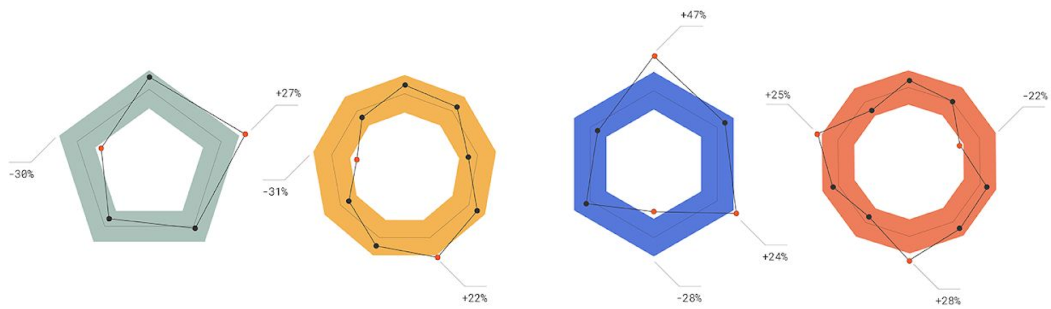
⟨MED⟩GON



Medigon.. Your blood, your data.

A new visual language to understand our bodies

A thesis submitted in partial fulfillment of the requirements for the degree of Master Science in Data Visualization at Parsons School of Design.

By: Batool Akbar

Advisor: Daniel Sauter

May 2019

Table Of Content

Abstract

Hospitals and clinics are starting to give direct access to patients to view their laboratory test results through online portals [1]. Patients view these results that usually come in tables of numbers without guidance of health professionals. Therefore, the form in which these results are presented is essentials to help patients interpret their test results appropriately. Currents formats are text heavy, designed for domain experts, and significantly lack visuals. To fill gap I present in this thesis: Medigon, a visualization-based toolbox of blood test results. Medigon uses geometric shapes, colors, and normalization to show test results in a way that helps non-experts better understand the meaning of their results. Users can enter their own data, interact with the visuals and export a report of the results shown to them. In this thesis, I show a description of the functionalities of the tool and discuss the design choices of the different components along with an illustration of a case-study.

Introduction

In an era where data is easily accessible remotely through a mobile application or a web browser, the number of people who view different data elements increases. The health section is no exception with more hospitals providing direct access of data to their patients [2]. This raises a challenge in how to show this data in a way that is easy to understand by non-experts. Current formats to show test results in traditional tables are challenging for patients to comprehend and understand their implications [cite]. A study has shown that only one-third of people with low numeracy and literacy skills were able to tell when the results of one blood element was not in the normal range while given a reference to standard ranges of that element [3]. It is also challenging for patients to understand whether a certain result is good or bad, and assess the risks of small versus big changes to their numbers across different blood elements [4]. For example, doctors would know that a 1% change in one blood elements could be serious while a 5% change in another blood element is not [2]. Therefore, given an expected low health literacy of patients, tools for communicating this data with the patients should be designed specifically for this targeted audience as opposed to using existing data portals that are used by health professionals. There has been some attempts in the past few years to design visualizations of data in the health domain. The Visualizing Health Project designs intuitive visualizations of health risk data using graphic displays that are evaluated by the public through their research [5]. Also, numerous design challenges took place recently such as VizRisk in 2015 organised by the US Department of Health and Human, which was won by the Health Outcome Navigator that visualizes data related to diabetes using Tableau [6]. Another example is the Health Design Challenge that happened two years earlier hosted by The Office of the National Coordinator for Health Information Technology, which received more than 230 submissions [7]. In line with these efforts, I present a tool in this thesis that utilizes design concepts in visualizing blood test results to patients. My contributions in this thesis are:

1. Normalize blood test results for more simplification.
2. Use polygons as a visual language to communicate the results better.
3. Interactive interface that allows the patient to participate.

In the remaining of sections of this thesis, I discuss the data in the next section and describe the toolbox in details in following two sections titled Toolbox and Narrative Page. Then, I go through a case-study and finish with the conclusion.

Data

The following data shows the minimum and maximum values of the normal range, and units of measurement of each blood element. [8] The most common blood test performed can be categorized into four groups: Complete Blood Count (CBC), which is the most performed one among the four groups, it evaluates the general condition of the body by counting the number of cells such as White Blood Cells, Red Blood Cells, and Platelets. The second group is Differential Blood Count (DBC), it measures the five types of White Blood Cells to evaluate the body's immune system [9]. The third group is the Basic Metabolic Panel, this test helps the doctor to control the side effects of some medications the patient might be taking [8]. Last group is Renal and Liver Function Test, this test is for kidney disease, it evaluates the kidney's performance by measuring the level of Albumin[10].

In the dataset below, there are thirty blood elements that are considerably different from each other, it creates complexity and ambiguity in understanding the meaning behind blood test results. Normalization and using visualizations are the key to transform the data into meaningful values.

Datasets

1.

Complete Blood Count	Normal Range Min	Normal Range Max	Unit
White Blood Cells	4500	11,000	mm3
Red Blood Cells	4300000	5900000	mm3
Hemoglobin	13.5	17.5	g/dL
Hematocrit	41	53	%
Mean Corpuscular Volume	80	100	m3
Mean Corpuscular Hemoglobin	25.4	34.6	pg/cell
Mean Corpuscular Hemoglobin Concentration	31%	36%	Hb/cell
Platelets	150,000	400,000	mm3
Red Cell Distribution Width	11.8	15.6	%

[8]

2.

Differential Blood Count	Normal Range Min	Normal Range Max	Unit
Neutrophils	40	80	%
Lymphocytes	20	40	%
Monocytes	2	10	%
Eosinophils	1	6	%
Basophils	0.5	1	%

[8]

3.

Basic Metabolic Panel	Normal Range Min	Normal Range Max	Unit
Blood Glucose	0	140	mg/dL
Calcium	8.5	10.9	mg/dL
Sodium	135	147	mmol/L
Potassium	3.7	5.2	mEq/L
Bicarbonate	23	30	mEq/L
Chloride	98	106	mmol/L

[8]

4.

Renal and Liver Function Tests	Normal Range Min	Normal Range Max	Unit
Blood Urea Nitrogen	6	20	mg/dL
Serum Creatinine	0.5	1.2	mg/dL
Aspartate Aminotransferase	8	48	U/L
Alanine Aminotransferase	7	55	U/L
Bilirubin	0.1	1.2	mg/dL
Gamma-Glutamyl Transferase	9	48	U/L
Alkaline Phosphatase	45	115	U/L
Prothrombin Time	9.5	13.8	sec
Partial thromboplastin Time	60	70	sec
Albumin	3.5	5	g/dL

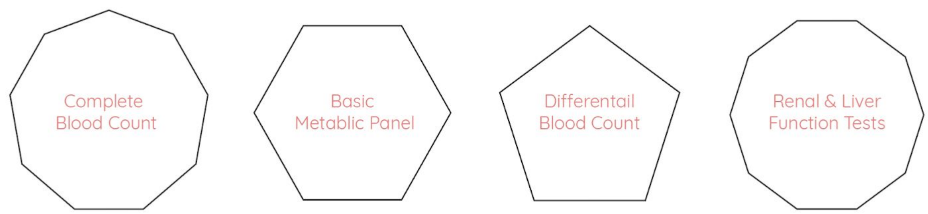
[8]

Toolbox

1. Layout and Structure

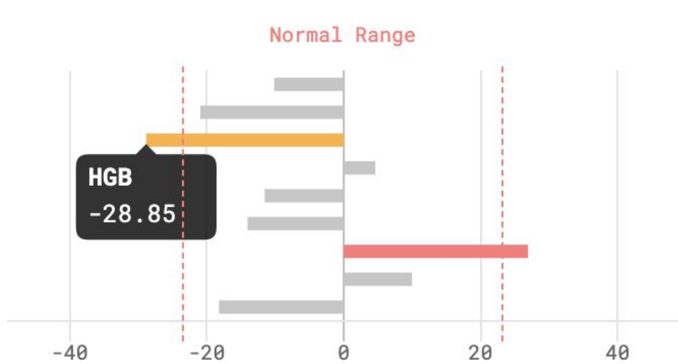
The toolbox is the core of the project, it works as a dashboard that allows the user to interact with the data. It consists of four cards, each card represents a blood component that is fitted in a polygon [Figure 1]. For example, the Basic Metabolic Panel is represented in a hexagon because it consists of six elements. Furthermore, the controlling window contains five slides, the first slide includes the user's demographic information, Blood Pressure, and Body Mass Index inputs.

[Figure 1]



The other four slides are linked to the four cards with their polygons, they are all color coded to make it easier for the user to know which input belongs to which polygon. Every slide has range sliders to select the input before it translates into a visualization. To understand the results better, an analysis is laid out in another card, it shows the polygon again without the scales to focus more on the location of results and where they stand when compared to the normal range. Additionally, the card also shows a mirrored-barchart that translates the distance between the point result and the center of the normal range into a percentage. The negative side is for below normal values, and the positive side is for above normal values, the normal range is bordered in red lines [Figure].

[Figure 2]



One of the main features of the toolbox is the option to download the results to keep them on the personal records of the user to be used in the future when needed. The report includes demographic information, and all the test results with their visualizations. The layout of the report is adjustable, it rearranges the content to fit all the results in one page to show concise report that is easy to understand and remember.

2. Functionality

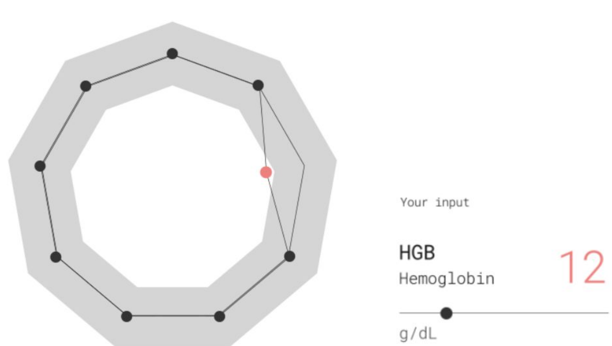
Visualizations

To make it easier for the user to understand the test results, the output of every blood component is represented in a different visualization. Each visualization is composed of a radar chart scaled from 0-100, the polygons function as additional axes in the chart and they range from 50-80. The polygons represents the area of the normal range for a blood component, which is shaped as the thickness of the polygon [Figure 3]. The barchart have the same function as the radar chart, it shows the test results after normalization. However, it translates the normalized value into a more meaningful number, it measures the distance between the outlier point in the polygon and the center of the normal range, and translate it into a percentage [Figure 2].

Sliders

Each element in the toolbox serves a function, the sliders take the actual value of the test result and convert it into a normalized value to fit it in the polygon. The results automatically updates as the value on the slider changes, if the value goes above normal, the point turns into a different color, and vice versa if it goes below normal. The same function applies to the barchart, the bar turns red when it goes off the red lines. This function helps us to have a general idea about the test results by just looking at the visualization.

[Figure 3]



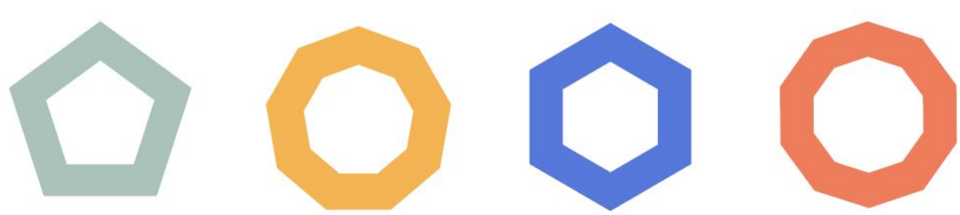
3. Design Decisions

Principles and elements of design are important aspects in the process of building any tool. Choices of colors, typography, whitespace, and layout among other aspects make a significant difference to the user experience. Furthermore, design aesthetics gives an identity and a personality to the work. As such, I decided to focus on these three design elements colors, typography, and grid to form the toolbox.

Colors

Colors have great psychological impact on humans' mood and behavior, it makes it challenging to decide on a color scheme for the project [11]. The type of work influences the meaning of colors and enhances the user experience, for example science fiction websites are usually in dark themes with analogous colors, while dating websites are in warm themes with monochromatic colors. Health websites should look friendly and professional in the same time for the user, because they convey serious information. Medigon deals with important and complex information and simplifies it using visuals. Therefore, I decided to go with complimentary colors for two reasons; their performance at color-coding, and their impact on the user.

Complimentary colors are the colors that are opposite to each other in the color wheel, for example: red and green, blue and yellow, and therefore they are always distinguishable. The four polygons in the toolbox are distinct, each polygon has a different number of sides and a unique color; Complete Blood Count is in a yellow nonagon, Differential Blood Count is in a green pentagon, Basic Metabolic Panel is in a blue hexagon, finally Renal and Liver Function Tests is in a red decagon [Figure 4]. The polygons are color-coded with the sliders to make the blood components easily identifiable.



[Figure 4]

Because users are going to trust the interface with their blood test results, they should feel confident and convinced with the process. Complementary colors are suited to provide these feelings to the user because they are clear and straightforward colors, which reflects the goal of Medigon.

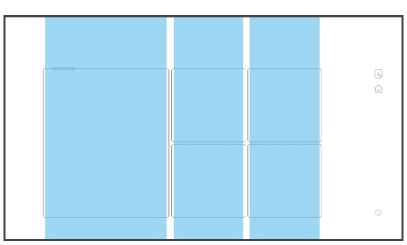
Typography

As with any design element, typography gives a unique personality to the interface. In order to give the users a feel of close and direct interactivity with their blood test results as if they were in a laboratory, I decided to go with a mono typeface since it has medical characteristics. Moreover, typeface is not the only decision to make in typography; hierarchy is an essential design principle to communicate the information effectively to the user.. Type organization guides the users' eyes to know where to start reading and focus and what part of the page to focus on. For example, in the toolbox, I used the same type point in the visualizations' titles and in the controlling window title to show that they are parallel to each other.

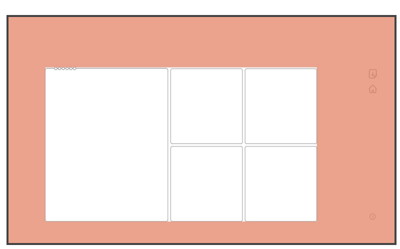
Grid

The skeleton of the page that include columns, gutters, and margins are all essential elements to create a good grid for the content. I started designing the page with setting the margins first, because they define the area that will hold the content. Then I decided to go with a three-column grid to have a rectangular layout for the cards as it makes it easy for the users' eye to switch between the controlling window and the cards quickly. Lastly, the gutter between the cards makes them look unified but also makes them look independent.

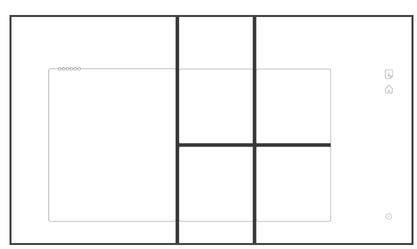
Columns



Margins



Gutter



4. Implementation

Normalize Data

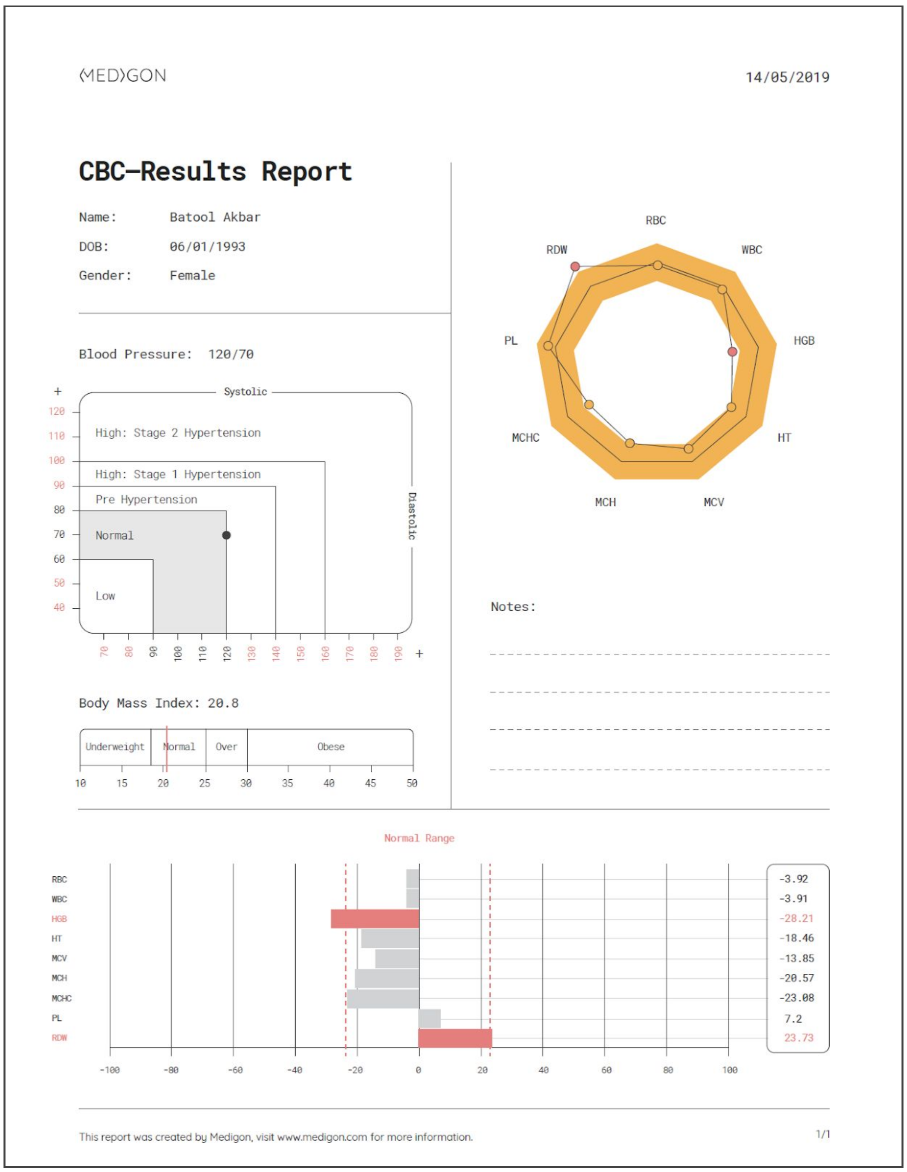
The data introduced before contains inconsistent values and normal ranges, which makes it impossible to fit all blood elements in one visualization. Thus normalizing test results is the first step in bringing the interface to life. Normalization is the process of converting irregular values to more consistent values by eliminating all units and standardizing the values. In our case, we remove blood elements' units like mm3, g/dL, Hb/cell...etc, and unify the values so they all fit in one scale.

Set Scales

Now that all the values are normalized, they are comparable and can all fit in one scale. Radar chart is the best representation for the normalized data, because it gives an overall look of final results without looking at the values. Since almost everyone is familiar with the 0–100 scale, all values are normalized to be fitted in this scale. Even though most of the times we consider 0 to be the lowest number, and 100 the highest number, it does not apply to our scale. The normal range takes place in the middle of the scale, thus the range starts from 50 and stops at 80; it means 65 is the ideal number because it is the center of the normal range. We conclude from this that the value does not matter in this case, but we look at where it is located on the scale. Given that the area of the normal range is different among blood elements, the normalization of the normal range of all blood elements rescales the original data to fit in the 50-80 area of the visualization. Some elements have a wider normal range than others, however after normalization, all visuals will show the normal range in 50-80, upnormal in 80-100 and below normal in 0-50. The selection of these cut-off points is based on the ranges discussed in the data section above. For example, in the Complete Blood Count component, white blood cell have a normal range from 4,500 to 11,000 mm3 while the normal range of Hemoglobin starts from 13.5 to 17.5 g/dL. Although the size of normal ranges for these two blood elements is significantly different, both will be rescaled to the 50-80 range in the toolbox which provides a consistent view to the user to ease their experience and enable comparisons across different blood elements. The same process applies for the 80-100 and 0-50 ranges.

Export Results

One of the main features in the toolbox, is the option to export the results as a PDF, and the reason why it is an important feature is because it secures the users information by saving the file locally. After the user is finished from filling all the information and test results, by clicking on the download button, all the visualizations and demographic information layout on a PDF to download. This downloaded report can be given to doctors for future visits, and can be kept as a record to compare different reports.[Figure 5]



[Figure 5]

Narrative Page

The narrative page is a guide for the user to learn the language and features of the toolbox before interacting with it. It consists of two scrollable columns, one column is for body text and the other column is for the animations. This page is important because it explains major concepts in the interface such as normalization and polygons using animations. It starts with discussing the problem of the current blood tests format, and it shows an example in the animation. The next section introduces the four main blood components, and uses the Complete Blood Count as an example for all the sections. After that it explains normalization and why it is an important step in the process, which leads to the final section; polygons. The section discusses how the polygons are representing the normalized data by using the Hemoglobin as an example in the animation, and why they work better than any other visualization.

Discussion

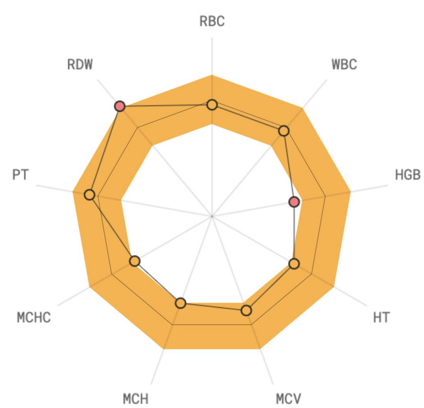
One of the main motivations to work on this project was my personal experience with my blood test results. I used to have my blood tested frequently for different reasons, and everytime I received my results from the lab it left puzzled with their meanings. As a result, I had to ask health professionals to explain all the numbers to me, which made me think of solutions to communicate the results better to non-professionals like me. Using a real dataset is an important step to show that the interface works well. Therefore, I will use my own dataset as a case-study to test the usability of the interface with a real dataset.

Case-Study

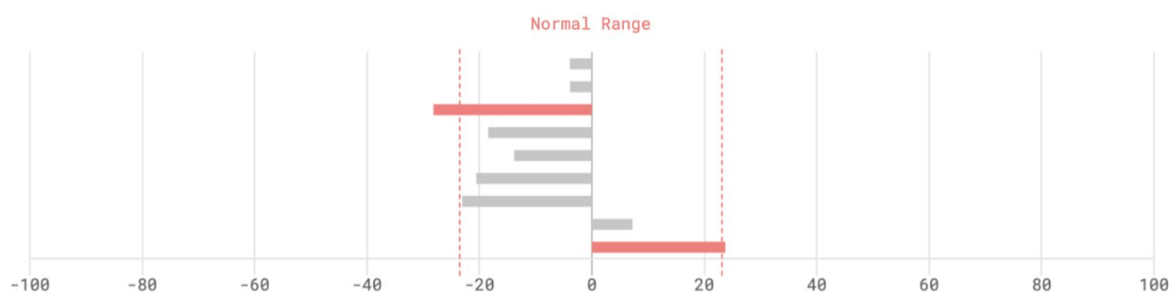
Test component	Result	Standard Range
WBC (x10(3)/uL)	7.21	4.00-10.10
RBC (x10(6)/uL)	4.33	3.58-5.19
HGB (gm/dL)	11.2	11.0-15.5
HCT (%)	36.4	31.5-44.8
MCV (fL)	84.1	78.0-98.0
MCH (pg)	25.9	25.2-32.6
MCHC (gm/dL) Comments: Below low normal	30.8	31.0-34.7
RDW (%) Comments: Above high normal	15.8	12.0-15.5
POLYS (%)	65.3	37.1-78.1
LYMPHS (%)	24.0	13.7-50.9
MONOS (%)	9.3	3.0-11.9
EOS (%)	1.0	0.0-5.0
BASOS (%)	0.3	0.0-1.0
IMMATURE GRANULOCYTES (%)	0.1	0.0-1.0
PLATELET COUNT (x10(3)/uL)	313	140-425
MPV (fL)	9.9	8.6-12.1

Complete Blood Count results report from Patients Fusion.

The report is in a tabular format that shows the test component, test results and the normal range. The problem with this report is that, first it does not show how far the results are from the normal range. Second, it only provides comments on the abnormal results, but it does not highlight the results that are almost off the normal range. Finally, the units are meaningless, which makes it more confusing for the person to understand it. I used Medigon to visualize my data, the figures below show the final visualization of the test results.



[Figure 6]



[Figure 7]

With just looking at the polygon [Figure 6], I can see that there are two abnormal results without checking the result value or the normal range value for that element. Additionally, I notice that there are few elements that are almost off the normal range because they are not completely inside the polygon. The barchart [Figure 7] measured the distance between the results and the center of the normal range and turned into a percentage, I know that my Hemoglobin level is low because it is in the negative side of the chart, and it is -28% away from 0, which is the ideal score.

Conclusion

In conclusion, data is the new currency in this world, and it is becoming more and more valuable everyday. Data is everywhere, it is around us, and it is even inside us. Now with smartphones and full coverage networks, with one click we can easily access our own data including the ones provided from hospitals. However, blood test results are usually laid out in an unintelligible format raises questions about their meanings, they are heavy-texted, they contain multiple units and ranges, and they lack visuals. As such, It makes it hard for patients to understand what is a good result and what is a bad result without asking experts. Therefore, Medigon was built specifically to solve this communication problem by simply using data visualization, interactivity, and normalization. Medigon toolbox accepts the actual blood test results, normalize the values and fit each blood component in a polygon. Polygons are a useful feature in the interface because they represent the normal range for all blood components, and they illustrate the results without showing the numbers. Furthermore, normalization makes it possible for each blood component to be fitted in one polygon. Finally, interactivity allows the user to try all the values to learn what is a good result and what is a bad result. Data should not be complex or illegible, with visualizations and some design thinking, people can interact with their own data.

Bibliography

1. Laine, C., and F. Davidoff. *"Patient-centered Medicine. A Professional Evolution."* JAMA. January 10, 1996. https://www.ncbi.nlm.nih.gov/pubmed/8531314?dopt=Abstract.

2. Zikmund-Fisher, Brian. *"Data Visualisation Could Help Patients Understand Their Test Results Online."* The Conversation. January 21, 2019. https://theconversation.com/data-visualisation-could-help-patients-understand-their-test-results-online-30624.

3. Zikmund-Fisher, Brian., and Exe, Nicole L., and Holly O. Witteman. *"Numeracy and Literacy Independently Predict Patients' Ability to Identify Out-of-Range Test Results."* Journal of Medical Internet Research. August 8, 2014. https://www.jmir.org/2014/8/e187/.

4. McCray, Alexa T. *"Promoting Health Literacy."* Journal of the American Medical Informatics Association : JAMIA. November 23, 2004. https://www.ncbi.nlm.nih.gov/pubmed/15561782?dopt=Abstract.

5. *"Visualizing Health."* Visualizing Health. 2014. http://www.vizhealth.org/about/#about-this-project.

6. *"Health Outcome Navigator."* Tableau Software. https://public.tableau.com/views/HealthOutcomeNavigator/HealthOutcomeNavigator?:showVizHome=no#1.

7. Va. *"THE PATIENT RECORD."* Health Design Challenge: D Collab // THE PATIENT RECORD. January 2013. http://healthdesignchallenge.com/.

8. *"Normal Lab Values - Common Laboratory Values."* Meditec. https://www.meditec.com/resourcestools/medical-reference-links/normal-lab-values/.

9. *"Blood Differential: MedlinePlus Lab Test Information."* MedlinePlus. April 15, 2019. https://medlineplus.gov/lab-tests/blood-differential/.

10. *"Know Your Kidney Numbers: Two Simple Tests."* National Kidney Foundation. October 17, 2018. https://www.kidney.org/atoz/content/know-your-kidney-numbers-two-simple-tests.

11. Schrader, Kelsie. *"The psychology of color in healthcare design"* Shield Casework. July 2. https://www.shieldcasework.com/the-psychology-of-color-in-healthcare-design/.