions on the results generated by the Wolfram|Alpha web service and the Numberstand prototype, that I developed for this research project. I have compared the personal explanations generated by Numberstand with the general ones from Wolfram Alpha and the results are promising.**

I. Introduction

Nowadays the numbers we encounter cover a wider range than ever before. Government budgets, natural disaster casualties and an amount of unique web page views are some examples of large numbers that extend this range.

This research project arose from the frustration of puzzling numbers communicated in all sorts of media. A newspaper stating 3.5 million people are having the flu, mainly causes reactions limited to: 'Wow, that's a lot'. Nevertheless, the number stays puzzling and hard to envision. This is due to the fact that our numerical sense is insufficiently developed to conceive such large numbers. Such statements are hard to comprehend because we are not able to put the number in context.

When solely a number is communicated, a receiver of the message might try and put the number in context himself, by means of calculations using related familiar quantities. Another way to understand a number could be by exploring it, searching the web for explanations. However, search engines such as Google, Bing and Yahoo amongst others, are not capable of serving explanations of a number. Modern search engines mainly serve web pages containing the same search terms and are not able to interpret and act upon the user's input. However, Google has extra functionalities built-in to its search engine, such as a calculator to convert a wide range of units and currencies. Recently, Google introduced the Knowledge Graph [1]. Knowledge Graph is a semantic web based technique that enables users to explore collections of results that are related to the search input. e.g. if you search for an author's full name, the service also outputs all books written by the author, its birth date, close relatives and other related facts. If applicable, these results are in itself linked to web pages containing information about the objects. Google's mission is to organize the world's information and make it universally accessible and useful. Despite the extra abilities, search engines in general are still not able to explain numbers in a useful, understandable way.

A service that tries to accomplish this is Wolfram|Alpha [2]. Its goal is to provide a single source for definitive answers to factual queries. It uses the achievements of science and other systematizations of knowledge to provide such answers. The self proclaimed "Computational knowledge engine", aims to bring expert-level knowledge and capabilities to the broadest possible range of people, spanning all professions and education levels.

Not long ago, the communicator of a number had no knowledge of his audience on a personal level. Nowadays, modern technologies allow us to gather and analyze all sorts of personal data. Since mobile devices, social media and other personal web accounts became tools we use on a daily basis, it became possible to gather and analyze personal data to build a user profile. In this research I experimented with such data to explain the value of a number in a personal context. A newspaper stating a group of people as big as the population of the province of South Holland, Netherlands (3.5 million people) is having the flu, might make more sense to readers from The Netherlands who are familiar with that area. If this figure was explained relating to a large city in for example India, it would not make sense for most Dutch people. Geographical data like this could serve as a landmark quantity to individuals. Such data is also a source, spanning a wide range of quantities. Envisioning a number by calculating fractions or multiplications of such landmark quantities is easily achieved [3]. This research project aims to explore if such explanations help people to conceive large numbers and put them into context.

For this research, I developed the Numberstand prototype web application (blend word of 'number' and 'understand'). This website builds a user profile based on personal information gathered by means of a questionnaire. It then uses this information to explain any entered number by using familiar quantities and concepts. The main question this study aims to answer is: Will explaining large numbers in a personal context using Numberstand, help an individual to gain a better sense of its value?

II. Context

A. One, two, many

All the languages of the world have selected a set of round numbers. This universality causes all humans to be confronted with the difficulty of envisioning large quantities [4]. The larger a number, the less accurate our mental representation of it. Therefore, we express small numbers much more often than large ones.

Most languages have distinct expressions for the first two numbers. The number three, is proven to be related to the word many. Looking for example at Latin and French, there is a plausible connection between the Latin words 'tres' and 'trans', which mean 'three' and 'beyond'; the same can be said for the French 'très' and 'trois', meaning respectively 'very' and 'three'. Uncivilized societies, such as The Bushmen of South Africa, are proven to have no number words beyond one, two and many. These words are so inarticulate that it may be doubted whether they attach a clear meaning to them [5].

The English language, among others, assigns a particular role to statements that involve round numbers, such as 'thousand' and 'a million'. Such statements have a tendency to be interpreted vaguely rather than crisply [6]. An arthropod with twenty-one body segments and forty-two legs, is commonly called a centipede in English (one hundred feet) and a "mille-pattes" in French (thousand-legs). "We pay attention to the numerical regularities of nature only inasmuch as they fit in with our cognitive apparatus, which is biased toward small or round numbers" [4].

B. Number Sense

The term 'number sense' is described as an intuition that helps us make sense of numbers and mathematics including the abilities of flexible mental computation, numerical estimation and quantitative judgment [3] [7]. It refers to a person's general understanding of number and operations. Moreover, it is the ability to use this understanding in flexible ways to make mathematical judgments and to develop useful strategies for handling these numbers and operations. It reflects an ability to use numbers and quantitative methods as a means of communicating, processing and interpreting information.

The scope of our direct number perception is quite limited. Our reaction time considerably increases when we need to distinct quantities larger than four [8]. We need mental grouping or counting to be able to distinct larger quantities.

Through a series of remarkable circumstances we learned to aid this exceedingly limited perception of number with the ability of counting. "Counting enabled that extraordinary progress which we have made in expressing our universe in terms of number" [5]. Our hands and fingers are proven to be the tools we use to count and group and to communicate those quantities. Uncivilized groups who have not reached the stage of finger counting, are almost completely deprived of all perception of number. Such is the case among numerous tribes in Australia, the South Sea Islands, South America, and Africa [5].

The ability to recognize the relative value of a number and the ability to sense the general size or magnitude of a given number is a behavior that develops with mathematical maturation and experience. The level of number sense necessary for children and adults today may become more and more important. We encounter a greater range of numbers, in more varied contexts. "In a technological age, it might be said that the possession of number sense is one major attribute which distinguishes human beings from computers. There is every reason to believe that the 21st century will introduce additional reasons for an increased focus on developing and maintaining number sense" [7].

The triple code model shows that we estimate, subitize, compare and approximately calculate numbers to gain a mental analog magnitude representation [9]. Using this mental representation we are able to understand and communicate numbers verbally or in written text. A numerical representation is spatially coded into a non-verbal 'mental number line' [10]. All numbers we encounter fit somewhere on this mental number line. However, when we're not familiar with near connected numbers we are not able to cope with such numbers. Numbers we are familiar with and are able do calculations on are so-called 'landmark quantities' [3]. Examples of such landmark quantities are: the average height of an adult, the weight of an infant, the freezing point of water and the duration of a year. More specifically, personal landmark quantities could be for example the size of a room in your house, the length of your car or the amount of money in your savings account. These landmark quantities support approximate reasoning. A mental model can be constructed with representatives of numbers near or connected to the numbers given in a problem. Simple and round calculations such as fractions or multiplications, are means to relate a landmark quantity to other numbers encountered in different contexts.

C. Precision

"Round numbers are always false."—Dr. Samuel Johnson

Round Numbers suggest Round Interpretations in measure expressions. This RN/RI principle works as follows: Short, simple numbers suggest low precision levels. Long, complex numbers suggest high precision levels [11]. Mistaken precision is when one tries to increase the level of precision, set by the original sender of a number. A clear example of mistaken precision is described in the following anecdote: "...a museum guard told visitors that the dinosaur on exhibit was 9.000.006 years old. Upon questioning, the guard explained that he was told the dinosaur was 9.000.000 years old when he was hired, six years before" [12].

If, for instance, a large amount such as €43 million is communicated, what we actually know about its precision is that it lies between €42.5 million and €43.5 million. At first this seemed to me as a negligent way of reporting a number. All of a sudden it becomes of little importance whether there is an additional million Euro. However, it is actually a quite functional manner of reporting such numbers as we know that the larger a quantity is, the fuzzier our mental representation of it. In most cases there seems to be no advantage for the receiver to be informed with a quantity of a higher precision. Therefore there is no necessity for the sender to applying a higher precision in such instances. Hence, we don't feel the need to express large precise quantities [4].

D. Trigger a mental representation

At the Information Graphics Congress 2013 held on 1 March 2013 in Zeist, Netherlands [13], John Grimwade visualized the distance of the world record in long jump and the height of the world record in high jump, in an effective way. First he solely communicated the number to sense the audience's reaction. After that he actually visualized it by theatrically walking the distance of the long jump. The majority of the audience only then actually realized the value of the number. From that moment on they probably had a better mental representation of it. Next, he lowered the truss lighting fixture hanging above the stage to visualize the height of the world record in high jump. This again evoked a similar reaction from the audience.

After a few weeks or so, it became quite hard for me to recall the actual height and distance of both world records. This is because I only visited the location that one time and I couldn't remember the actual measures of the stage and the portrayed distances. It would've had a similar effect and would create a longer lasting understanding if I could relate it to something I'm more familiar with. As a matter of fact the distance of the long jump is nearly the same as measured from the front window to the back door of my living room. I don't need to know this exact distance. I only need to know it is true to be aware what an incredible achievement this world record is.

E. Personalization

Todays technologies enable us to present personalized information by means of collecting and analyzing data of mobile phone usage, web browsing and social media activity. The objective of a web personalization system is to provide users with the information they want or need, without expecting from them to ask for it explicitly [14]. As digital markets converge, personalization will be ubiquitous in digital interactive devices, from hand-held computers through mobile telephony devices to digital TV.

Personalization technologies range from commonplace use of databases, cookies, and dynamic page generation, to esoteric pattern matching and machine-learning algorithms, rule-based inferencing, and data mining. The features of modern mobile phones make them familiar tools for quantifying personal patterns and habits. This data reveals a lot about your regular locations, habits, and routines [15]. Such techniques of gathering and analyzing personal data could be used to personalize number explanations.

F. Summary

Visualizing a large, precise, fuzzy quantity, helps creating a mental representation of its value. However, by solely presenting a number and the context, it proved to lack communicating the value and impact of a number. So, possessing a well developed number sense, does not instantly evoke the right mental image. People sometimes need to be triggered to start the process of envisioning a number. If such an explanation would be related to a personal landmark quantity, it would evoke a longer lasting mental representation. This was the main inspiration to develop the Numberstand project. This project utilizes personal landmark quantities to make sense of the value of a large number encountered in varying contexts.

III. Project Description

A. Introduction

We live in an age of big data. An age where more and more personal data is gathered and analyzed by all sorts of devices and organizations. Data could be extracted either directly from information provided by a user or indirectly by means of collecting data from search engine entries, social media platforms, on and offline shopping behavior among many other sources. The knowledge gathered from this data ranges from demographics, location data, ethnicity, job history to reading habits, topics your interested in, charitable giving, friend connections, political leanings amongst many other claims that could be made based on personal data. We may even be unaware of all the knowledge obtained from the collected data. This is clearly described in the case of the Target retailing company that predicted a teen girl being in an early stage of her pregnancy, based on the type of products she bought at the store, even before she knew she was pregnant herself [16].

The technologies available today enable us to incorporate personal data to describe numbers in a personal context in order to explain them. To answer the question whether personalized explanations are helpful to understand relative large numbers, I developed a web application prototype called Numberstand. The application collects personal data by means of a questionnaire. It aims to use this data to explain any entered number by generating explanations based on the user's familiar quantities and concepts.

Ideally, a wide range of personal user data could be used instantly to experiment with which data is useful for generating personal number explanations, and which is not. Big technology companies such as Google and Facebook gather and analyze such personal data and are thus in a advantageous position to perform this experiment. Unfortunately I am not in the position to use and manipulate such a large amount of personal data. Moreover, this is not the focus of this research project. The aim is to gather insights and learn from using personal data to explain numbers. Besides the fact of simply not possessing the data, it could in theory be possible to use data from existing sources by means of public API's (Application Programming Interfaces). However, I chose to gather all the personal data by means of a questionnaire. I decided upon this for the following reasons:

1) Using all sorts of existing sources, such as social media accounts, complicates the setup and process of the user evaluations.
2) The evaluations would depend on the availability of other services and the data provided by these services.
3) The evaluations would be burdened with the participants' potential privacy concerns on using the personal data.
4) Not all participant are active on the same social media platforms.

By letting the participant in control over the data filled out in the questionnaire, he directly controls the data used in the application. This has the additional advantage that users will not be puzzled by potentially far-fetched explanations which could lead them away from an honest opinion on the actual generated result. Additionally, in this research it is not the aim to test a fully functional application, which could surely benefit from existing personal data sources. To answer the initial research question it is irrelevant to incorporate such existing sources.

In an experiment setup, the Numberstand prototype is compared with the Wolfram|Alpha web service by means of informal user evaluations. Wolfram|Alpha tries to explain numbers by using a wide range of existing knowledge. It calculates any input using knowledge of: mathematics, linguistics, units & measures, statistics, dates and times, finance, geography amongst several other categories. Opposed to Wolfram|Alpha, Numberstand uses a range of personal data to explain numbers, such as demographics, lifestyle characteristics, social connections and financial details. The aim is to gain insight in the usefulness of the different aspects of the results from Wolfram|Alpha and Numberstand, and see if personal number explanations are favorable over general ones.

B. Prototype design

The Numberstand prototype is a web application optimized for relatively small touch devices such as smartphones and tablets. It is a website that looks and feels like a native smartphone or tablet application. For flexibility purposes a web application is developed. The main benefits of this consist of the platform and location independences. The application is built using HTML, CSS, PHP, a MySQL database, the JQuery Mobile Framework and JavaScript.

The user logs in with the credentials provided in the invitation email. On the homepage he finds the instructions to use the application. Subsequently the user is asked to fill out their profile. After the profile is finished as complete as possible, the user is able to convert any number in the two categories: people and money. On the about page the user finds more information on the research project and contact details.

1) Used data sources: In this application population data from cities, provinces and countries is used. One of the most complete and reliable source for country data is the CIA World Factbook [17]. This data is maintained by the government of the USA and is therefore assumed to be reliable. The population estimates from July 2013 were used in this prototype.

The World Factbook does not contain population data from cities or provinces. The University of Leipzig and University of Mannheim collaboratively host a semantic web version of Wikipedia called DBpedia [18]. The DBpedia SPARQL endpoint was queried to gather a list of city names and populations from The Netherlands. Only data from Dutch cities is gathered using SPARQL, because most participants in the user evaluation currently reside, and/or are born in The Netherlands. For the few remaining foreign participants the data is manually gathered for the specific place of birth from Wikipedia.

2) Profile data: The profile page is split up into four categories that together form the entire questionnaire and thus all collected personal data. The four categories are 'personal', 'lifestyle', 'social' and 'financial'. This setup is chosen to guide users trough the process and enables them to keep track of the progress. See Table I for a complete overview of the profile page input fields.

TABLE I. PERSONAL DATA GATHERED WITH NUMBERSTAND PROTOTYPE WEB APPLICATION

Category	Data	Parameters
Personal	Gender	Male / Female
	Date of birth	Day, Month, Year
	Place of birth	Country, City
	Current residence	Country, City
Lifestyle	Work	Yes / No Time spent per week
	Study	Yes / No Time spent per week
	Relationship	Yes / No For how long
	Sleep	Average time per day
	Drinking alcohol	Yes / No Preferred types
	Smoking	Yes / No Preferred type Frequency Price per packet
	Sports	Competition or Recreational
	Competition sports	Team or individual
	Recreational sports	Gym or other type
	Description of sport (if applicable)	Type of sport Season duration Experience in years No. of team mates Contribution costs
	Pets	Yes / No
	Description of pet	No. of pets Animal type Montly costs
	Belongings	Car, Bike, Mobile Phone, Computer, Tablet
	Description of the belonging	Product name and type Value
Social	Household size	No. of people
	Close family size	No. of people
	Entire family size	No. of people
	Facebook	Yes / No No. of friends
	Twitter	Yes / No No. of followers / following
Financial	Salary / Net income	Amount of income
	Housing payment	Rent / Mortgage
	Rent	Monthly costs
	Mortgage	Monthly costs Total mortgage
	Groceries	Periodically costs
	Mobile phone plan	Average monthly costs
	Health insurance	Average monthly costs
	Magazine subscr.	Average monthly costs
	Clothes	Average monthly costs
	Shoes	Average monthly costs
	Regular purchases	Type of purchase Costs per item
	Savings	Periodically savings Total savings

3) Conversion: On the convert page, the user chooses the number category for which he wants to convert a number into his personal context. The application is able to convert numbers from two distinct categories: people and money. Next, for the chosen category, the user enters the number he wants to convert. By clicking the convert button the input is calculated using the personal data.

Numberstand generates results for the category people in the following order: The application first tries to find combinations that represent the same value. For this it uses the data about groups of people from the user's profile first. Usually these are relatively small numbers of people e.g. family size, sports team size or friends on Facebook. Most of the time these numbers are too small to explain a large amount of people. So when these personal related groups of people could not be applied to the requested input, the application tries to match population data from cities, provinces and countries it assumes the user is familiar with. This data is extracted from the user's place of birth and current residence. It assumes the user is familiar with other cities in the region of these places. For the place of birth and current residence, it uses population data from cities in the same province, nearby provinces and the country itself. It also tries to multiply them by two or three. This mechanism is based on our ability to perform simple calculations on familiar landmark quantities. Someone born or currently living in Leiden, South Holland, Netherlands will get results based on all the cities in the province; the province of South Holland and The Netherlands. This is a personal result. When no corresponding population of a city, the province or the country can be found in this set of data, it tries to find a result using population data from other provinces of the same country. This is a 'semi-personal' result. If Numberstand is still not able to find a corresponding entity in the data, it generates a result from the list of all the countries in the world. This is a general result.

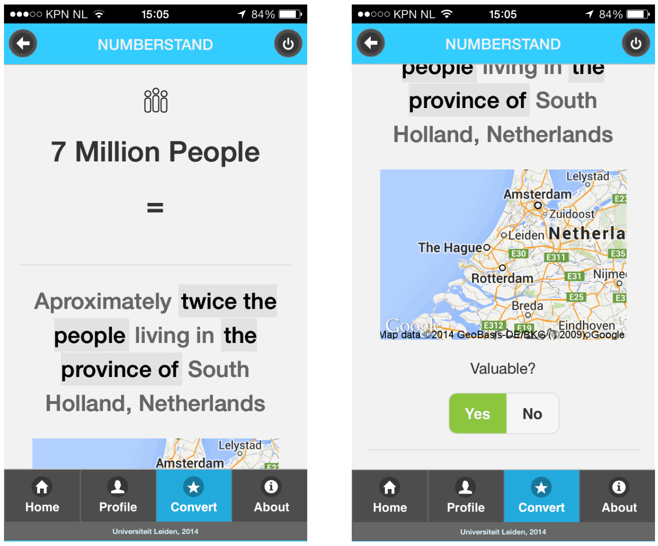
See Table II for a selection of personal, semi-personal and general results for the category peopl. See Figure 1 for an example of a personal result in the Numberstand environment.

TABLE II. Examples of explanations generated by Numberstand for the category people

Type	Explanation
Personal	Aproximately all people living in Leiden, Netherlands
Semi-personal	About everyone living in the province of Friesland, Netherlands
General	Aproximately the total population of Lebanon

For the category money, only personal results are generated. This is done in the following order: The application first checks if the familiar groups of people could be multiplied with familiar money amounts from the user's profile. An example of such a result is: "if your entire family would buy the same mobile phone as you have". Due to the relatively small groups of people gathered directly from a user's profile, as described earlier, this mechanism does not cover numbers containing more than six figures for an average user. To also cover million Euro amounts or more, I used the assumed familiar cities, provinces and country populations from the user's profile in the generation of results. Also, the aspect of time is brought into the equation. A result containing these extra parameters could for example look like this: "if the total population of Leiden, Netherlands would pay a half year of health insurance premiums like you do.". The time aspect is only applicable to a user's periodically spendings. The app also multiplies the population data with the value of belongings and regular purchases. Using these mechanisms, the app is able to cover a wide range of results for converted money amounts. It has to be seen if the used concepts and the proposed explanation structure were the right choices made.

In generating the appropriate results the application takes a margin of 5% above and below the entered number. e.g. if the user enters € 100.000 or 100.000 people, it would gather all data that is, or adds up to, a number between 95.000 and 105.000.



(a) Top of page (b) Bottom of page

Fig. 1. Example of a personal result for the conversion of 7 million people

IV. Experimental Methods

The evaluations were focused on gathering insight on several aspects of number explanations.

1) Is geographical data useful in this respect?
2) To what extent is it valuable to multiply familiar concepts in an explanation?
3) Is it favorable to explain groups of people using the concept of round multiples opposed to decimal multiples?
4) Is there a noticeable difference in personal and general results from Numberstand compared to Wolfram|Alpha?
5) Which aspects of the generated explanations seem valuable?

To test this, informal one on one interviews were conducted to gather first impressions on the usefulness of the results generated by Numberstand compared to the Wolfram|Alpha service. Participants were sent an invitation email containing a short introduction of the project, user credentials and information on the user policy.

An interview took about 45 minutes to an hour. Filling out the profile took roughly 10 to 15 minutes, depending on the amount of information the participant was able to enter. The remainder of the interview took another 30 to 40 minutes. All interviews were held in the period from 27 January through 10 February 2014.

A. *The Experiment*

The participant was informed he would be questioned four different numbers. All numbers originated from recent Dutch news items. For each number the participant was asked to explain its value in their own words. If describing the value of a number was hard or if he was not confident in the described value, he was asked to describe how he would approach getting a better understanding of the number. Next, the participant was asked to convert the number using the Wolfram|Alpha online service. And finally to convert the number using the Numberstand prototype. See table III for an overview of the interview structure. This structure merely served as a guidance for the interviewer. During every interview the focus was to determine the aspects that make up someone's mental representation of a number's value by questioning what participants think and why they think it.

TABLE III. INSTRUCTIONS FOR EACH NUMBER DURING USER EVALUATION

#	Instruction
1	Explain the value of the number in your own words
2	How would you approach getting a better understanding of the number's value?
3	Use the Wolfram|Alpha service to convert the number
4	Use the Numberstand prototype to convert the number

B. *Numbers*

The four numbers used in this research were covered in news items on the radio, TV, the web and in newspapers. It are two numbers about amounts of money and two numbers about groups of people. See Table IV for an overview of the covered numbers.

TABLE IV. NUMBERS TESTED DURING USER EVALUATION

Category	Number	Description
People	668.000	Amount of unemployed people in The Netherlands
	4.000.000	Ratings for popular Dutch TV show 'Boer zoekt vrouw'
Money	€ 43.000.000	Total value of real estate fraud committed by a family of three people
	€ 774.000.000	The amount of the fine the Rabobank (large bank in The Netherlands), got for their influences on the European Libor investment rates

C. *User group*

The application was tested with 15 participants. Of these tests, 12 were informal one on one interviews. The remaining three participants were instructed to test the application and did so in their own time. After testing, these participants shared their experiences during an informal talk. All participants had at least a decent understanding of English.

D. *Analysis*

The audio from all one on one interviews was recorded with permission of the participant. These recordings served as a back up for the analysis. During the interviews the focus was mainly on analyzing the reactions of the users and on their opinions on the different types of results generated by the Numberstand application and the Wolfram|Alpha service. Besides, the focus was also on finding out which type of number explanations evoke the most vibrant mental representation. This could be their own explanation, a result from Wolfram|Alpha or from Numberstand. It is also possible the user still has no clue about the value of the given number. In this case both services tested, fail in their goal to explain the number. With the results generated by Numberstand, we distinct personal, semi-personal and general results. I try to see if there is one type of result that stand out from the rest.

Besides the empirical analysis, the Numberstand application contains feedback buttons that enables the user to provide feedback on the usefulness of an explanation. The user is able to set a radio button to either yes or no (See Figure 1(b)). I specifically chose this setup for a number of reasons. It's a way to force the user to think about and decide upon the value of the generated number explanation. Moreover, I think that the personal explanation either helps understanding the number or it does not. If the explanation a user came up with himself, or the alternative explanation Wolfram|Alpha generated were more valuable than those generated by Numberstand, the result from Numberstand was marked as not valuable. Ideally, these feedback buttons would also serve as a way to gather useful quantitative user data.

V. RESULTS

Most participants reacted delightfully surprised on the generated explanations from the Numberstand application. Although the opinions on the usefulness of the results vary a lot between individuals, some aspects of the results seem useful and some not.

During the interviews, participants sometimes lost sight of the original context of the number and were focused more on the surprising results generated by Numberstand.

Looking at the feedback generated with the built-in valuable buttons, we see that these results vary too much between individual participants to be of any value. It seems this feedback data is insufficient to base conclusions upon due to the fact that all explanations differed between individual participants.

A. *Number of people*

The explanations of the two tested numbers generated by Numberstand were mainly semi-personal and general results. The second number did not match any personal results for people living or born in The Netherlands.

1) Unemployment rate: This number, see Table IV, was repeatedly explained in the participants' own words as: "About a million" and by dividing the total population of the Netherlands, thus coming up with "About $\frac{1}{25}$ of the total population". This explanation is comparable to the actual rate of the working population, which is a useful representation to understand this number. By knowing the rate is equal to 8.5% or 1 out of 12 of the working population, you are able to reflect this number on colleagues, friends or family members who have a job or are unemployed.

Wolfram|Alpha generated the following results:
≈ 1.2 times the current population of Macao. (≈ 578.800)
$\approx$ number of people who attended the Woodstock Music & Art Fair (≈ 500.000)
Besides these two results it also generated results on the approximate heat production, the approximate weight and airflow needed to compensate for body odor, which are far from applicable explanations for this matter.

For all people born or living in The Netherlands, Numberstand generated the following explanation: "The total population of the province of Friesland, Netherlands". This is a semi-personal result, as no participant was born or currently resided in Friesland. To put in perspective that a relatively small, but still an entire province of The Netherlands, would be unemployed, is a fun fact to know according to the majority of the participants. All people found it was a much more valuable explanation than their own explanation and the ones generated by Wolfram|Alpha.

Besides this semi-personal result, Numberstand also generated a general result. By coincidence the population of Montenegro is as big as the group of unemployed people in The Netherlands. The majority of the participants did not find this useful because they were not at all familiar with the size of Montenegro. Moreover, the ones that claimed to be familiar with Montenegro, found it hard to map this population to the context of unemployed Dutch people.

2) TV show ratings: All Dutch participants related this number to a fraction of the population of The Netherlands. It was explained as 25%, a quarter or one out of four of the total Dutch population. The foreign participants related the number to the city they were born or a nearby city thereof. These initial explanations were sufficient for the participants as no participant came up with a description for the second instruction, see Table III.

Wolfram|Alpha could not come up with a usable comparison and only generated the non-applicable type of results described earlier in section V-A1.

The Numberstand prototype could not find a matching personal result for Dutch participants. Thus, it generated general results containing populations of the countries Bosnia and Herzegovina, Lebanon and Liberia. These foreign countries were unfamiliar to all participants and thus, they marked it as not valuable. For the foreign participants the number was related to the population of nearby cities which they did judge as valuable explanations.

The fraction, one out of four, the Dutch participants came up with themselves, seemed a more valuable explanation than the general results from both Wolfram|Alpha and Numberstand. The total population of the Netherlands could be seen as a landmark quantity which is easily divided by four.

3) Other numbers discussed: With three participants we discussed the issue of subconsciously ignoring an amount of casualties mentioned in a news item. When such an event took place at a distant location we seem to be less likely to consciously reflect upon the impact. The recent natural disaster of the Philippines was discussed, which caused about 6000 casualties according to the latest reports. No participant was able to reproduce this number from their memory. It seems this is a common issue with events happening far away opposed to events happening nearby. We discussed if it would help to relate such numbers to groups of people they are familiar with. In all instances the amount of casualties could be related to a nearby village. This explanation seemed to evoke a better mental image than the solely communicated number in the news items.

4) Summarizing findings on numbers of people: A semi-personal result generated by Numberstand seemed to evoke a valuable understanding of a large number opposed to the solely communicated number, the explanations from Wolfram|Alpha and the general results from Numberstand. Participants had a landmark quantity with which they were able to calculate their own explanation. In this respect, general results generated by both services were not able to evoke a more valuable mental representation. The amount of casualties discussed, showed that a personal result would possibly work for this matter.

B. Amount of money

For both tested numbers the application generated personal results for almost all participants. Converting the first amount of money, led to generating more than ten explanations for most of the participants. For a few there were over 50 different explanations. See Table IV for the tested amounts.

1) Real estate fraud: Participants explained this number in their own words in similar ways. The few explanations and associations boiled down to: about the value of a group of houses in a particular area, a small country government's budget, brand sponsor deals and company investments It were either these explanations or participants were simply unable to envision the given number.

Numberstand mainly generated explanations using the geographical data. There were no results that incorporated social data because this data seemed not sufficient to be used in a calculation to explain this large number. The value is too high to generate a result incorporating familiar group sizes such as family size, sports team size or friends on social media platforms. The combination of the population of a familiar city or province and fixed spendings or fixed values of belongings, worked best as explanations for this number. A number explained as "Everyone living in City X paying the same mobile phone bills for a month" or "All people living in City X would pay the same health insurance premiums for a year", where City X was their hometown or a familiar city, were examples of striking results. The fixed value of a belonging worked even better than an explanation that incorporated a periodically spending. Example of a striking explanation is: "All people living in City X buying Product Y", where Product Y is a specific laptop computer or car the participant owned or a specific product he frequently buys. Income, rent, mortgage payment and health insurance premiums were proved to be strong concepts of monthly spendings while leisure, clothes or groceries spending were too variable and felt too vague to conceive in most explanations according to the majority of the participants.

Although there were some striking results, there were also much explanations that seemed too far-fetched. Using a city the participant is not really familiar with, or an ill-defined money amount such as leisure, or an arbitrary time span such as three months or a half year, are examples of aspects that cause an explanation to become far-fetched. The time aspect seemed in most cases a step too far for participants to be able to understand the statement. The interviews suggested that the period of a month and a year seemed to work best. Explanations using the periods of three months and a half year seemed to be hard to conceive. Such time spans serve probably not as landmark quantities. These findings corresponds to the fact that we are biased to nice round numbers.

Three participants were not at all able to envision a population multiplied with a familiar amount of money, to the tested amount of money. Their opinion was that it was too hard to imagine such a large group of people multiplied by a relatively small amount of money. Relating back to the news item, the communicated money amount seemed to drop in value. It seems like this is because of the decreasing accuracy of large numbers which is inherently to the workings of our cognition. It could also be that there was a flaw in the structure of the explanations. It might be that a restructured sentence that conveys the same message, does evoke a mental representation value that helps a user with understanding the value of a number.

2) Fine for bank: At first, no participant could come up with a decent explanation in their own words. After mentioning the amount of Euro's is equal to $1 billion, it caused reactions as if some were more familiar with this number. Again we see here that we are likely to attach more value to such round numbers. Although it does not change the fact that participants aren't able to sense the value of this number at all because they were not able to explain it in their own words.

Solely entering the number, without the context of Euro's applied, in the Wolfram|Alpha search field generated the following: "$\approx$ 0.12 times the number of people alive today. ($\approx 6.5*10^9$)" With a bit of imagination and calculations, users could come up with the explanation that "if 12% of the entire population of the world would donate € 1, the bank would pay off its fine". This was a reasonable explanation for a minority of the participants. The majority felt this explanation was a too far-fetched.

Testing with Numberstand, the same applied here as mentioned with testing the former number: only geographical data was used in generating explanations. Also the same type of results were generated, evoking similar reactions and opinions by the participants.

3) Summarizing findings on money amounts: The tested amounts of money were quite large and thus, almost no results were generated incorporating small familiar groups of people such as one's family, sports team or Facebook friends. Using a large group of people combined with a relatively small amount of money, created the effect of the number dropping in value. It seems that, the bigger the group of people, the fuzzier the explanation becomes, just like it does with the conception of large numbers in general.

It seems that some people attach a landmark quantity to a population of a familiar area, without knowing the actual number corresponding to the population. The population of such a familiar place could from then on be used in other explanations and a user might be able to relate the different explanations to each other to gain more knowledge and strengthen the landmark quantities.

Some participants tried to calculate the population of the place used in the explanation, before they could tell it was a valuable explanation to them or not. I assumed that people don't need to know the population of a place as long as they are familiar with it in terms of size. If someone actually needs to know the accompanying number of a population, he is probably not familiar enough with the size of the place or simply unable to envision it. Therefore it is proven not to be a personal landmark quantity. Such places proved to be irrelevant parameters in an explanation.

The additional map of the geographical location was said to be useful by some participants. Other's did not find it of any use. It could be more valuable if the map shows a border around the corresponding place, to add to the effect of a landmark quantity.

It was surprising to see that participants also learned other things from the explanations than just the relation to the entered number. Some saw relations between explanations concluding that for example two cities had the same population.

VI. Related Work

A. Infographics

Static or animated infographics and interactive visualizations are common ways to communicate a set of numbers. These graphics use either abstract figures in relation to others, such as lines, dots, circles and other shapes, or real world concepts such as the size of an average human, a football field or an airplane, to convey the value of multiple numbers at the same time.

There are many resources on such graphics. Books that teach on the important aspects of creating such graphics [19] [20] or that present state of the art examples [21] [22] and frequently updated websites serving topical examples [23] [24].

Infographics closely related to this research project are a series of examples that report on the US economy. [25] These graphics are either static sequential images narrating the value of a number, or animations conveying the value. The message is built up step by step using landmark quantities such as a hunderd dollar bill, a full pallet stacked with such bills, a football field of pallets, and so on. The idea is that this way it is possible to 'look at the numbers'.

B. Dictionary of numbers

This web browser extension for Google Chrome aims to make sense of numbers one encounters on the web by giving a description of that number in human terms. [26] Dictionary of Numbers puts quantities one is unfamiliar with in terms one can understand. This project uses a similar approach to explaining numbers as Numberstand does. Opposed to Numberstand, it does not personalize number explanations. It presents alternative text based explanations that one might understand better. When you encounter '8 million people' on a web page, the extension adds "population of New York City" between brackets, inline, right after to the original number. See Figure 2 for an example.

The Top 5 U.S. Wildfires of 2012
Whitewater-Baldy Complex Fire, New Mexico:
Largest fire In New Mexico history
The Whitewater-Baldy Complex Fire started as two fires that merged, both caused by lightning. The Whitewater fire was first detected on May 16th, and the smaller Baldy fire was detected a few days earlier on May 9th. These fires then 297,845 acres [≈ Los Angeles, California, USA (city)] until it was merged on May 24th and together burned a total of 100% contained on July 23th. Mid-July rain showers helped fire crew contain this fire. This fire was difficult to contain due to rugged terrain with gusty winds, and relative humidity less than 3%. The fire consumed timber, mixed conifer, poderosa pine, pinon/juniper, and grasses. The suppression costs of the Whitewater-Baldy Complex Fire surpassed almost $23 million [≈ Typical endowment (liberal-arts university)]. according to the GACC. This is the largest fire in New Mexico history, which surpassed the previous record of 150,000 acres[≈ Toronto] consumed by the Las Conchas Fire in 2011 .

Fig. 2. Screenshot of number explanations presented inline on a web page, generated by the Dictionairy of Numbers web browser plugin.

C. Facebook Demetricator

The interface of Facebook is filled with numbers. These numbers, or metrics, measure and present the social value and activity, enumerating friends, likes, comments, and more. Facebook Demetricator is a web browser addon that hides these metrics [27]. e.g. Friend counts disappear: '16 people like this' becomes 'people like this'. Through changes like these, Demetricator invites Facebook's users to try the system without the numbers, to see how their experience is changed by their absence. The aim is to disrupt the prescribed sociality these metrics produce, enabling a network society that isn't dependent on quantification.

VII. Conclusion

The inaccuracy of perceiving large numbers, is inherent to features or deficiencies of our cognition. Our direct number perception is limited to four and we therefore need mental operations such as grouping and counting to be able to distinct higher quantities. The use of words and symbols allows us to move beyond the limits of approximation. However, we are biased to using small and round sets of numbers. These numbers are easier to comprehend and to communicate with.

Explaining large numbers has proven to be an interesting challenge. The interviews and discussions conducted in this research confirmed it might be possible to explain large numbers using personal data. The question whether personalized explanations using the Numberstand application are a valuable way of explaining numbers, depends on the level of an individual's number sense, arithmetical capabilities and familiar landmark quantities. Using familiar geographical data as so called landmark quantities seems to be a useful way to envision groups of people. Such a landmark quantity was proven to be used by participants by means of simple and round calculations, to understand other amounts of people which could be related to this quantity. e.g. Using the total Dutch population (16 million people), participants were able to easily calculate that 4 million people is a quarter of the total population.

Incorporating groups of people from geographical data to explain large amounts of money is a different matter. Opinions on these explanations varied from person to person. Incorporating a familiar fixed amount of money applied by a familiar group of people seemed to be a valuable explanation. However, incorporating ill-defined money amounts or arbitrary time spans proved to be of insignificant value. Such parameters did not contribute to generating useful explanations.

The small number of participants (15) is a factor in the credibility of the results. Although, the personal discussions and comments did provide first insights in the valuable aspects of number explanations. All participants were able to envision populations of familiar geographical area's, mapped to groups of people mentioned in a news item. All participants, except three of them, were also able to envision these landmark quantities used in an explanation of an amount of money. Ideally, conducting evaluations with a larger test group could possibly provide more valuable insights. It is important to note that the developed prototype could be refined and extended in several ways. It would be beneficial to experiment with several of such prototypes to gather more insights in the valuable aspects of personal number explanations. This however, is outside the scope for this graduation research project.

Concluding this research, I composed a list of hypotheses that could form a starting point for future research.

- Geographical data can possibly be used to envision groups of people.
- It is possible to expand someone's number sense by introducing new landmark quantities.
- A population of a familiar area can act as a landmark quantity, even when that person does not know the actual number of that corresponding population.
- Familiar fixed money amounts are useful quantities to compare to, and explain, other money amounts. Familiar periodical amounts of money are less useful in this respect.
- A month and a year are time spans that are easily understood and mapped to explanations using periodical amounts of money. Three months and a half year are less appropriate to use in this matter.
- Not being able to recall numbers from memory is a common issue with events happening far away opposed to events happening nearby. Relating an event happening far away to a nearby landmark quantity, evokes a better mental representation than solely communicating a number.

VIII. Future Work

It might be that personal number explanations could benefit from using more types of personal data and familiar landmark quantities. In this research only a small range of personal data was used to gain initial insights in personal number explanations. Besides the used personal data, it is important to see to what extent incorporating a number's context helps evoking a better understanding of the number's value. It is quite a challenge to do this due to the endless variations of number contexts.

Experimenting with other types of evaluations and structures could furthermore advance this research. It would be good to examine the different impacts of the explanations when a participant is presented with the number in question in varying ways. e.g. verbally explaining a number, reading a news article or hearing a number on the radio. The important thing is to see if a personal number explanation has a different impact when the source differs. Besides the presentation of the number in question, it is also a good idea to experiment with different structured explanations. Sometimes the explanations seemed far-fetched but it did not became clear if this was caused by the used personal data, the flawed explanation structure or maybe even something else.

Furthermore I think that personal number explanations are subjected to evaluation. Meaning, that one explanation might not make sense at a certain moment but maybe does a few years later. It would be to create a prototype that learns based on a user's personal experience and the rated explanations. Mobile devices such as smartphones are able to constantly track a user's location. Such devices enable to flexibly experiment with more types of location data rather than just the user's entered place of birth and current residence. Also, if the user marked an explanation as not valuable, the prototype should be able to analyze what aspects are not valuable, learn from such analysis and serve more valuable explanations during future queries.

Acknowledgment

I would like to thank all participants of the user evaluations. Special thanks go out to my supervisor Bas Haring for asking the right questions and steering me in the right direction, my peer reviewers Fred Balvert and Guido Huijser for their questions and feedback, and to Arne Boon for discussions and input. Furthermore, thanks to V2_ Institue for the Unstable Media, for the opportunity to present this graduation project at such a vibrant location.

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