THESIS

A DESIGN RESEARCH TO NUMBER SENSE & THE DESIGN OF NUMBERS

Design, Research & Concept
by Aline De Feyter

THESIS

A DESIGN RESEARCH TO NUMBER SENSE & THE DESIGN OF NUMBERS

Aline De Feyter ©2020
International Master in Visual Arts Graphic Design:
Reading Type and Typography — READSEARCH

PXL MAD SCHOOL OF ARTS

Under supervision of

READSEARCH { Ann Bessemans
María Pérez Mena
Carl Haase

This master's thesis came about (in part) during the period in which higher education was subjected to a lockdown and protective measures to prevent the spread of the COVID-19 virus. The process of collection information, the design research method and/or other design research work could therefore not always be carried out in the usual manner. The reader should bear this context in mind when reading this Master's thesis, and also in the event that some conclusions are taken on board.

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1 ACKNOWLEDGMENTS

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2 ABSTRACT

The main goal of this design research is to make sense out of number (non)sense through the process of collecting various number notations. The resulting archive is presented in a series of 11 books including this thesis, each book covers an individual number from 0 to 9 about historical information on various ways of representing numbers. These first 10 books will be referred to as *The Encyclopedia of Number (non)Sense*, offering a multicultural approach to number notation systems.

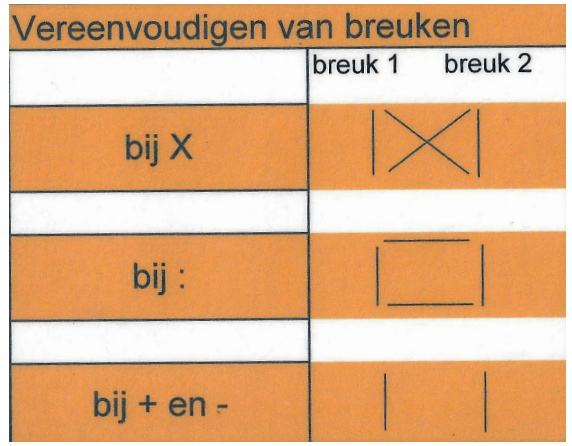
Leading to questioning the current way numbers are designed following ages of conventionality, the development of how numbers were written, read, and systematically used for counting. The overall book design allows the encyclopedia and its content to be consulted more easily in comparison to the current online archives and scattered questionable sources on the web. The navigational systems designed for this book series are divided into micro and macro layers, revealing the content in a user-friendly manner to be utilized by researchers and designers.

Thanks to the newly shed light upon known facts about number notations and number (non) sense collected in the archive, typographical experiments were conducted alongside simultaneously during the design process of the encyclopedia. These experiments or hypotheses should be viewed as *extra muros* and will be thoroughly explained in the second chapter of the 11th book – being this thesis – as to approach the question of how our current Hindu-Arabic numbers could be redesigned. This redesign is focused on a specific group of readers with mathematically related learning difficulties such as dyscalculia, or readers without dyscalculia but with a general lack of number sense and numerical insight. These designs are fueled by scientific research articles and my fascination with numbers.

3

INTRODUCTION TO NUMBER (NON)SENSE

Dyscalculia is a specific and complex learning disability regarding mathematics, number sense, serious lack of the ability to memorize or automatize systems in general, and the lack of strategic insight or ability to obtain and maintain a (correct) problem-solving methodology. • In education, several aiding study cards •• and tools are provided by professional speech therapists and remedial teachers for support. However, their approach (considering its design) is not always optimal and the study cards rarely help. That is at least my experience struggling with math from childhood on. Those cards offered alternative measurements and numerical systems that were difficult to understand on top of the already difficult learning material, resulting in too much information that has to be processed.



Besides understanding and having to learn mathematical systems in general people suffering from the consequences of dyscalculia lack number sense. Number sense is the mastery of the meaning and value of a number(s) and is a term used by neuropsychologists and speech therapists. It is the basic insight and understanding of numbers, mostly applied in daily life and mathematics. Number sense develops in the brain during pre-school and forms the base of all number-related knowledge such as telling time and estimating values to make daily (basic) calculations that are taught in primary school. The ability to recognize symbols or other visual representatives to write/express numbers is not naturally obtained nor genetically present but have to be taught. •••

As a (type) designer with the learning disability dyscalculia, the interest in numbers and number sense came very naturally into my life. With a formation in typographic design and design research, this disability has become my strength.

• VAN LUIT, HANS. 2018. *DIT IS DYSCALCULIE, ACHTERGROND EN AANPAK*. BELGIUM, LEUVEN: LANNOO CAMPUS P. 25

•• AN EXAMPLE OF A STUDY CARD, 2013. PROVIDED BY REMEDIAL TEACHER SMIDS, ILSE.

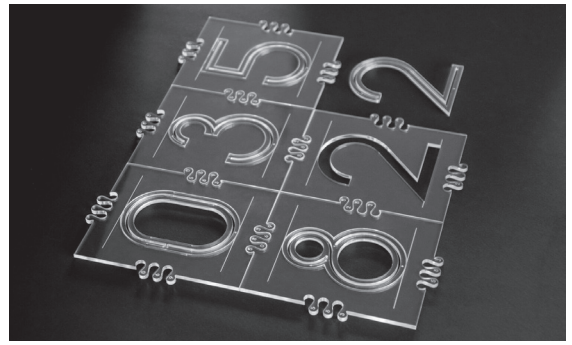
••• VAN LUIT, HANS. 2018. *DIT IS DYSCALCULIE, ACHTERGROND EN AANPAK*. BELGIUM, LEUVEN: LANNOO CAMPUS P. 12, 25, 151, 180, 193

My knowledge about dyscalculic experiences has led and is still feeding my fascination with rethinking numerical systems and designs to help others understand the complexity that numbers might have for a minority of the population. My fascination with numbers and how their designs could be optimized is everyday enforced due to several, previous and ongoing (some of them will be explained below), design projects, and design research topics throughout my educational career as a master in typographic design. The projects where I'm most proud of I focus on typographic approaches for developing tools or design typographic books that might share new and interdisciplinary viewpoints or techniques concerning the disability of number sense.

During my Master in Graphic Design at Sint-Lucas Antwerp, I designed a book called *Dyscalculie ontcijferd* (Dyscalculia deciphered, ••••) to visually elucidate the definition and existence of dyscalculia in the educational field (De Feyter, 2019). This book serves as a visual and practical translation or communicative guide of possible issues caused and influenced by dyscalculia. Helping the reader(s) such as teachers, parents, researchers, students, or children with/without dyscalculia to discuss, compare and understand their way of thinking and methods to solve (mathematical) problems. The book, in essence, is designed to give the reader(s) visually more insight in what this disability includes, and how dyscalculia could be approached as a way of visual and creative thinking instead of being solely a label in education, daily life, or on the work floor. Yet another design research project – the outcome of the Studio Typo Type as part of the MA Reading Type & Typography at PXL-MAD School of Arts in Hasselt, Belgium – has developed into a tool to assist in writing Hindu-Arabic numbers correctly.

•••• DE FEYTER, ALINE. 2019. *DYSCALCULIE ONTCIJFERD*. ANTWERP, BELGIUM. URL: HTTPS://ALINEDEFEYTER.COM/HOME/DYSCALCULIEONTCIJFERD

Learning various research and design methods within the READSEARCH research group lead to the development of this prototype regarding the tool for writing numbers (De Feyter, 2019 – 2020). —



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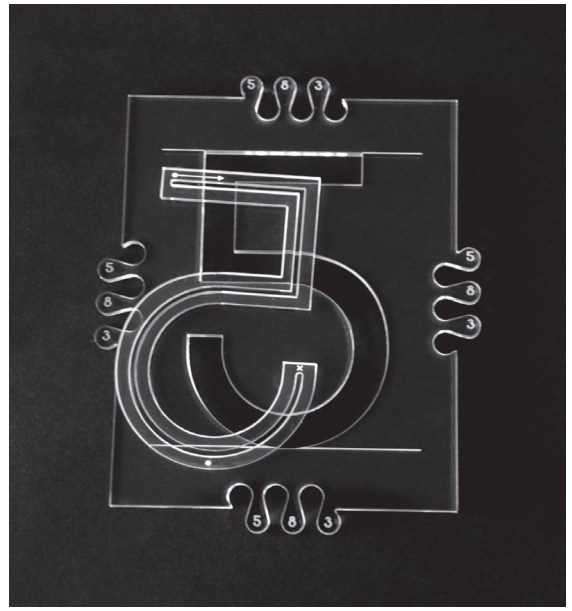
In these projects I believe that typographic design can influence the way we think about numbers and use them in daily life, being it for regular or struggling readers. Typography has an impact on how easy we can focus on the content or the meaning of the text. Most of the people (mostly non-designers) don't realize this invisible power that typography holds, namely reading/deciphering numbers and letters without actually seeing them. ÷



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As soon as we start noticing letters or numbers, or in other words need to pay attention to these abstract symbols, we start deciphering and feel uncomfortable because our 'reading process' is hampered. In this project, a combination of multidisciplinary fields takes place, such as decisions made during the design process of the type designs based on neuropsychological research to number sense and reading research. Resulting in supporting tools and a new visual presence of numbers, setting the course for questioning the present visualization of numbers, and reimagining or redesigning their future.

— DE FEYTER, ALINE. 2019-2020. *PROTO TYPE OF THE WRITING TOOL*, EXECUTED IN ACRYLLIC PLEXI. 3 MM THICK, 15 X 9 CM. ANTWERP, BELGIUM. URL: HTTPS://ALINEDEFEYTER.COM/HOME/WRITING-TOOL

÷ UNGER, GERARD. 2018. *THEORY OF TYPE DESIGN*. NETHERLANDS, ROTTERDAM: NAI010 PUBLISHERS

4

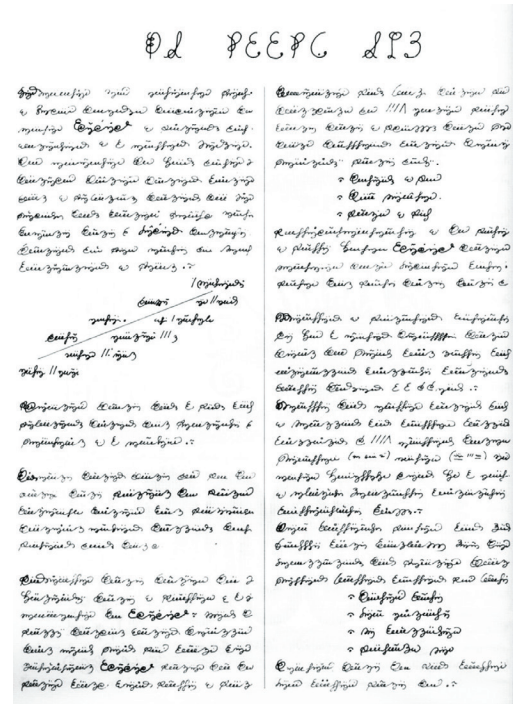
THE ENCYSLOPEDIA OF NUMBER (NON)SENSE

THE DESIGN OF NUMBERS THROUGH TIME AND SPACE

INTRODUCTION TO A DESIGN RESEARCH TO NUMBER (NON)SENSE

4.1

I have always been confronted with trying to decipher numbers and systems, in a way my fascination has grown for this particular process. To illustrate my obsession with deciphering the symbolic value of abstract figures called numbers through design, the mysterious (up until now) undeciphered *Codex Seraphinianus* by Luigi Serfini [1] is a perfect example. This codex and its unsolved script resemble the level of complexity that readers who lack number sense or numerical insight, experience while dealing with numbers or reading material that contains number strings. Looking more closely at the pages from the Codex, the written symbols make no sense at all to the reader, even though they are supported by explanatory illustrations. Vaguely recognizing similar abstract symbols but not knowing their meaning (yet) and trying to decipher a text from this codex, is like an attempt to make sense out of nonsense.



[1] SERAFINI, LUIGI. 2013. *CODEX SERAPHINIANUS*. US, NEW YORK: RIZZOLI INTERNATIONAL PUBLICATIONS.

When learning about the individual value of a number to make sense of abstract representations, this learning process is similar to the alphabet. An interesting method to learn to write and read or firstly understand and automatize the alphabet is the alphabetcode. This is a methodology developed by Erik Moonen as a different educational approach to decoding (writing and reading) the Latin alphabet and Dutch language. [2]

[2] MOONEN, ERIK. 2012. *DWAALSPOOR DYSLEXIE*. ANTWERP: STANDAARD UITGEVERIJ. P.13

In the alphabetcode, naturally present knowledge of speech or pronunciation gained through mimesis during childhood is brought in relation to the unknown skills of writing and reading. There is a connection made between what is naturally obtained from the child's environment and what is technically learned. In other words: Moonen's methodology brings what makes sense or what is known in relation to the nonsense or what has yet to be understood. Reading and writing are skills that are not naturally obtained, meaning they have to be learned and taught. This approach has proven to benefit dyslectic children learning how to write, memorize, and read the Latin alphabet more efficiently creating stronger readers. Hence it could be interesting for children with dyscalculia or other mathematically related learning disabilities to have the opportunity to take a similar approach to learn about numbers and mathematics.

The beauty of nonsense – the fascination of the act of deciphering – leads towards researching numbers and their notations on a very large scale. *What is the origin of number notations? How rich is their evolution? What other writing systems, manners of number reading, or dealing with numbers have emerged through history and how did they evolve into the notation system(s) used today? Would it be possible to collect and design a nonexistent archive containing solely number depictures through time, space, and different origins/cultures? And in the end, could this archive with new sources shed a light on how to deal with numbers in general? Could it inject new design projects or approaches that are anchored in a global wealth instead of a geographic one?*

From the perspective of typography, specific designs focused on the communication of the value or identity of numbers could aid in a deeper numerical insight while reading, writing, and learning.

These thoughts (and personal fascination with number sense) have led to the following research question: *Is it possible to collect every piece of number system/notation that humanity has created around the world? And if so, how can that be collected so that it can inspire other designers to create new systems that improve current ones in terms of legibility for the particular purpose to enhance numerical insight?*

THE ROAD TO COLLECTING & ARCHIVING

4.2

✦

The capacity of human knowledge and the development of number sense has grown tremendously since prehistoric times up until now. This evolution occurred simultaneously with how numbers were conceptualized, visualized, and systemized. 𝍠 From a historical point of view, there is a lot of research and data on the occurrence and evolution of numbers and their notation systems. However, the current information available in existing sources is about the entirety of the script, focusing on its language and linguistic values. The current information and research referred to holds knowledge such as various decipherments of extinct or ancient scripts on numbers and their notational system.

𝍠 A. BOUCENNA. *ON THE ORIGIN OF THE ARABIC NUMERALS / SUR L'ORIGINE DES CHIFFRES ARABES*. DÉPARTEMENT DE PHYSIQUE, FACULTÉ DES SCIENCES, UNIVERSITÉ FERHAT ABBAS 19000 SÉTIF, ALGÉRIE

Even though these open sources exist and are accessible, reliable information specifically on number notation systems is difficult to find and is often scattered on the web. Causing this niche of information to be easily overlooked and creating the misconception of what seems to be a gap in our knowledge on numbers and their history. Data solely on numbers is cumbersome to get a hold on because they simply do not play a leading role (yet) in any of the available (online) archives or libraries. The sources that were consulted such as the online archives *Scriptsource* and *Unicode*, hold a mass of information on scripts, symbols, and notation systems but lack a specific user-friendly and structured overview purely on number notation systems.

The current knowledge on alternative notation systems and scripts is vast, including some undeciphered scripts of that some pieces of information are unspecified This depends on several external factors, a few are how many manuscripts or ephemera were preserved and remained intact through cultural influences or conflicts in history and whether or not they are deciphered today. As this content has never been displayed before with a focus exclusively on the cross-cultural evolution of numbers, this led me to first collect all the data on numbers within the given time. Such as the counting system, writing system, reading direction(s), geographical origin(s), language(s), period, and their design. These visualizations and layers of information will, later on, form the foundation for the design of this archive.

The process of carefully collecting and archiving this (visual) information focused on numbers intrigued me as a designer, inspired and fascinated with unfamiliar number shapes.

The overwhelming amount of raw data collected over time from various sources, now asks for the appropriate medium to become an archive. The archive must have a clear structure and be user friendly for this kind of specific information in opposition to the already existing unclear and time-consuming research sources. Above all, the archive must function well so researchers of various fields of expertise, designers, and readers of interest can utilize the data embedded in the archive. Respecting the historical value and origin of this field of research and the sources used to collect the information, the idea to create *The Encyclopedia of Number (non)Sense* emerged. The encyclopedia consists of 10 books that hold information on the individual numbers 0 to 9 such as their design, system, and origin. The 11th book - being this thesis - is an addition to the research and an in-depth annotation of how the encyclopedia could be used in the future. Much like the *Codex Seraphinianus* (Serafini, 2013) [1], forming the intriguing Encyclopedia of Number (non)Sense bringing forth hidden facts and shedding new light on numbers in terms of design, theory, and history.

As the project progressed, careful thought was put into the determination of the content hierarchy to make the data in the archive available and easy to utilize.

[1] SERAFINI, LUIGI. 2013. *CODEX SERAPHINIANUS*. US, NEW YORK: RIZZOLI INTERNATIONAL PUBLICATIONS.

First, the content was divided into micro and macro navigational layers, the visual features of the numbers, the script's title, and its period of existence are considered macro layers of information. This is the layer with that the reader will be confronted firstly when consulting the book(s). The remaining information such as the writing system, counting system, geographical information, language, and references are considered micro-layers of information. The micro-level holds more specific and detailed information for in-depth research within each script. Each of these categories of information can be individually used as a navigational system.

Thanks to this functional approach to the archive – depending on the reader's research question and method of consulting the encyclopedia – it can be used in its full extension providing both a quick and broad visual overview and detailed information along with references for that the medium of an encyclopedia is perfect. In this case, the term encyclopedia is defined as an academic medium typically known for holding a large amount of specified information. An encyclopedia can hold more in-depth content and has the ability to offer both theoretical information and raw data along with visual material in comparison to a dictionary, codex, or catalog. Whereas a catalog, for example, is known to hold less complex navigational systems and merely provides an overview of the content. Thus the medium of an encyclopedia can hold a large archive and is known for its navigational systems either based on a parameter of time or based on the alphabet. In the Encyclopedia of Number (non)Sense the content is arranged on time, as the alphabet is not globally known and this arrangement of content makes more sense to the utilization of the books. An alphabetical list is kept in the back of the books in the index (Encyclopedia, p. CXLVI – CXLVIII).

The thorough complexity and simplicity of the navigational systems when consulting the encyclopedia, allows the reader to compare numbers based on the parameter of time as each individual book could be seen as a timeline. Providing both detailed information on each individual scripts period of existence alongside a visual overview at the cutting edge of the book series. The reader can also make use of the glossary explaining its terminology with references and page numbers aside at every beginning of each book or enjoy the visualized synopsis at the ending. Included in the glossary, for example, are the writing systems of the script that the numbers originate.

Such as *abjad*: a form of writing in that the vowels are omitted or optional, as frequently seen in Hebrew and Arabic scripts. *Abugida*: a form of writing in that the consonants and vowels in a syllable are treated as a cluster or unit; typical of scripts from South Asia. *Alphabet*: a segmental writing system having symbols for individual sounds, rather than for syllables or morphemes. *Logographic* writing system: also known as an *ideographic* writing system in that each symbol represents a complete word or morpheme. *Logo syllabary* (a.k.a. *logographic*): a writing system in that each sign is used primarily to represent words or morphemes, with some subsidiary usage to represent syllables. *Syllabary*: a form of writing where the symbols represent syllables--most commonly a vowel-and-consonant combination. 〓

Another example aside from the writing systems of the script, specified for the numbers are the counting systems that can be found in the glossary under the terms: binary, quinary, octal, decimal, duodecimal, hexadecimal, vigesimal, and sexagesimal. Every layer of information included in the books is designed as clearly as possible, systematic, and functional being of value to its content and context for research.

〓 HOLLOWAY, STEPH. SCRIPTSOURCE STAFF. 2020. *WRITING SYSTEMS*. CONSULTED ON 18/05/2020. URL: HTTPS://SCRIPTSOURCE.ORG/CMS/SCRIPTS/PAGE.PHP?ITEM_ID=GLOSSARY

Throughout history, numbers were not only visualized by means of writing. In fact, physical representations for numbers were often used before making the step towards writing or drawing. To make sure a broad overview of number representations is given, signing numbers and counting on your fingers or other body parts is included in the encyclopedia (Finger Counting, Encyclopedia p.128 – p.145). To get an overview of all the different ways of counting by using your hands or other body parts through eras and various cultures, questions arose. Are there similarities in the way we currently count on our fingers with older writing systems? What are the major differences and what way of counting makes the most sense? The way people count on their fingers depends just like the archive of symbols (Number Notations, Encyclopedia p.1 – p.126) on language, time, cultural influences, and habits. Of course, there are more records kept of written, printed, or engraved matter in opposition to the number of records on finger counting. This data is strongly reliant on habitual and cultural influences that may get lost more easily due to changes in traditions and the course of time. The data in the encyclopedia is thus defined by recordings based on cultural memory and the overview provided in the map made by Seidenberg.

The design of the encyclopedia is a homage to the classical medium with a contemporary twist, essential elements of the regular encyclopedias remained throughout the book design. Such as the layout of the pages foreseen with a two-column grid for the body text, explaining every piece of information with illustrations if necessary. All the content in the encyclopedia is printed black and white – that is again a common feature in encyclopedias – maintaining consistency in the content while keeping the focus on the design of the shape of number notations instead of their color.

BARROW, J.D. 2003. *PI IN THE SKY.* LONDON, CAMBRIDGE: OXFORD UNIVERSITY PRESS. THE COUNTER CULTURE. P. 48 FIG. 2.7.

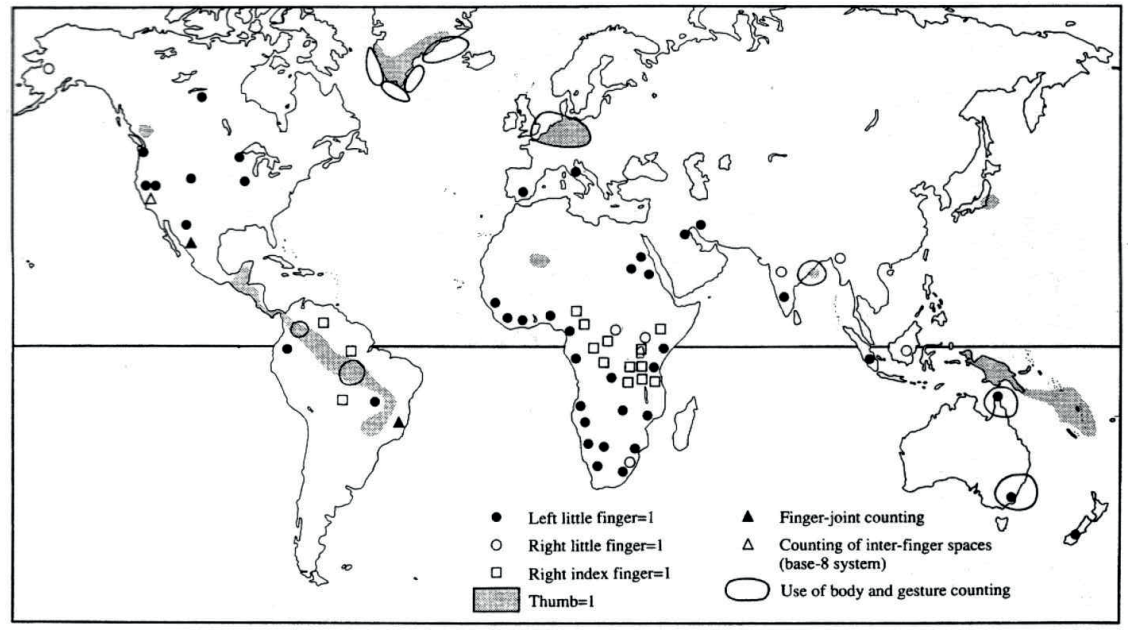


Figure 2.7 The distribution of finger counting techniques based on data first compiled by Abraham Seidenberg from historical and anthropological sources. The different symbols indicate the areas that use different fingers or the thumb to commence counting with the number 'one'. Also shown are the cultures employing finger-joint counting on one hand to count to four, and on two hands count to eight. Extensions of finger counting which employ other parts of the body to count beyond ten are also marked.

On the title pages, a modern twist has been taken upon the classical æsthetic of ornamental frames, inspired by books and type specimens between the ages 1600 – 1800. The online archive of the Museum Plantin Moretus in Antwerp was consulted for inspiration on ornaments in books dating from that period.

On that note, the typefaces used are serifs among the display typeface Arthemys designed by Morganne Vantorre.

Arthemys is based on the 18th century æsthetic, it is born to the meeting of a type specimen by Nicolas Gando and engraved letters of cartographies of that period in time containing beautiful decorative ligatures.

ARTHEMYS
DISPLAY
LIGHT

18th century
aesthetic

The visual consistency and structure in the design have been given to each individual page by using subtle alternates in the typography. Such as caps, undercast and differences in point size, allowing more (visual) distinctiveness between sources and references from other elements on the same page. With this simple and repetitive structure, a few systems still proved to be very cumbersome in practice

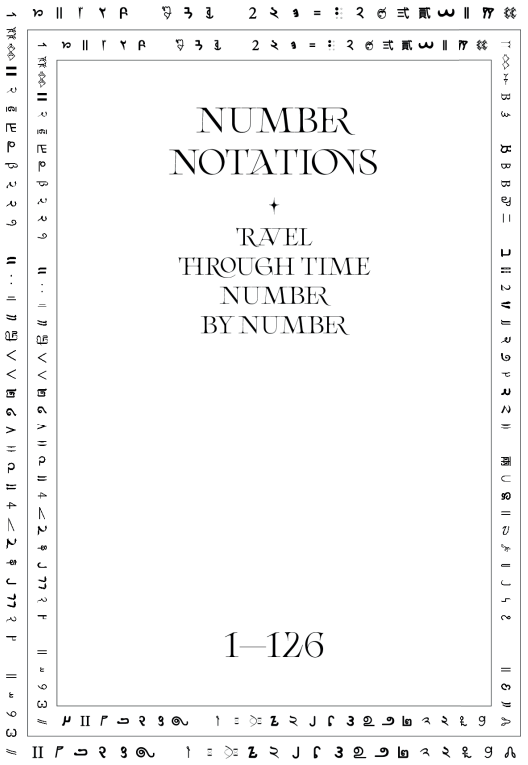
MUSEUM PLANTIN MORETUS, 2020. *ONLINE ARCHIVE*. ANTWERP, BELGIUM. CONSULTED ON 12/07/2020. URL: HTTPS://SEARCH.MUSEUMPLANTINMORETUS.BE/SEARCH/SIMPLE

VANTORRE, MORGANNE. 2020. *ARTHEMYS DISPLAY LIGHT.*

such as the usage of niche terminology on the pages of the individual script. Resulting only in lost time to the reader or researcher using the encyclopedia as they continuously have to go back-and-forth between the glossary and the correct page number. As a solution to this classic use of books holding large archives, symbols were assigned to each counting system. For example, allowing the reader to locate the information quickly through visual recognition. The reader can skim through the data more easily without having to look up every term in the glossary. The overall design of the encyclopedia brings a union to historic data, æsthetic and functional features with a contemporary vision on both its content and design.

The design choices of the archive follow the historic value of the classical encyclopedia, adding a layer of content on the design æsthetic. Similar conventional elements from resource and research manuals such as the way libraries, archives, and research journals' structures are embedded in the encyclopedia's design system.

Examples of these classical elements seen in known research documents are title pages, a glossary declaring the terminology by definition, index, synopsis, and colophon, alphabetically arranged in subcategories depending on geography. These structural and æsthetic elements typically known to be related to archival works are used in the encyclopedia's design and system. The quality of the navigation system's design, however, differentiates itself due to the division of the content into micro and macro layers. The benefit of this layered system is that the book can be used in various ways depending on the researcher or designer's method or research question. The raw data in the encyclopedia can now be expanded on and utilized by designers and researchers in the field of typography and number sense.

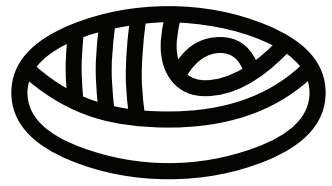


DE FEYTER, ALINE.
2020. *ENCYCLOPEDIA OF NUMBER (NON)SENSE*.
ANTWERP, BELGIUM.
NUMBER NOTATIONS P. 1

This design research project to number sense resulted in a wide variety of existing number notations worldwide and its history both in terms of design and theory. The information made available in the Encyclopedia of Number (non)Sense is easily accessible in comparison to before, having to skim through huge (online) archives to obtain the needed information about numbers and their (design) history. For this reason, the archive created during this research is a valuable research document, holding various layers of in-depth information.Such as the design of numbers, their writing system, ways of physically signing numbers, counting systems, and their cultural origins. Functionally designed for being consulted by academics, (type) designers or readers who take an interest in the developmental (visual) history of numbers and design.

From this point on, the known and unknown can be questioned as insights such as gaps in our current knowledge that appears more clearly. Other facts such as visual or time-based relations between various scripts also emerge thanks to the overview provided in the encyclopedia, which is of historical importance.

For example, the most important influential moment in the history of numbers, that has come forward in the design of the encyclopedia is the invention of the number zero or the concept for the value of nothing. First (visually) introduced by the Mayans of Yucatan (Encyclopedia nr 0, p.11).
The Mayans did not know how to use or apply this concept in calculations yet, but understood the concept and had a specific symbol assigned to it. As the need for more efficient number (notation) systems grew by time and more complex methods in mathematics were required,



DE FEYTER, ALINE.
2020. *ENCYCLOPEDIA OF NUMBER (NON)SENSE*,
NR 0 - HYEROGLYPH,
MAYAN. P.11

caused the symbols assigned to numbers and their writing system to change alike. This kind of historical conclusion can be made from the way the encyclopedia is designed, as some pages and scripts lack the representation of the number zero for example. Containing blank pages in comparison to scripts that do have a representative symbol for the number zero occurring later on in the timeline. Thus the books provide among other data, a source of (visual) information on when certain numbers were introduced and at what point humans found a way to include and use them.

Many numbers may also look similar to each other stylistically or may as well be the exact opposite of each other, this is also a conclusion that can be made thanks to the focus on the visual aspect of numbers in the book design of the encyclopedia. The insights researchers and designers gain from this archive are of significant importance for the further evolution of the design and general approach to numbers and number sense. The content of the encyclopedia that is of interest to (type) designers is the diversity in how the numbers were visualized individually. Being able to look into similarities in various scripts or contradictions in their form leading to sources of cross-cultural inspiration.

4.5 CONCLUSION OF THE ENCYCLOPEDIA OF NUMBER (NON)SENSE

The encyclopedia, both its process and results contributes to a deeper understanding of number sense and the beauty of nonsense.

The knowledge on the design and history of number systems/notations around the world is now collected in a series of books, with easily accessible designed references and navigational systems. The reader or researcher using the encyclopedia is confronted with a mass of structured and well-designed information leading them to question their current view on numerals, their symbolism, (historical) value, design, and the way they are written or used.

The encyclopedia initiates a conversation on reflecting upon how number sense is/has been approached and inspires to question how numbers are/could be dealt with now and in the future. The conversation handled further along in this thesis is the role design takes on in terms of legibility considering the purpose to enhance numerical insight for a focus group of readers with dyscalculia, a lack of numerical insight, or number sense. For example, another perspective on math or numbers is comparing number sense to language. Each notation system in the encyclopedia has its own vocabulary, grammar, and writing system.

In the history of type design and typography, Hindu-Arabic numbers are designed following fixed conventions. With the encyclopedia at hand, the opportunity is created to question these conventions as there are many more ways to depict a number making more sense to the focus group. The conclusions that can be read off the design of the encyclopedia do not only bring a historical value and overview but also serve as an invitation for creative curiosity to numbers and how they make sense. Overall the encyclopedia including this thesis opens up a conversation, crossing the borders of various scientific and design fields of expertise on a global scale.

0 1 2 3 4
5 6 7 8 9

COWLES MICHAEL. 2005. *STATISTICS IN PSYCHOLOGY: AN HISTORICAL PERSPECTIVE*. U.K.: PSYCHOLOGY PRESS.

DE FEYTER, ALINE. 2020. *ENCYCLOPEDIA OF NUMBER (NON)SENSE*. ANTWERP, BELGIUM. HINDU-ARABIC P. 68

5

TYPOGRAPHICAL EXPERIMENTS WITH TE DESIGN OF NUMBERS

ŒCONSIDERING ©NVENTIONS IN TYPE DESIGN

INTRODUCTION 5.1

The following hypotheses or typographical experiments have their roots in the encyclopedia as a source of inspiration for innovation, questioning the current design of Hindu-Arabic numbers. During its process of creation, the research question developed into *how could the current Hindu-Arabic numbers be redesigned, breaking with design conventions?* With this question and the reading issues of dyscalculics in mind, based partially on my personal experiences and off previously conducted interviews in the book *Dyscalculie ontcijferd* (Dyscalculia deciphered, p. 199 – 227. De Feyter 2019). The following type designs and experiments for the hypotheses are also inspired by scientific articles, such as ongoing reading research and research to number sense from various fields of expertise. In various ways, those scientific theories, research results, and perspectives are applied to the (type) design practice. As was taught by READSEARCH hosted by Ann Bessemans and María Pérez Mena, who have inspired me on several levels. First of all, the way Maria and Ann taught me about design thinking and how such a design process can play a main role in design outcomes. Second, Ph.D. students Walda Verbænen & Janneke Janssens. Walda because of her persistence in designing new, yet familiar letters, to assist in learning the Dutch phonology. Janneke because of her innovation and research in hierarchical systems in book design.

The hypotheses are design solutions for a selection of reading difficulties with numbers, specified for a group of readers struggling with number sense in an educational context and daily life.

Covering the following topics: the enhancement of differentiation between reading numbers, alternative type designs were made such as Opticus, Opticus Italic, and strategically colored numbers. Aside from aiding differentiation of individual numbers affecting their legibility, these designs are made to lower reading mistakes. Such as reversion in reading or incorrect number identification, for these specific issues, ligatures for large number strings were designed. Aspiring to increase insight in numerical values while reading, a design experiment with the positional relation to values (place-value system) based on reading and writing habits took place.

5.2 THE INFLUENCE OF TYPE DESIGN ON READING, WRITING & DEALING WITH NUMBERS

✦

With the overall history and current knowledge of numbers in hands, it is now possible to reconsider and rethink the way numbers are or have been designed.

The current conventional elements to designing (Hindu-Arabic) numbers inside typefaces are the variables: tabular, proportional medieval, and monospaced medieval numbers. The difference between those design variables is the spacing and positioning, being determined by the way they are meant to be used by graphic designers.

The spacing of tabular numbers is similar to a monospaced typeface, with even spacing making the numbers equal in width and neatly aligned at all times. Tabular numbers are meant to be used in calculations, formulas, or graphs. Proportional medieval numbers, on the contrary, are meant to be used in reading texts and are often seen in page numbers of reading books as well. In this case, the numbers are designed as if they are letters, respecting their spacing considering ascenders and descenders of numbers such as 9 or 6 spaced like the letters q or b. As a means to not disrupt the reading rhythm in sentences or longer texts, in contradiction to tabular numbers. The third variable being the monospaced medieval numbers are a hybrid between the tabular and proportional numbers. Their width is equal as is the case with tabular numbers but their rhythm (on the baseline) is similar to the proportional medieval numbers.

The reason why the conventional designed Hindu-Arabic numbers should be revised is that it may hold the possibility to be more beneficial for readers lacking number sense. Improving both the readability and legibility of numbers, perhaps changing the view on how numbers could be approached (in an educational context). Changing the appearance of numbers, their positioning in a page, or color could aid dyscalculics more to differentiate and identify numbers more easily. Allowing more room in their working memory to focus on a problem-solving attitude or method towards a task rather than focusing on making sure they are not confusing, reversing, or imagining any wrongly interpreted numbers.

One of the difficulties caused by the learning disability dyscalculia and children engaging numbers for the first time during their education around the age of 4 – 5 years old is not being able to apply lateralization correctly.

POHLEN, JOEP. 2010. *LETTERFONTIJN. OVER DRUKLETTERS*. (4TH EDITION). NETHERLANDS, ROERMOND: UITGEVERIJ FONTANA. P.121

Resulting in reversing numbers and as a consequence, not knowing what number is exposed or visualized right away impacting the capacity of the working memory. ⁝

Learning to identify the correct number and assigning the correct value to its symbol is, of course, possible but the learning curve is much slower for dyscalculics in opposition to children without the learning disability. In later stages of education age 11 – 12 years old, the child having difficulties with number sense at the age of 4 – 5 years old may cause a backlog on their basic arithmetic skills from 2 up until 4 years. If number sense could be supported by means of rethinking the way numbers are designed or approached through design, it would offer aid where needed.

The reversing of the numbers 45 to 54 for example, happens partially due to a lack of number sense but can happen to those with and without learning disabilities. Experimenting with legibility and type design can result in a solution to help prevent such confusion.

According to Professor Hans Van Luit, a Dutch specialist in remedial teaching (field of orthopedagogy) at the University of Utrecht (Netherlands), dyscalculics have more persistent difficulties with *mapping* for example∴ In other words: making the connection between six physical objects – such as cubes that are often used in math classes to represent a certain value – and the symbol of the number 6. Prof. Hans Van Luit states that an important step that should be made before introducing the abstract symbol 6 (six), tally marks should be used (Dit is Dyscalculie, 2018).

⁝ VAN LUIT, HANS. 2018. DIT IS DYSCALCULIE, ACHTERGROND EN AANPAK. BELGIUM, LEUVEN: LANNOO CAMPUS

∴ VAN LUIT, HANS. 2018. *DIT IS DYSCALCULIE, ACHTERGROND EN AANPAK*. BELGIUM, LEUVEN: LANNOO CAMPUS. P. 107

Tally marks are used to introduce counting - one by one and in pairs– similar to how we count on our fingers. A tally is a notation being a dot or 'I' mark, symbolizing the value of one. When grouped by five, the fifth tally mark draws diagonally through the four other marks placed vertically in opposition to each other. This is one way of using a tally system, other positions of marks could be used such as the known systems gathered in the encyclopedia such as the Sumerian script (p.4), Cuneiform variants (p. 5 – 10, 13), Mayan Hieroglyph (p. 11), Linear A or B (p. 12, 16), Hieratic (p.14), Cypro-Minoan (p.15) and others. The essence is that by placing one tally differently the whole image it creates can be seen as a different value, increasing or decreasing. Making it easier to count, instead of having to count each tally individually over and over. After introducing a tally system to children either by counting on their hands, by marking tally's or using an abacus they would learn to recognize a group of six dots as the value of the concept 'six'. The next step would be to bring the taught concept or the amount of tally's representing 'six' into relation with the assigned symbol of the script.

About that last step in this learning curve: the issue and backlog with mapping cause dyscalculics or children with weak mathematical performative skills to not see the relation between the concept of the value 'six' and the value expressed in tally's (IIIIII) to the symbol 6. In their eyes, these relations make no sense as if attempting to decipher the previously mentioned *Codex Seraphinianus* (Serafini, 2013) ⁝ a clear sign of the lack of understanding numerical values can be seen in the amount of struggle when asked to sort numbers on a number line, arranged from smallest to largest or vice versa. The order or structure dœs not make any sense to these children (or adults), causing them to guess where the numbers should be placed.

Each educational system has a particular perspective, method, and philosophy on how these learning difficulties should be approached. In the classical education system, there is an overall dire need of abstractness in relation to number sense. Introducing the concept of numbers more abstractly could be done by applying design thinking in education, providing both teacher and pupil with alternative learning and thinking strategies. For example with the existing FUTE method ∴ Similar to the product design master classes of Cas Holman: asking design students not to design a new mug, but instead give them the task to design a way to transport liquid.∴ Number sense could be approached differently as well, of course not by changing the current teaching methodologies but by bringing design thinking and solutions into the classroom. For example, through type design and how reading, writing, and working with numbers could be made easier to approach for children and adults alike (with dyscalculia or a lack of number sense) learning the Hindu-Arabic numbers.

Next to the most common, classical education system, there are a few alternative teaching techniques and systems such as the Steiner school or the Freinet school ∴ among others, providing a more creative, open-minded, and hands-on approach to theoretical learning material. Such as the introduction of writing and reading numbers, the Steiner school approaches number sense by linking numerical values to body parts and rhythm. For example: counting on a certain beat assisted by music, allowing children to count on their fingers during calculations. Embodying all calculations and measurements to provide deeper insight and understanding. Embodying means learning through physical references, f.e. using the body as a measuring tool to compare distances and dimensions.

∴ *DE FUTURE TEACHING (FUTE) METHOD*. 2020. A PROJECT IN COLLAB WITH UNIVERSITIES FROM NORTH- AND WEST-EUROPE, FUNDED BY THE ERASMUS+ PROGRAM.

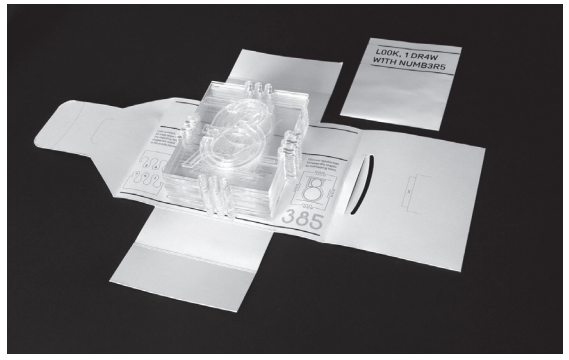
∴ CAS HOLMAN ON NETFLIX. *ABSTRACT, DESIGN FOR PLAY*. CONSULTED ON 20/09/2019.

∴ DE STELTLOPER. *FREINETSCHOOL, EEN OVERZICHT VAN VLAAMSE FREINETSCHOLEN*. CONSULTED ON 31/05/2020. URL: HTTPS://WWW.FREINETSCHOOL.BE/WIE_IS_FRIENET_EN%20WAARVOOR_STAAT_HIJ/S/6/

Another way of embodying abstract learning material by using physical references when the topic of square meters is handled in class, for example, a workshop would be held to build a life-size square meter with the children to gain a deeper level of insight in 3-dimensional space and wrap their head around the abstract meaning of a square meter. ∴

FROM IDEA TO DESIGN 5.3

The writing tool previously mentioned in the general introduction, a still ongoing research project to mirrored and reversed writing of numbers – a prototype was made ∴ – is specifically designed to aid with the familiarization of the Hindu-Arabic number shapes. It is an example of how type design could be brought into an educational context, providing both (remedial) teachers and children with a new approach to numbers in contradiction to the classical writing booklets.



∴

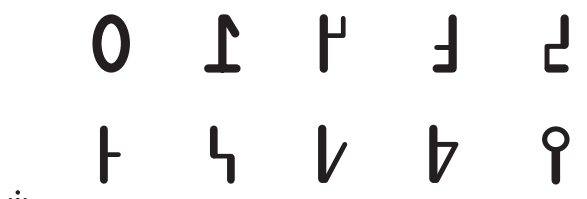
The writing tool is intended for children to learn about the proportions of numbers, the writing movement, and build a correct sense of directionality, learning through puzzling and comparing number shapes. Developed for children aged 5 – 8 years old, consistently struggling with the reversing of numbers in writing. By letting children use the writing tool freely without any instructions, they can gradually learn from their own mistakes considering mirrored or reversed writing. During this period of research into reversed and mirrored writing of numbers, the research in other regions in the world has not been able to be proved or disproved any growth in this educational aspect.

∴ FEDERATIE VAN RUDOLF STEINERSCHOLEN IN VLAANDEREN. 1998. *LEERPLAN WISKUNDE, SECUNDAIR ONDERWIJS – 1STE GRAAD – A-STROOM*. GENT: EUROPEAN COUNCIL OF R. STEINER-WALDORF SCHOOLS.

∴ DE FEYTER, ALINE. 2019-2020. *PROTO TYPE OF THE WRITING TOOL*. ANTWERP, BELGIUM. URL: HTTPS://ALINEDEFEYTER.COM/HOME/WRITING-TOOL

Within this study there is currently a lack of research on this particular topic, leaving room for the improvement of strategies for educational purposes.

While looking into both the notational system and the design of numbers during the progress of archiving the information in the Encyclopedia of Number (non)Sense, questions considering their symbolism and origin arose. This way of thinking set the course of reading among others Adrian Frutiger's iconic book: *Signs and Symbols, Their Design and Meaning* (1989). Questions such as: *what is the vocabulary of numbers? How are they categorized? How could number sense be tackled starting with our current (historical) knowledge?* Inspired to experiment with writing systems and research the decimal place-value system used when counting Hindu-Arabic numbers. This way of thinking resulted in various typographical experiments, as a response to the design opportunities ideas emerged to how number sense could be handled design-wise. These reconsiderations of type design have not been made randomly, every experiment focuses on a specific reading issue related to number sense. In the following chapters each hypothesis, its typographical experimentation, scientific base, and methodology will be explained.



5.3.1 OPTICUS

The contrast that is present in the numbers from the N'Ko script (Encyclopedia, p.119) especially the numbers 2 to 9, inspired me to experiment with the balance of number shapes. Just like the Hindu-Arabic numbers, N'Ko is based on a dec-imal counting system and alphabetic writing system. [1]

[1] DE FEYTER, ALINE. 2020. *ENCYCLOPEDIA OF NUMBER (NON) SENSE*. ANTWERP, BELGIUM. N'KO P. 119

Its origins are from Africa and the script was created by Soloman Kante around 1949 to write the Bambara language spoken in Mali. [1] The visual contrast in N'Ko numbers is present in its design due to its origin of writing with a broad nibbed writing tool.

Before the 18th century, the writing tool would determine the design of the let-ters and numbers in the history of Western typography, later on, typefaces would be made into wood or lead for printing multiples instead of having to write each page as was a custom for bibles and manuscripts for example. The period of industrialization past the 19th century led to the invention of the com-puter and digitized fonts emerged, this is how typography is currently designed. Through the history of type design within the Latin Alphabet and Hindu-Arabic Numerals, thick-thin contrasted type is classified as Realen and Mechanen (Pohlen, Letterfontijn over drukletters). This kind of contrasted typefaces ought several reasons for design such as the æsthetic value that is embedded in the history of typography determined by the initial broad nibbed writing tool, or technical reasons to spare ink during the printing process. [2] In this experiment, however, the reason for using thick-thin contrast in the design of numbers lies elsewhere.

The designed numerical set called Opticus is a typographical experiment based on Adrian Frutiger's [3] and Rudolf Arnheim's statements on balance in design and shapes. When we speak of general balance in design, it means that all the shapes are equal to each other in means of spacing and directionality. In physicist terms: the forces between multiple shapes must be equal to be in balance. Balance can be mathematically measured, but there is always a need for optical changes to be determined by the eye's intuitive sense. For example, Greek columns in temples are not straight pillars.

[1] HOLLOWAY, STEPH. SCRIPTSOURCE STAFF. 2020. *N'KO*. CONSULTED ON 03/04/2020. URL: HTTPS://SCRIPTSOURCE.ORG/SCR/NKOO

[2] POHLEN, JOEP. 2010. LETTERFONTIJN. *OVER DRUKLETTERS*. (4TH EDITION). NETHERLANDS, ROERMOND: UITGEVERIJ FONTANA. CLASSIFICATION SYSTEM FROM MAXIMILIEN VOX 1954. P. 56

[3] FRUTIGER, ADRIAN. 1989. *SIGNS AND SYMBOLS. THEIR DESIGN AND MEANING*. NEW YORK, VAN NOSTRAND: REINHOLD PUBLISHERS.

If the stem of the pillars would be per-fectly straight, the columns would appear very narrow due to the frog perspec-tive of where people stand. Instead, the columns are optically enlarged in their middle section or given a 'tummy' as to achieve optimal balance in the architec-ture. Making it appear perfect-ly straight columns, this same technique of mak-ing optical corrections is often applied in type design as well.

0 1 2 3 4
5 6 7 8 9

Our eyes love symmetry and balance, f.e. linear typefaces such as Verdana are typefaces without heavy contrasting in comparison to Didone typefaces such as Bodoni, both typefaces are in balance. When a shape is off-balance as visually demonstrated by the circle in the square, it attracts the eye to the so-called error or disruption in the symmetry.

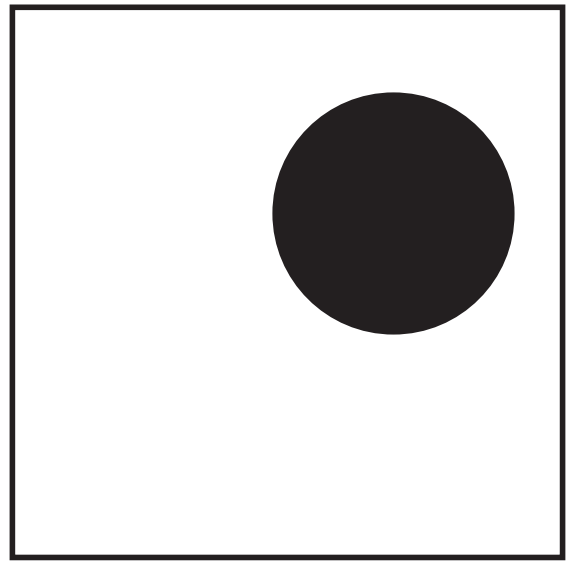
0 1 2 3 4
5 6 7 8 9

But how dœs one know it is off-balance, without actually measuring the space around the circle in comparison to the square? According to Rudolf Arnheim in Art and Visual Perception, A Psychology of the Creative Eye (1974) our visual experience is dynamic, this means that the black circle gives us a sense of directionality and movement inside the white square due to its position.

DE FEYTER, ALINE. 2020. *OPTICUS REGULAR.*

The circle seems to be moving towards the corner of the square as the space around it is smaller in that specific area. This is the information the reader or perceiver gets intuitively, from glancing at the figure for an instance.

In the design of the numeral set Opticus, this off-balanced distraction (a thorn in the eye) is used as an advantage. Disrupting the balance in the usually optical-ly perfected typeface could draw more attention to crucial characteristics of the number shape. Aiming to enhance the recognition of numbers and their legibility at first glance. Most importantly, the numbers will be more distinctive in op-position to each other. For example, the numbers six and nine will not be as eas-ily confused or reversed while reading as they won't be each other's exact reflection in the design.
If the six would be rotated to form the number nine, the number would look completely different from the six as the characteristic ar-eas would have been differentiated. Each numeral will express their own unique features of importance for their legibility. The question is, how extreme should these features be stressed? If the difference in the shape is too extreme, the read-ability would decrease in (smaller) print. But if the contrast is not strong enough, the features wouldn't be noticed.



96

The goal of this experiment is to reach a certain balance between the differentiating details in the numerals while maintaining the ability to read fluently without disrupting the reading rhythm and bringing balance to an imbalanced typeset. The high-contrasted features in the design of Opticus are based on the data collected from the cognitive neuropsychological research to Spatio-temporal dy-namics of visual letter recognition (Fiset et Al. 2009).

POHLEN, JOEP. 2010. *LETTERFONTIJN. OVER DRUKLETTERS.* (4TH EDITION). NETHERLANDS, ROERMOND: UITGEVERIJ FONTANA. CLASSIFICATION SYSTEM FROM MAXIMILIEN VOX 1954. P. 56

ARNHEIM, RUDOLF. 1974. *ART AND VISUAL PER-CEPTION, A PSYCHOLOGY OF THE CREATIVE EYE.* ENGLAND, LONDON: UNIVERSITY OF CALIFORNIA PRESS. P. 19

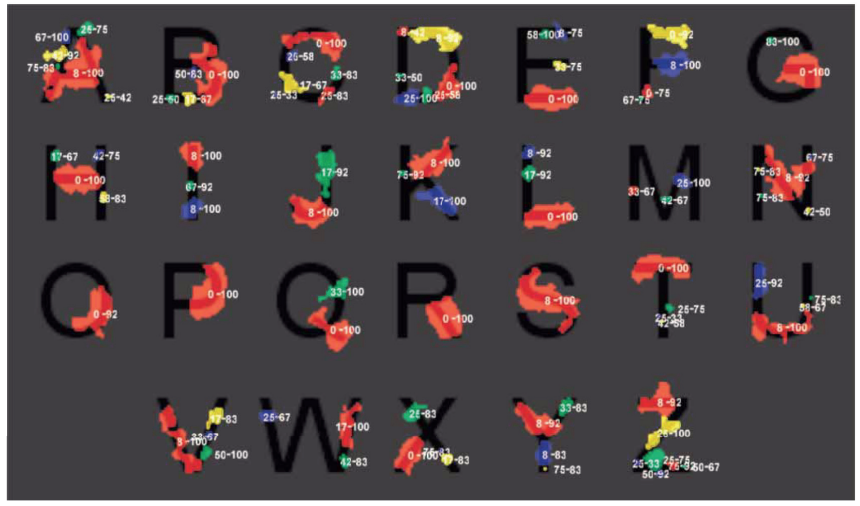


Figure 2. *Colours show space–time clusters (collapsed on the time dimension) significantly correlated with correct letter identification ($p \leq .001$) superimposed upon the appropriate letter. Four colours were used to help cluster segregation. The numbers in white near each cluster indicate the beginning and end of this cluster relative to stimulus onset.*

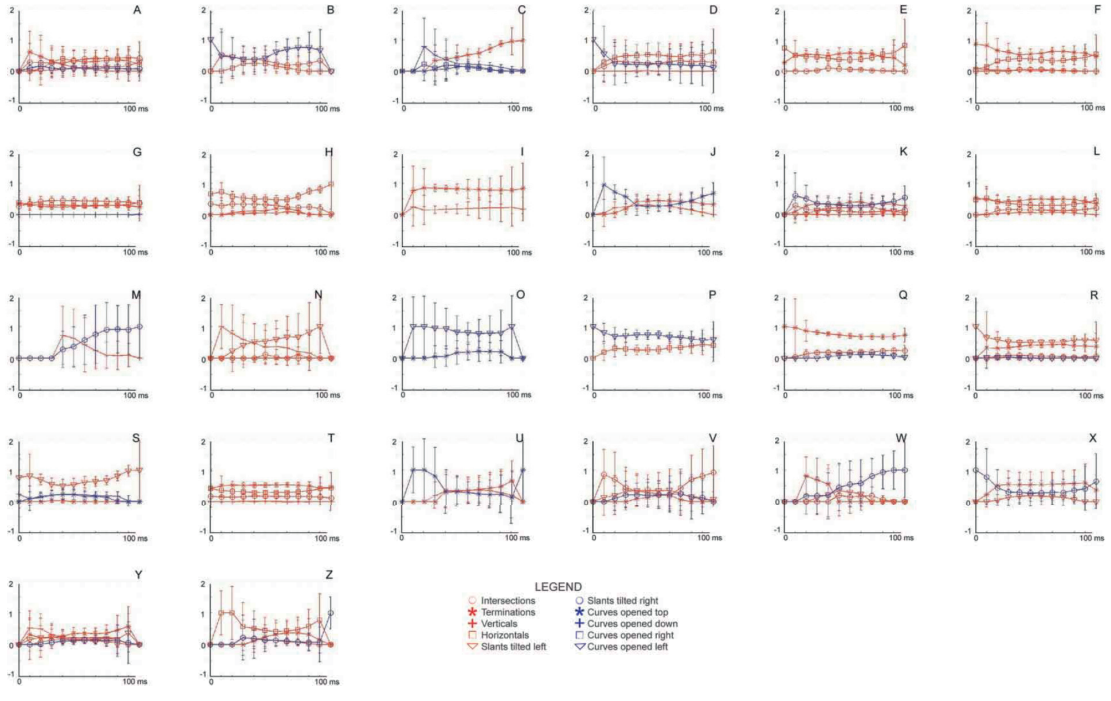


Figure 4. *Results of the a priori feature analysis performed on each letter and each frame. Each graph shows the relative importance of the features comprised in each letter of the alphabet. Note that if no significant pixel fell on one of the feature comprised in a letter (e.g., no significant pixel fell on the vertical bar in letter "B"), there is no curve corresponding to this feature in the graph. Error bars indicate 95% confidence intervals.*

The resulting charts from this research shows the most crucial features of recognizing letters of the Latin script. This data however excluded Hindu-Arabic numbers thus I com-pared the uppercase Latin script and numbers of the same linear typeface (Arial) used in the testing material. Numbers share visual features with some of the capital letters so the data was very compatible. The extracted data from the comparisons could then be used to form the base of the designed typeset Opticus.

Numerals: Arial, red areas of the numbers are crucial for recognition.

1	*1 comp. to I* terminations, verticals	5	*5 comp. to G* intersections, horizontals
247	*247 comp. to Z* slants tilted R, horizontals	69	*69 comp. to S* slants tilted L, terminations, curves opened top
358	*358 comp. to 8* curves opened L, horizontals	9	*9 comp. to P* curves opened L, horizontals
4	*4 comp. to H* intersections, horizontals	0	*0 comp. to O* curves opened top, curves opened L.

OPTICUS ITALIC 5.3.1.1

In this experiment, the numbers of Opticus are slanted or italicized with the purpose to prevent the reversing of numbers (in-text use) and provide the reader with a better sense of value and direction. Opticus could help with the identification of reading singular numbers, however in case of reading larger numbers starting from two digits, Opticus Italic might offer more reading support. Benefitting both the reader's numerical insight and guiding the reader's eye along the number string due to its design. According to Rudolf Arnheim reading slanted or italicized text (or in this case numbers) gives the reader more sense of direction. As the reading direction is related to the angle of the italicized type design, being left to right in this experiment.

As Rudolf Arnheim states, directionality and balance in a shape are determined by three factors: being the starting point, the strength, and the outgoing point of the shape. The direction of visual forces is determined by the attraction of neighboring elements.

FISET, DANIEL & BLAIS, CAROLINE & ARGUIN, MARTIN & TADROS, KARINE & ETHIER-MAJCHER, CATHERINE & BUB, DANIEL & GOSSELIN, FRÉDÉRIC. (2008). *THE SPATIOTEMPORAL DYNAMICS OF VISUAL LETTER RECOGNITION.* COGNITIVE NEUROPSYCHOLOGY. 26. 23-35.

Such as the negative (invisible or white) space around letterforms and the space between letters or numbers surrounding each other, as is the case in every text. . When we manipulate the rhythm of these letterforms surrounding each other by using italic for example instead of a regular angled typeface the structure of the text will shift and the attention will be drawn to the italic instead..

A generally used angle for an italic to atone the most comfortable degree for reading would lie between 6 – 12 degrees according to Glyphs app website. Instead of complying with this convention, the italicized version of Opticus is determined to follow suit with the place-value system in the decimal (base 10) counting and writing system. In other words, the angle of Opticus Italic increases or decreases gradually along the number string as a sequel according to its value . The sharper the angle, the bigger the value and eventually the regular designed number would be the smallest or vice versa. The visual movement the angles create in larger number strings could aid reading numbers more fluently and provide a deeper sense of the estimated value, hence increasing the reader's number sense and numerical insight.

Numerals: Opticus, Regular

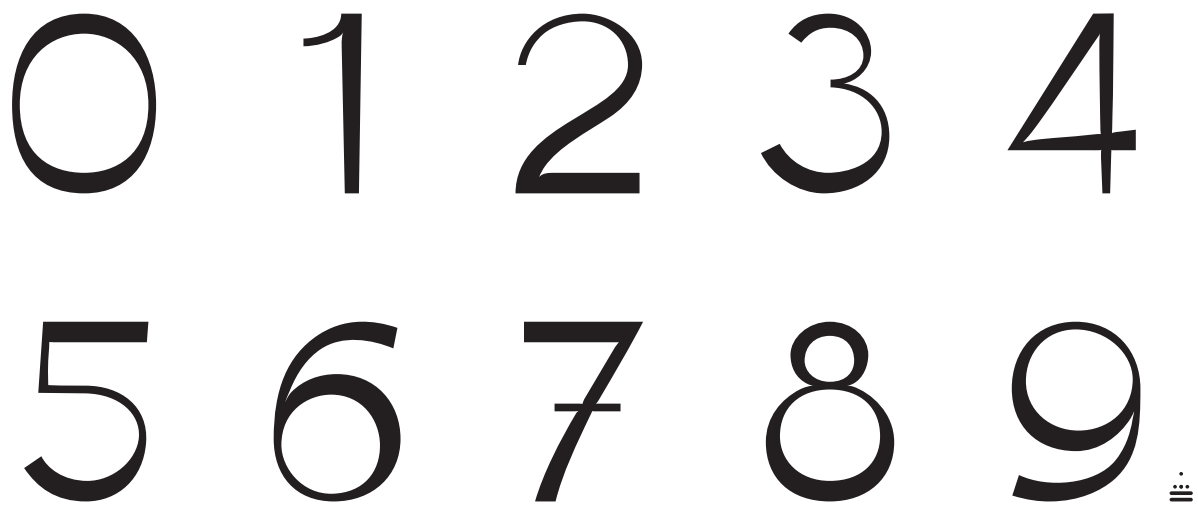
1 2 3 4 5 6 7 8 9

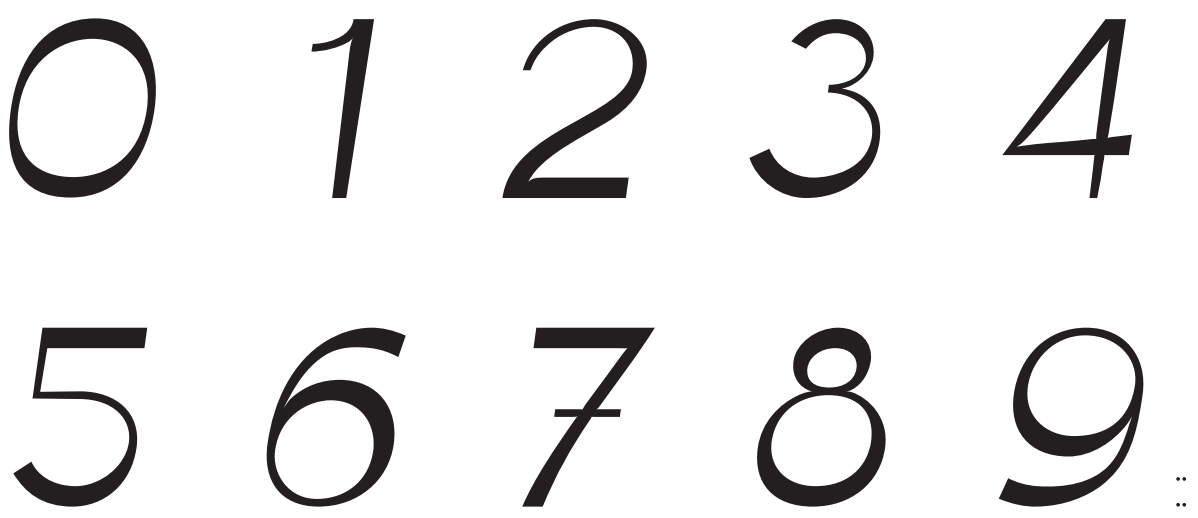
Numerals: Opticus, Italic
Gradually slanted with the reading direction.

1 2 3 4 5 6 7 8 9

. ARNHEIM, RUDOLF. 1974. *ART AND VISUAL PERCEPTION, A PSYCHOLOGY OF THE CREATIVE EYE*. ENGLAND, LONDON: UNIVERSITY OF CALIFORNIA PRESS. P.26

.. FRUTIGER, ADRIAN. 1989. *SIGNS AND SYMBOLS. THEIR DESIGN AND MEANING*. NEW YORK, VAN NOSTRAND: REINHOLD PUBLISHERS. P.178, 179





0 1 2 3 4 5 6 7 8 9

0° angle *Opticus, Regular*

0 1 2 3 4 5 6 7 8 9

1° angle

0 1 2 3 4 5 6 7 8 9

2° angle

0 1 2 3 4 5 6 7 8 9

3° angle

0 1 2 3 4 5 6 7 8 9

4° angle

0 1 2 3 4 5 6 7 8 9

5° angle

0 1 2 3 4 5 6 7 8 9

6° angle

0 1 2 3 4 5 6 7 8 9

7° angle

0 1 2 3 4 5 6 7 8 9

8° angle *Opticus, Italic*

5.3.2 COLOR & NUMBER IDENTIFICATION

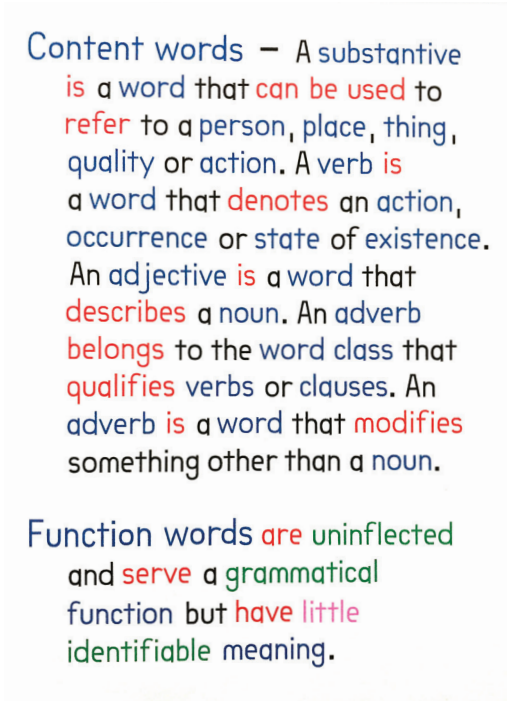
The idea to use color and bring it into relation with number identification crossed my mind due to insights gained from fascinating articles, relevant to the research topic of redesigning Hindu-Arabic numbers to enhance number sense. The typographic experiment takes upon a different pathway in comparison to the other experiments, that have clear roots in the encyclopedia. Nonetheless, this experiment is part of the creative process and opens up to the idea of using colored type designs instead of the conventionally designed black typography.

Typefaces are usually designed in black and white, this is a global convention that allows the design of both the positive and negative shapes during its process of creation. Black typography allows the type designs to be judged based on its shape instead of its color and is considered 'neutral' as the color might affect the judgment on the shape during the design process. Although smart and strategic use of color applied to typography has proven to be beneficial for understanding the reading material more in-depth and enhancing the reading comfort. Based on the fact that color aids with reading text, why could it not benefit reading numbers or form a bridge between its symbol and value?

In a project by Salome Schmuki – a book design for a school – the color is strategically used in the text, functioning as a reading guide. One of the interviews in Salome Schmuki's book Dyslexia — chunking along a straight line — at the crossing turn left (2012) resulted in the knowledge that the usage of color was found beneficial by (dyslectic) readers....
Certain aspects of the syntax in sentences were highlighted in a different color than the rest of the text (green, red, and black) adding more structure, and allowing a deeper understanding of the reading material within the reader.

Based on this knowledge, colors could be used as a reading guide for numbers similar to how newspapers or articles are structured by using different sizes and weights in the text. Guiding the reader's eye through every aspect of the article is a systematic and structured way while reading. By using color as a reading guide instead of a typeface's weights, numbers in the text or larger formulas in advanced mathematics could be highlighted in different colors.

Instead of using color in the typography itself as in Salome Schmuki's method, a colored overlay on top of the complete reading material could also be a promising solution. Previous reading research to the usage of color in relation to the Scotopic Sensitivity Syndrome (also known as the Irlen Syndrome) by Sandra Irlen (founder of the Irlen Institute at the University of California Los Angeles, USA) proves this benefit. An aiding method for reading was developed by using color, resulting in a custom set of tinted glasses improving the test subject's reading level and comfort. [3] Later on, Arnold Wilkins developed a device to optimize the workflow of this research, called the Colorimeter. The exact tint of the glasses used to be determined per individual test subject that proved to be time-consuming, the Colorimeter, however, sped up this process. [4] The tinted glasses that were made based on the data from the Colorimeter, were tested on a longer-term by readers and are statistically more reliable.



[1] SCHMUKI, SALOME. 2012. *DYSLEXIA — CHUNKING ALONG A STRAIGHT LINE — AT THE CROSSING TURN LEFT.* NETHERLANDS, MAASTRICHT: JAN VAN EYCK ACADEMIE. S11, 223.

[2] NOBLE, J., ORTON, M., IRLEN, S., ROBINSON, G. 2004. *A CONTROLLED FIELD STUDY OF THE USE OF COLORED OVERLAYS ON READING ACHIEVEMENT.* AUSTRALIAN JOURNAL OF LEARNING DISABILITIES 9, 14–22.

[3] WILKINS, ARNOLD. 1996. *HELPING READING WITH COLOR.* DYSLEXIA REVIEW. CAMBRIDGE UNIVERSITY. P.5

Resulting in aiding with migraines and an increment was noticed in reading comfort and speed or fluency, especially in the case of reading small and dense texts. One test subject using the glasses stated that a particular hue of yellow prevented illusionary distortions such as reading was as saw, the reader was not aware of this mistake. Based on this statement, tinted overlays could be applied on top of reading material in their design or a yellow-tinted paper could be used instead of a harsh white. Perhaps this particular hue of yellow could minimize reversals or other unconscious reading mistakes.

Inspired by Salome Schmuki's strategic use of color and the practical approach to theoretical material in alternative teaching methods such as the Steiner school, the idea occurred to bring number sense in relation to color as a bridge to understanding its value. The question occurs if color (coded) numbers could aid with their identification, or broaden the approach on number sense gaining a deeper level of numerical insight.

One approach could be by assigning a primary color to a number according to their value, equations could be materialized in a practical way aside from counting on your fingers or the use of a physical relation as seen in traditional educational methods. For example, one (yellow) added with two (blue) equals three (green) as proposed in fig. 15. Primary colors are taught during kindergarten and could form a logical system for children as they learn the results of mixing colors through a painting before they are introduced to numbers. Bringing mathematics or numerical values in relation to the basic color theory that is already known at that point in their development, this could make more sense (especially for visual and contextual learners) with a lack of number sense.

If else the concept of adding and subtracting values could be explained in practice purely through color. In other words, the link between color mixing and defining the value of a number could help as children would be able to use their current knowledge on colors to ease the transition to new abstract concepts.

Another strategic use of color to enhance numerical insight is using color to highlight pairs. Children lacking number sense can't make any sense from recognizing a certain value when counting in pairs. Amounts greater than four are harder to recognize, with a lack of number sense it is even harder as counting in pairs is not fully automated in the brain.

For example with the tally mark system, dyscalculics often count one-by-one instead of in pairs. Exercise 14 from the book *Dyscalculie ontcijferd* (Dyscalculia deciphered, p.140 – 141) illustrates this problem more clearly. The subject is asked to count all the cubes in the figure (including the ones hidden from sight). ⁘ The first subject's method is visible, the subject is 10 years old without any lack of number sense, dyscalculia, or other learning difficulties. The subject in illustration a. has counted in pairs and used multiplications to come to the correct answer. In ⁙ the method of the subject is less strategic, this subject is also 10 years old but is confirmed with the learning disability dyscalculia causing a lack of number sense. The subject's method to solve the exercise is to count every cube one-by-one, illustrating the inability of applying a fitting problem-solving method and proving the inability of counting in pairs.

Applying the mixing of colors to basic mathematics could offer a secondary solution to understand the concept of adding and subtracting values. Or offer more insight into the apprehension of values depicted in a certain amount of tally marks or cubes.

Exercise

14

How many cubes do these figures count?

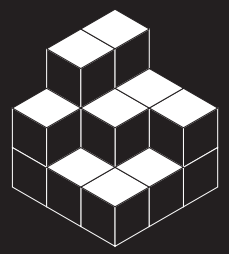


fig. 1

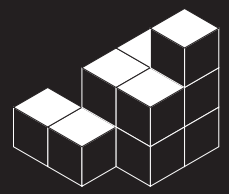


fig. 2

fig. 3

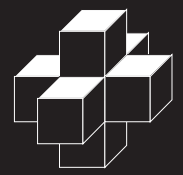


fig. 4

fig. 5

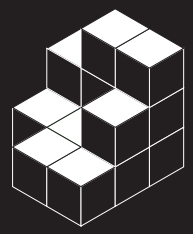


fig. 6

fig. 7

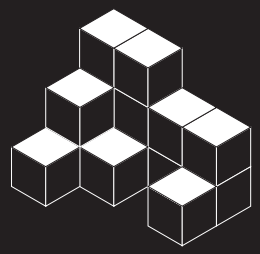


fig. 8

Method

14

Method of test subject (10 y/o) without learning disability or lack of number sense.

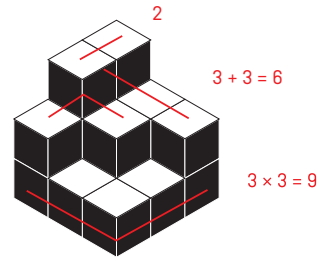


fig. 1

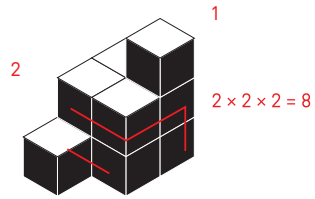


fig. 2

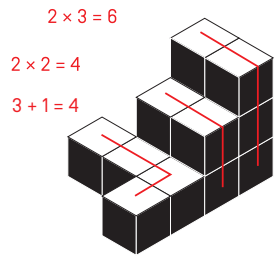


fig. 3

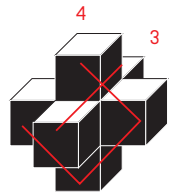


fig. 4

Method of test subject (10 y/o) with the learning disability dyscalculia.

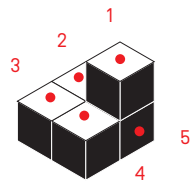


fig. 5

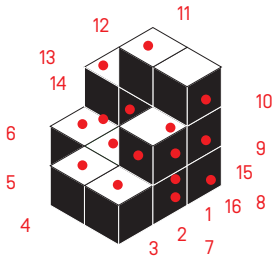


fig. 6

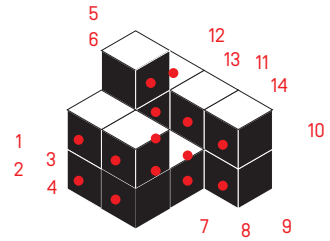


fig. 7

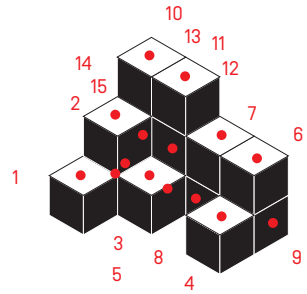
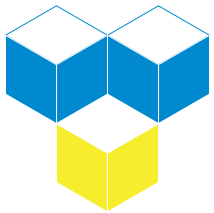


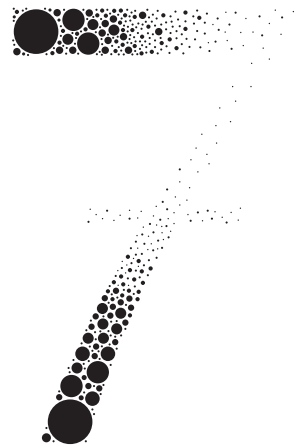
fig. 8



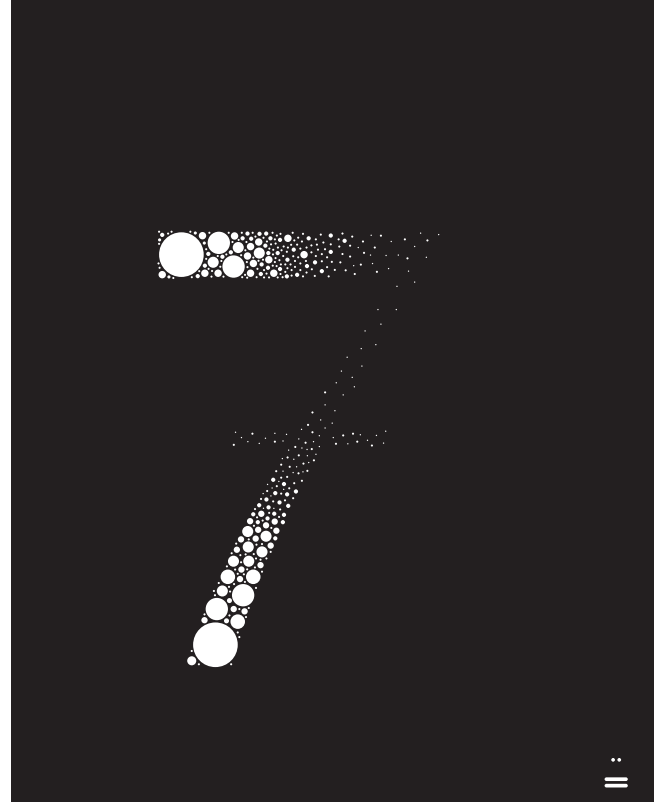
1 Would be yellow, 2 would be blue, instead of counting in pairs, you'd see a group of colors identifying with an amount or represented number. For example, two blue cubes and one yellow cube would mean three cubes in total. However, after attempting to match a functioning color system to numerical values, I concluded that such a system would contain too much information to process for children to learn. From the moment you want to work with larger numbers above ten, it would become too complex as the color-system is another systematic layer on top of the number system.

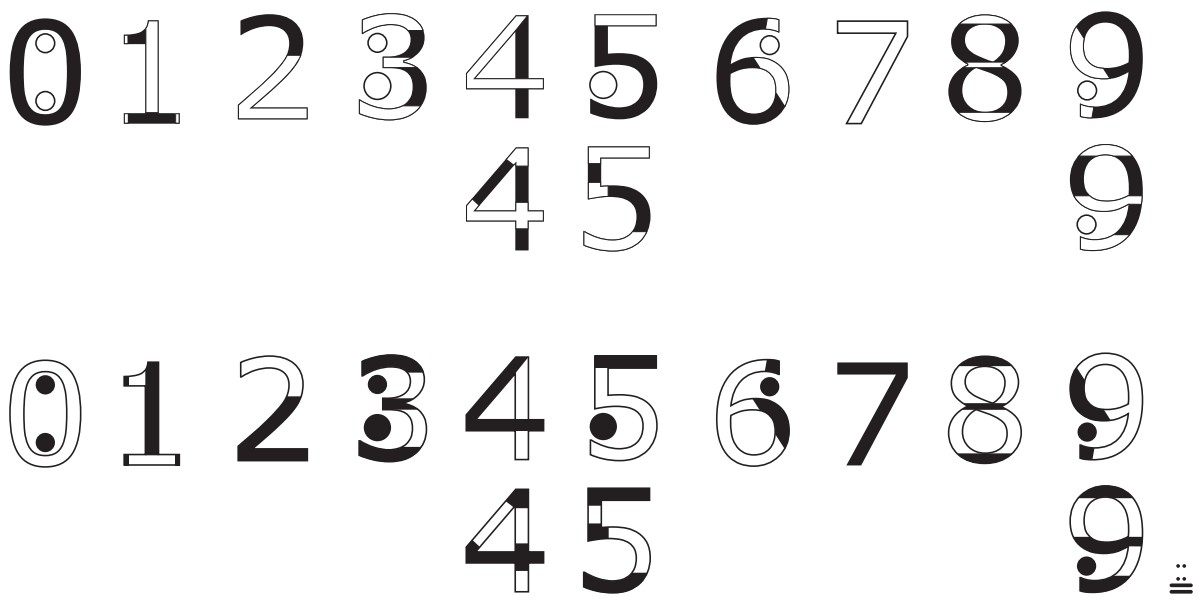
All together this design proposition would contain too much information to process for the reader, resulting in the same problem as occurs with the study cards provided by (remedial) teachers for dyscalculics. Instead, colors could be used in a similar way to draw attention to certain features in the numbers as is the case with the imbalanced design of Opticus. The usage of color could serve to attract attention when reading numbers. Based on the same principles as the design of Opticus and design theory on balance from Rudolf Arnheim. In this case, the off-balanced features extracted from Fiset et. al (2009) are accentuated with color instead of being applied as an alteration to the shape of the numbers. Color could attract attention to certain features in the numbers making them more distinctive compared to each other, preventing mistakes in identifying numbers and their legibility considering the most common mistake of reversing numbers during reading. This hypothesis is applied on the typeface Verdana, due to its common use in tests and tasks (for practical reasons) made by teachers and thus determining the reading material of children aged 4 – 5 years old in education.

ARNHEIM, RUDOLF. 1974. *ART AND VISUAL PERCEPTION, A PSYCHOLOGY OF THE CREATIVE EYE*. ENGLAND, LONDON: UNIVERSITY OF CALIFORNIA PRESS.



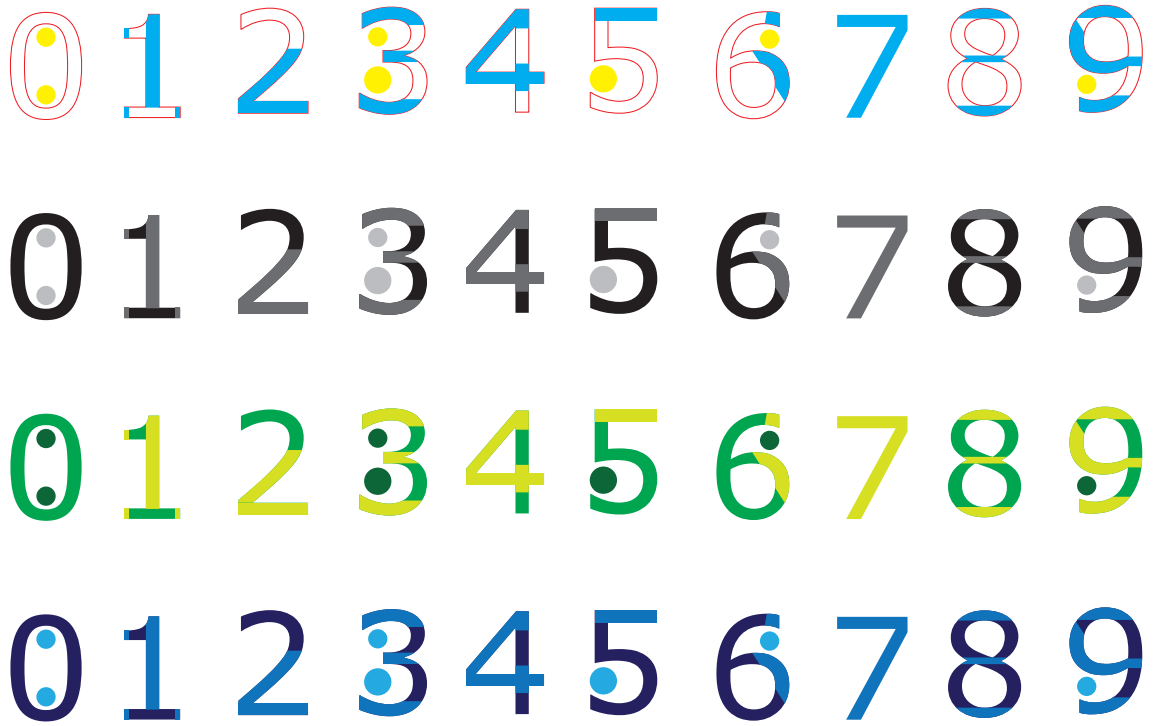
Opticus Regular filled with gradual dots, positioned according to Fiset et. al (2009) research results.





Verdana with a graphic application, positioned according to Fiset et. al (2009) research results.

Opticus Regular filled with colored gradual dots, positioned according to Fiset et. al (2009) research results.

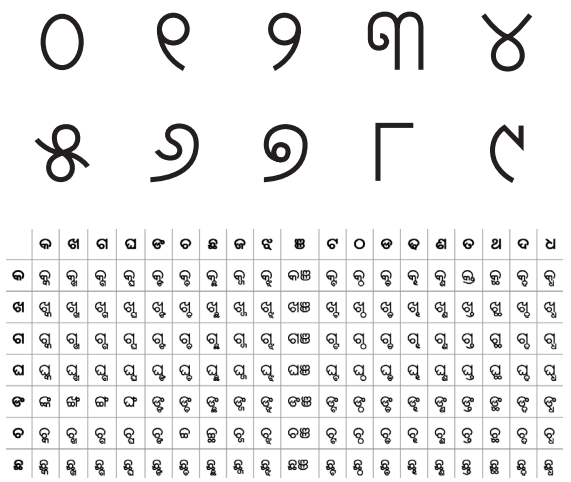


Verdana with a graphic colored application, positioned according to Fiset et. al (2009) research results.

LIGATURES FOR LARGER DIGIT STRINGS

5.3.3

In the Oriya (Odia) script (Encyclopedia 0 – 9, p.78) vowels and consonants are combined into one symbol per expression and interestingly, this script falls under the category of the abugida writing system. According to Scriptsource abugida is a form of writing where the consonants and vowels in a syllable are treated as a cluster or a unit; typical of scripts originating from South Asia. The following scripts are also classified under the abugida writing system in the En-cyclopedia of Number (non) Sense: Glossary p. X: Ahom p. 82, Balinese p.79, Bengali p.77, Bhaisuki p.76, Oriya (p. 78), Kharosthi (p.30), Meroitic Cursive (p.34), Tamil (p.33), among others.



The Oriya script could be compared to the Chinese (Encyclopedia 0 – 9, p. 2), Japanese (Encyclopedia 0 – 9, p. 32), or Egyptian Hieroglyphic (Encyclopedia 0 – 9, p. 1) logographic and logo syllabary writing systems.

What is interesting about these scripts and writing systems in particular in the context of this typo-graphical experiment, is how smaller letters and numbers are combined into a new symbol carrying a new meaning. Some numbers and letters are written in-side each other, others are written in an outlined column or attached, similar to the conventional ligatures of stylistic purposes in typefaces of the Latin script to where the Oriya script relates. The connection of figures for letters and numbers triggered the initial idea to design ligatures specifically for Hindu-Arabic num-bers.

DE FEYTER, ALINE. 2020. *ENCYCLOPEDIA OF NUMBER (NON) SENSE*. ANTWERP, BELGIUM. ORIYA P. 78

UNICODE. 2020. *MIDDLE EAST-I 9 MODERN AND LITURGICAL SCRIPTS*. UNICODE. MOUNTAIN VIEW, CA. CONSULTED ON 15/08/'20 URL: HTTP://WWW.UNICODE.ORG/VERSIONS/UNICODE13.0.0/CH09.PDF

HOLLOWAY, STEPH. SCRIPTSOURCE STAFF. 2020. *GLOSSARY*. CONSULTED ON 22/05/2020. URL: HTTPS://SCRIPTSOURCE.ORG/GLOSSARY

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Ligatures: Sabon, Regular 18,5 pt

The term ligature defined by Jœ Pohlen (Letterfontijn, 2016) is as follows: "*Ligatures are letter combinations designed due to the width of the lead letter 'f', the widened flag on top of. The width of the lead stick became so big that gaps occurred in opposition to the following letter.*" Thus, ligatures are designed to connect gaps in spacing and overlapping letters, this occurs among others in the letters f and i, for example, becoming fi. In the case of numerals, there are different spacings applied in tabular, proportional medieval, and monospaced medieval numbers. But neither of these variables are ligatures for numerals included or currently ever designed nor used in text or formulas.

In this hypothesis, the focus lies on increasing the readability of larger digit strings, similar in purpose as to why Opticus Italic was designed, but instead by designing ligatures. Aiding to read (larger) numbers correctly as seen in daily life on credit cards, telephone numbers, the pricing of products, or in mathemat-ics. Readers who have a lack of number sense and insufficiently trained or capable memory span for numbers such as dyscalculics, tend to make reading mistakes in number strings much more often and persistent in comparison to the occur-rence of a common mistake. Due to the insufficient automated mapping of numbers - relating a number to its correct value – as stated previously by Prof. Hans Van Luit. Causing the reader to easily reverse digits without being aware of their mistake.

These reading mistakes could be compared to the research to a stimulus-centered reading disorder for words and numbers by Arduino S. (et al., 2005). Within the case-study on a reading disorder in the left hemisphere of the brain (neglect dyslexia) experiments with how the placement of reading material in the page and words being mirror-reversed were conducted.

POHLEN, JŒP. 2010. *LETTERFONTIJN. OVER DRUKLETTERS*. (4TH EDITION). NETHERLANDS, RŒRMOND: UITGEVERIJ FONTANA. P.114 - 115

These tests resulted in the knowledge that the same type of left-sided errors in reading aloud was made, independent of the positioning of the letter string as words were positioned in the left, center, or right side of the page. More specifically the results of the visu-al field presentation (experiment 4a) suggest that the reading mistakes on the left-side of both word and number strings are related to the letters or numbers themselves, not their positioning on the page. The patient read aloud 126/197 (64%) digit strings incorrectly in the experiment, 102/126 (81%) of those errors involved the digits that occupied the first positions. Based on these results, ex-periment 4d had been conducted where the first digit or letter of a string had been made bold, as a means to attract visuospatial attention to the initial num-ber in the string. Making the first initial of a string bold is a design decision made based on the same reason as Opticus was designed. The thicker parts in Opticus draw the most visuospatial attention within the digits design to the most crucial features in the number (Fiset et al.) as a means to improve legibility and the recognition speed. In experiment 4d 8/55 (14%) reading errors were made, all affecting the first digit with the bold initial number strings.

In some cases reversing numbers while reading is caused due to 'crowding', for similar reasons as dyslexic readers experience this reading issue. Crowding is a visual distortion that can happen to any reader (not solely dyslexics) when con-fronted with large sequences of numbers, in a dense text, or in the case of hav-ing too little spacing around the numbers or letters. The visual distortion would cause letters to be reversed or visually seem to be merged together, as is explained by Kevin Larsson in his lecture on *Typography for Children* (ATypI Montréal, 2017).

ARDUINO, LISA S., DAINI, ROBERTA AND SILVERI, MARIA CATERINA (2005). *A STIMULUS-CENTERED READING DISORDER FOR WORDS AND NUMBERS: IS IT NEGLECT DYSLEXIA?* NEUROCASE, 11:6, 405-415.

LARSSON, KEVIN. ATYPI, MONTRÉAL. 2017 *TYPOGRAPHY FOR CHILDREN*. CONSULTED ON 17/03/2020. URL:HTTPS://WWW.YOUTUBE.COM/WATCH?V=J3Y-01TSTTG&LIST=PL0OMAZSH5W9OJSX9BSXEF8UZA44FWB255&INDEX=7&T=0S

Even readers with a well-trained memory span and developed number sense tend to make errors when reading or working with numbers con-sisting of more than five digits.

Reversing and confusing numbers are mistakes that also occur due to the fact that the number system dœs not work the same as language dœs because a number sequence is not predictable but a word might be. A collection of letters symbolizing individual sounds becomes a word with a meaning that is part of a sentence (depending on the language and writing system this may vary). Being able to relate sounds to symbols and create words, makes sense to the reader because it is a learned code with meaning, not a random string of letters with-out coherence. A large sequence of numbers such as 1289 6876 3490 2307, however, dœs not make any sense. Adults could identify it as some sort of banking number due to the way the numbers are constructed in pairs of four digits, but the sequence of digits has no systematic sense.

If the value of a number is too large to decipher at first glance while reading, the numbers are often read separately digit-per-digit disregarding their value. For example reading 245 as ‘two, four, five’ instead of ‘two hundred forty-five’ the number is remembered or read as a sequence of single digits and not as a solid number.

As a proposed design solution to this problem, numbers can be visually com-bined with a ligature when necessary to visually divide a large sequence into smaller sets of digits. Resulting in making the sequence easier to read and re-member or copy. These ligatures for numbers would be applied similar to how words are split into syllables, such as *su-per-mar-ket*. The numbers would also be structurally split into readable pieces per set of maximum three digits.

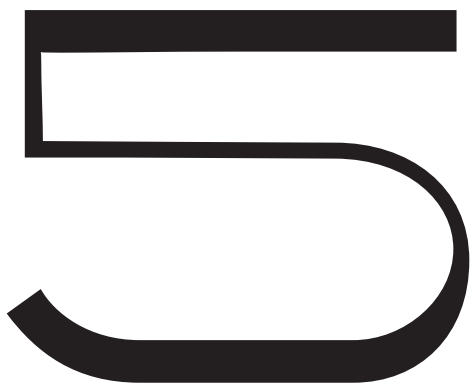
BEIER, SOFIE. 2017. *THE LEGIBILITY OF NUMERALS*. ATYPI, MONTRÉAL. CONSULTED ON 31/05/2020. URL: HTTPS://WWW.YOUTUBE.COM/

1350000, for example, could become 1.350.000 but without the necessity of using punctuation marks, leading again to reading a sequel of digits instead of read-ing the full value of the number.

As the design of ligatures for all possible number combinations would take up loads of time, I tried to keep a system in mind so the visual applications could be coded in a later stage of this experiment. The first ligature system is based on the data extracted from the cognitive neuropsychological research to spatiotemporal dynamics of visual letter recognition (Fiset et Al. 2009). As earlier men-tioned in the development and design of Opticus, this data formed the base of the initial type design. The important features for legibility and recognition of the numbers are accentuated by exaggerating the weight in the number shape, the less important features are designed thinner. There should not be drawn too much attention to the ligatures themselves as they could disturb the reading rhythm, having the opposite effect as it is intended. To prevent the ligatures from drawing too much attention to themselves, thinner areas in the type de-signs are used to make the connections between number shapes. As the thinner strokes don’t draw as much attention to whereas the thicker elements would be connected.

755

73

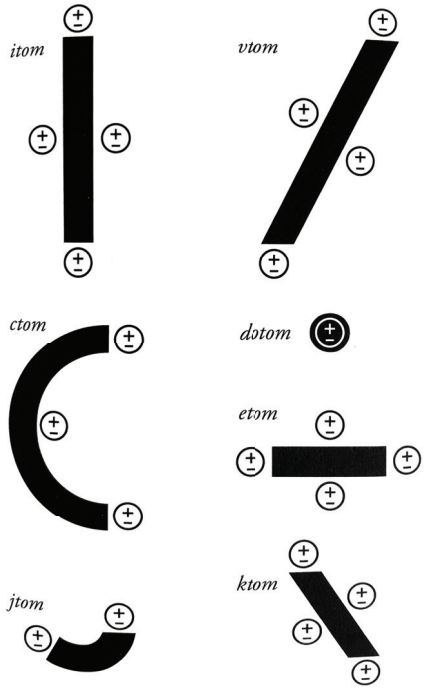


55

53

29

906



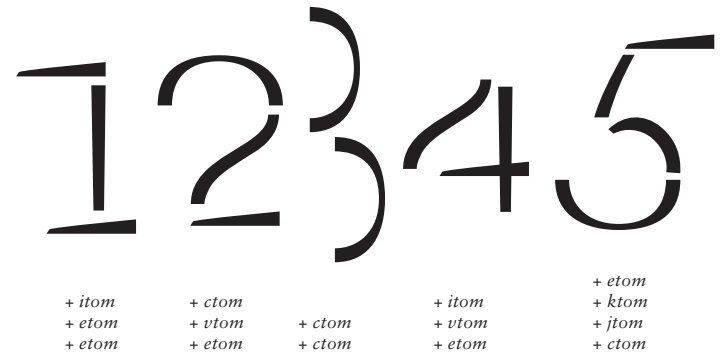
H.F., HENDERSON. WOODY, LESLIE. 2019. *UNDERSTANDING MOLECULAR TYPOGRAPHY.* NEW YORK: UGLY DUCKLING PRESSE. P. 3, 7

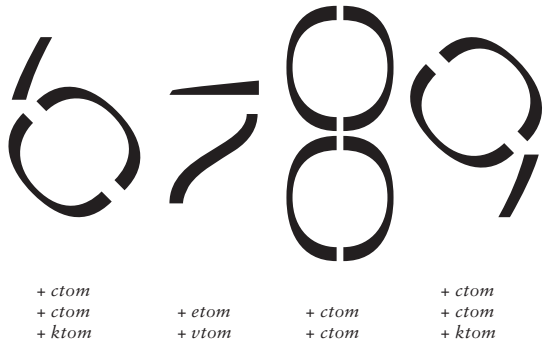
Another possibility that was considered as a functioning design system to create ligatures for numbers, is the molecular typography theorem about the science behind a balanced typeface from H.F. Henderson (1992).

Molecular typography is an approach to type design from the perspective of the scientist H.F. Hender-son. In his briefly explained theory, the scientist looks at typography as if it is a collection of molecules keeping each other and the letterform in balance. The theory on molecular typography was originally published in 1992 but was a trendy topic in the scientific field dating back to the 60s, 70s, and 80s. Based on the typtom anatomy, being the atomic units in all character forms constructing a composition of different typtoms. To demonstrate and illustrate his theory, the numbers were divided into typtoms to fit the formula modules. These 'molecules' were used to construct the ligatures and compare overlapping fea-tures, for example, the combination of the number two and four to create a ligature for twenty-four.

Seeing or using typography as a compilation of molecules and the formula's he created, could form the foundation of a balanced ligature set or system for numbers in opposition to the type designs based on the data from Fiset et Al. 2009. However the resulting compositions from the molecular type designs were interesting as an experiment to understand number shapes, they did not provide the intended balance that should enhance the understanding of numerical values through reading. The ligatures created in this system would draw too much attention to themselves when applied in reading material. Thus for the ligature system to be successful, the best experiment to enhance upon is based on the same data as Opticus is initially designed contracted from Fiset et Al. (2019) research results.

Opticus divided in typtoms, following the charts





Ligatures assembled following the resempling or matching typtoms.

5.3.4 PLACE–VALUE SYSTEM

The decimal place-value system determines the value of a number depending on where it is placed through the positioning of the units, tenths, hundreds, thou-sands, and so forth. The decimal counting system is used in 112 other scripts and ways of finger counting such as Hindu-Arabic script (p.29, 51), Hebrew (p.39), Nabatæan (p.36), Pahlavi (p.37, 38), Meroitic Cursive (p.34), Tamil (p.33), Chinese Han (p.2, 18), Counting rods (p.32), Kharosthi (p.30), Hattic (p.26), Roman (p.27), Old Italic (p.28), Greek (p.20, 21, 25), Old Arabian (p.23, 24), etc. The rest of the scripts can be found in the glossary p. 10 (noted as X) of the Encyclopedia of Number (non)Sense.

As earlier discussed in the hypotheses on ligatures designed specifically for num-bers and the research to the influence of color on reading, difficulties with link-ing a certain value to its correct position or orientation in writing or reading numbers - consisting of more than two digits – was mentioned. Focusing on one difficulty in particular: the reversed reading of numbers. What often leads to this reading mistake is crowding or partially due to the lack of number sense. Specifically the lack of knowledge and insight in the place-value system used in the decimal counting and writing system of Hindu-Arabic numbers. Due to the insufficient or incapability to atomize reading and understanding the decimal place-value system that falls under number sense, reversing numbers while reading is like reversed writing a mistake commonly made.

This problem definition is compatible with the subject of spatial orientation in A stimulus-centered reading disorder for words and numbers: Is it neglect dyslex-ia? By Arduino et Al. (2005, Psychology Press). In experiment 4b, is stated that the number of errors in reading aloud stimuli aligned horizontally (37%) on a page is greater than those produced in reading aloud stimuli presented vertically ... (15%) or mirror-reversed (16%) on a page. ...

Based on these statements, the amount of reading mistakes of horizontally aligned number strings could be reduced when the horizontal and vertical posi-tioning of the text were combined. The vertical position would increase the value of the number in opposition to the other digits in the same string. The horizon-tal position of numbers would maintain the conventional reading rhythm and direction from left to right in this experiment.

The direction of reading in this hypothesis is from left to right, relating to the West-European reading and writing habits. The way we read numbers and relate larger and smaller values to the left or right-oriented side of space depends on our culture's script and the habitual reading or writing direc-tion. This should be taken into account alongside the test results from reading mistakes depending on spatial orientation by Arduino et Al. (2005, Psychology Press). The relation of a numerical value to space orientation in reading and writing will be referred to as the "*spatial–numerical association of response codes*" also known as the SNARC effect. .... Samuel Shaki et Al. (2009) concluded that by testing Palestinians in the standard parity task with Arabic-Indic digits, a clear association between small numbers and right space and be-tween large numbers and left space was made.

...

... ARDUINO, LISA S., DAINI, ROBERTA AND SILVERI, MARIA CATERINA (2005). *A STIMULUS-CENTERED READING DISORDER FOR WORDS AND NUMBERS: IS IT NEGLECT DYSLEXIA?* NEUROCASE, 11:6, 405-415.

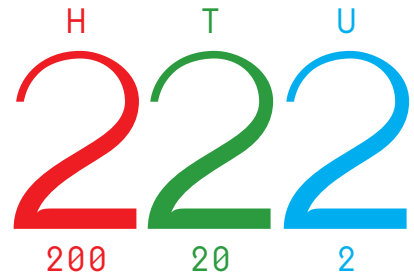
.... SAMUEL SHAKI, MARTIN H. FISCHER, WILLIAM M. PETRUSIC. 2009. *READING HABITS FOR BOTH WORDS AND NUMBERS CONTRIBUTE TO THE SNARC EFFECT.* PSYCHONOMIC BULLETIN & REVIEW.

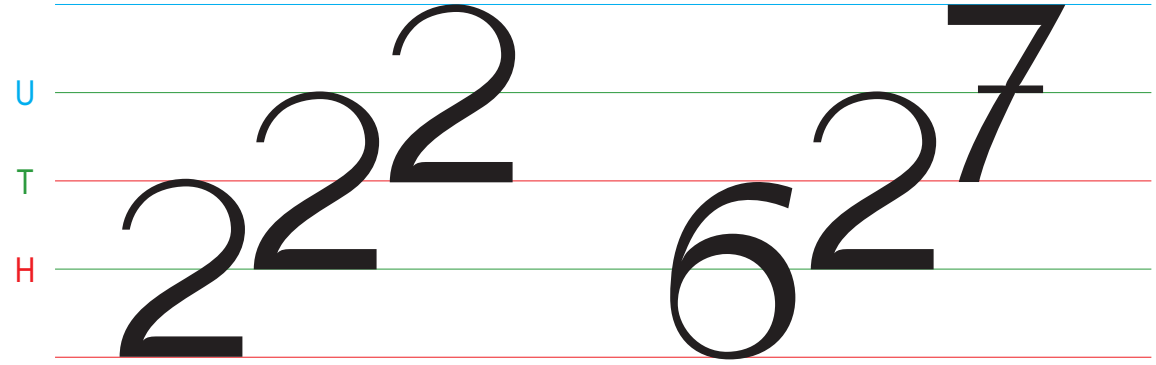
This is a reversed SNARC effect when compared to Western cultures, associating small numbers and left space and large numbers with the right space. For example, when Western readers are asked to make a (mental) number line the smallest number is oriented at the left side and the largest number on the right side. The conventional writing system in this experiment is maintained and exaggerated, visualized through a rhythmic approach.

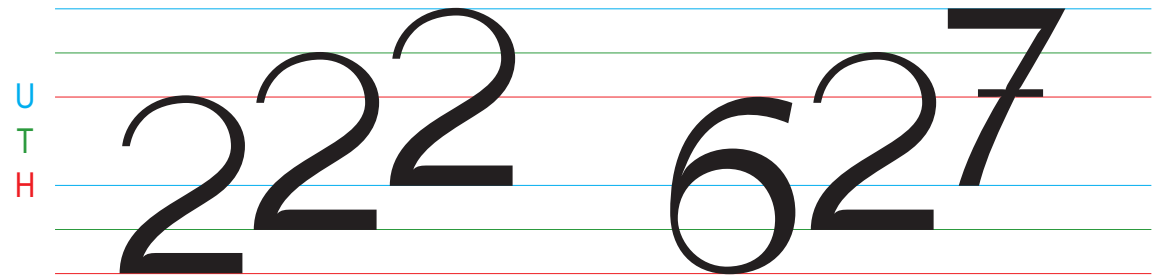
For example, 12 would look smaller than 120 due to its gradual increment on the baselines taking up more or lesser space. The positioning of the numbers going up or down would indicate the increased or decreased value of the num-ber. This could remind the reader of music scores, in particular how music notes would be read by musicians as instructions. Only in this case, applied to read number strings with their rhythmic horizontal and vertical positioning being a visual instruction to indicate their value more easily.

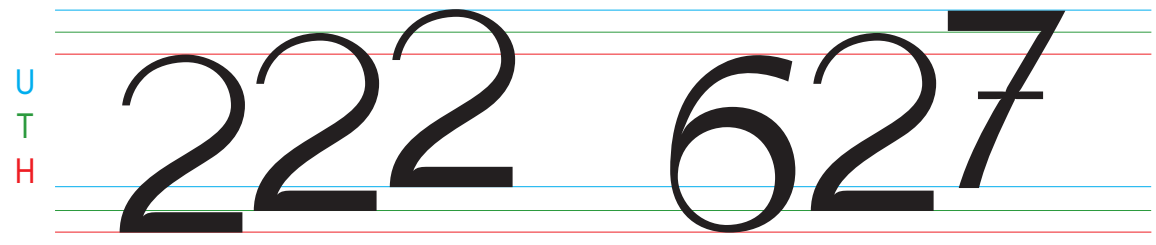
Rhythm is an important feature in type design, influencing the reading fluency and readability. A balance between the vertical rhythm of the strokes in the number shapes themselves, the horizontal rhythm of the baselines, and white space in between letters or numbers are kept in mind. Aside from using posi-tional rhythm as a visual feature to improve numerical insight while reading, it is important to maintain a fluently readable typeset. Respecting the rhythm in the individual number shapes and in opposition to the shapes surrounding each other as well, maintaining a balanced typeface.

BESSEMANS, A. 2014. *RHYTHM AND LEGIBILITY*. ATYPI, BARCELONA. CONSULTED ON 04/05/2020. URL:HTTPS://WWW.YOUTUBE.COM/WATCH?V=-S3YTUW4PQVK&T=1450S









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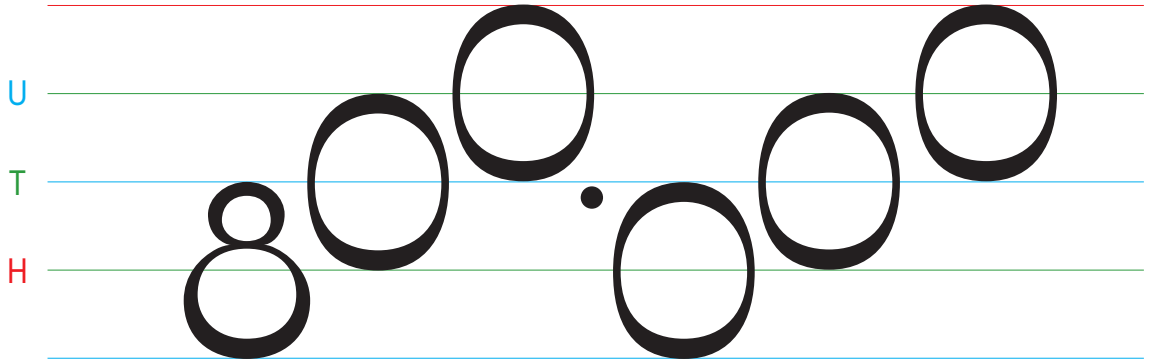
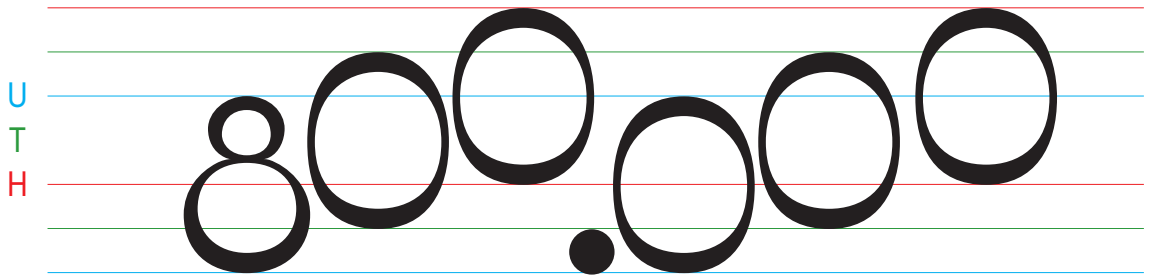
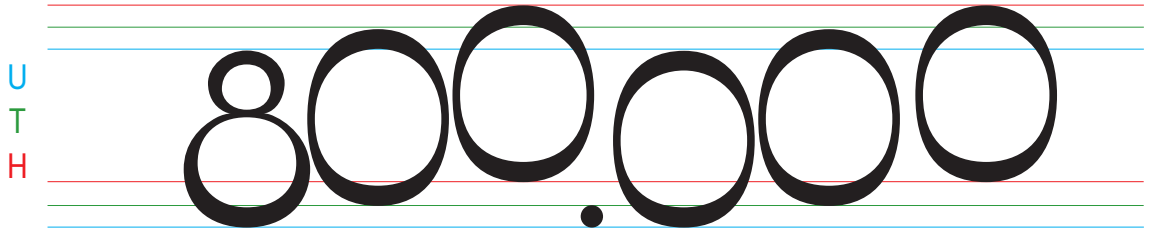






THE RELATION BETWEEN FINGER COUNTING & TYPE DESIGN

In history, the Pekai-Alue tribe located in Oceania, Papua New Guinea (Encyclopedia, p.142) uses the complete body as a reference to numbers. [...] Assigning a part of the body or a physical object such as pebbles (Bulla) fig. 23, 24, or tally marks, helps to memorize and visualize the abstract concepts. Working with representations of a number to perform calculations, aids to strengthen insight, and automate the calculating system.

Getting back to the topic of rhythm and its relation to learning to count, mentioned previously in the experimentation with the horizontal and vertical orientation of number strings. In education, the rhythm of music – is a simple beat – has proven to help children to remember and understand the chronological order of numbers more in-depth. This technique of embodying theoretical and abstract concepts such as numbers has been used in various ways depending on culture and time. To quote the historian Tobias Dantzig: *"Wherever a counting technique, worthy of the name, exists at all, finger counting has been found to either perceive or accompany it"*. [...]

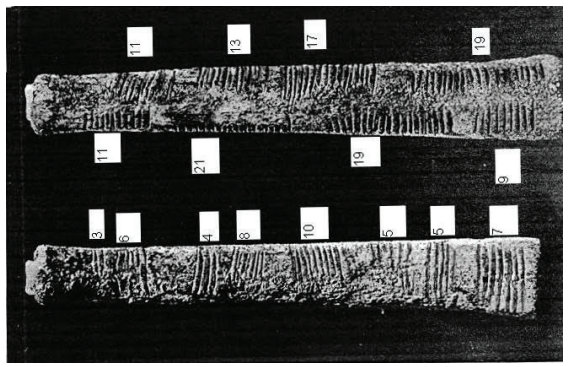
Digging into the history of numbers, there is no remaining linguistic memory causing the origin of the names of numbers to have no link with their shape. Only the Russian word '*piat*' meaning '*five*', comes from '*piast*' translating into '*hand*'.

[...]

[...] BARRY, CRAIG. 2010. *TALLY SYSTEMS OF THE UPPER SEPIK AND CENTRAL NEW GUINEA*. P. 2 - 3. CONSULTED ON 17/04/2020. UPPER SEPIK-CENTRAL NEW GUINEA. URL: HTTP://USC-NGP.COM/PAPERS/

[...] BARROW, J.D. 2003. *PI IN THE SKY*. LONDON, CAMBRIDGE: OXFORD UNIVERSITY PRESS. FINGERS AND TŒS. P. 45

The awareness and use of numbers took its earliest form in tally marks, proof of this was found in Africa on the *Lebombo bone* being the oldest relic of numerical notation dating back to 3500 BC. The tally marking system relates both visually and systematically to finger counting. They could be thought of as the roots of mathematics and the representation of numbers.



Lebombo bone with engraved tally markings. 3500 BC, Africa

Currently, there are two opposite opinions in the field of neuropsychology and education on the effects of counting on your fingers. According to the Dutch Professor, Hans Van Luit in his book *This is dyscalculia, background, and approach* (*Dit is Dyscalculie, Achtergrond en aanpak*, 2008), tally marks are found important for the development of number sense and arithmetic insight. Finger counting forms a bridge between mapping the abstract concept of numbers, their value, and the relation to their symbol. To a toddler aged 4 years old lacking number sense, this would be a very hard task and performed more slowly in comparison to toddlers of the same age group with better developed numerical insight. The test subject can't arrange the numbers according to their value on a number line without being able to count on their fingers as a representation of the values of the numbers. Out of this observation, Professor Van Luit concluded that finger counting is an aiding step towards the improvement of a deeper understanding of numbers and a preparation towards arithmetic skills.

The alternative learning methodology such as the embodiment of abstract concepts is applied in the Steiner school and has proven to assist the development of numerical insight. Such as the usage of rhythm and finger counting to encourage beginning mathematics and deepen the understanding of the concept of adding and subtracting.

The embodiment of numbers serves as a reference to their value based on rhythm, as an aid to memorize and relate. The identification of numbers through body parts always occurred through the historical evolution of number awareness, thus it is only logical that it is part of the current learning curve.

On the other hand, finger counting is also considered negative since it is also a behavioral sign of insufficiently trained working memory. Meaning the recognition or knowledge on the value of numbers (or number sense in general) is not automated, causing the child or adult to count on their fingers. This is presumed childish and unprofessional in society, hence the belief of counting on your fingers as a sign of having a tremendous backlog or even stupidity. This way of thinking results in skipping this important step in the learning curve, to move on to harder subjects and mathematics more quickly.

This hypothesis or design experiment is a proposition to make visual associations between the design of Hindu-Arabic numbers and the system of finger counting. How this could be conducted is for example, similar to applying the molecular typography theory by H.F. Henderson (Woody Leslie, 2009) using these basic elements to construct number shapes. In this context, the elements (typtoms) could be brought in relation to our hands or fingers. *Embodying numbers* (shape and value) can be taken literally from a type design perspective. Breaking down the numbers into bits and pieces and relating by form and design to the positions of our hands and fingers symbolizing a number.

IFRAH, GEORGES. 1987. *FROM ONE TO ZERO, A UNIVERSAL HISTORY OF NUMBERS*. NEW YORK: PENGUIN GROUP LTD.

VAN LUIT, HANS. 2018. *DIT IS DYSCALCULIE, ACHTERGROND EN AANPAK*. BELGIUM, LEUVEN: LANNOO CAMPUS P. 107.

DE FEYTER, ALINE. 2020. *ENCYCLOPEDIA OF NUMBER (NON)SENSE*. NR. 1. FINGER COUNTING, PHILLIPINES, P. 136 ANTWERP, BELGIUM.

Based on the archive of different ways of counting some type designs could be made, referencing the assigned body parts. The type designs could serve as visual instructions to relate between the physical representation of the number and the (written) symbol. In other words, typography could be the bridge between abstract calculating and the physical representation of numbers such as counting on your fingers, by the use of tally marks or other physical representations.

5.4 CONCLUSION OF THE TYPOGRAPHICAL EXPERIMENTS

✦

During the process of collecting and archiving the content of the encyclopedia, typographical experiments were conducted with Hindu-Arabic numbers as an example of how boundaries can be pushed in terms of (type) design and how the encyclopedia can be used by designers as a source of inspiration. The experiments are focussed on en-hancing numerical insight, legibility, and/or the recognition speed of numbers while reading, opening new pathways for further in-depth scientific research.

In general, these experiments bring new and innovative design proposals questioning the current conventionality of the design of numbers. Being an extension or *extra muros* to the imagination of how the design of numbers could be manipulated.

These hypotheses are a work in progress and can be tested and embedded into the relevant scientific literature in the future, brought in comparison to the current typefaces with their conventional and consistent design. Taking place within the classical education system, with young readers between the age of four to five years old. Both with and without mathematical related learning disabilities or backlogs on numerical insight and number sense, as to compare the results of this group to children of the same age without any signs of lacking number sense. Their reading performance of number strings would be compared to the other focus group and within each test, subject to measure the difference of reading numbers as they are presented now along with the resulting de-signs from this research.

Besides the experiments resulting in possible design solutions for reading numbers, they each have the potential to steer a course for future scientific and design research, opening up a conversation between academics and designers.

6

CONCLUSION OF THE DESIGN RESEARCH TO NUMBER (NON)SENSE

In this thesis, a multidisciplinary research to number (non)sense and how it could be improved through design to provide visual support for many children or adults with a weak sense of numbers, numerical insight, or dyscalculia has been brought together. Shedding new light on the current knowledge about numbers and their notational system, history, and design. This knowledge has been collected and given structure in the shape of an archive, designed to function as an encyclopedia or inspirational research document. As a whole the design research results in bringing forth research material in an accessible way, offering multiple approaches considering type design and reading research to dealing with numbers crossing the borders of both science and design.

As to the further development of this project, the encyclopedia could be digitized as some kind of search engine or online archive containing the same navigational systems and maintaining its functionality as is determined in the book design. A digitized platform would be easier to update with new discoveries and deciphered scripts over time and would be more accessible for researchers and designers on a global scale. However, the decision to design an encyclopedia for this project is still of great value as a homage to the historical roots of its content and context. In its essence, book design and web design are not that different. In both cases a structure and navigation system (or multiple layers of systems) is determined and the content is brought together in its online or printed medium.

7

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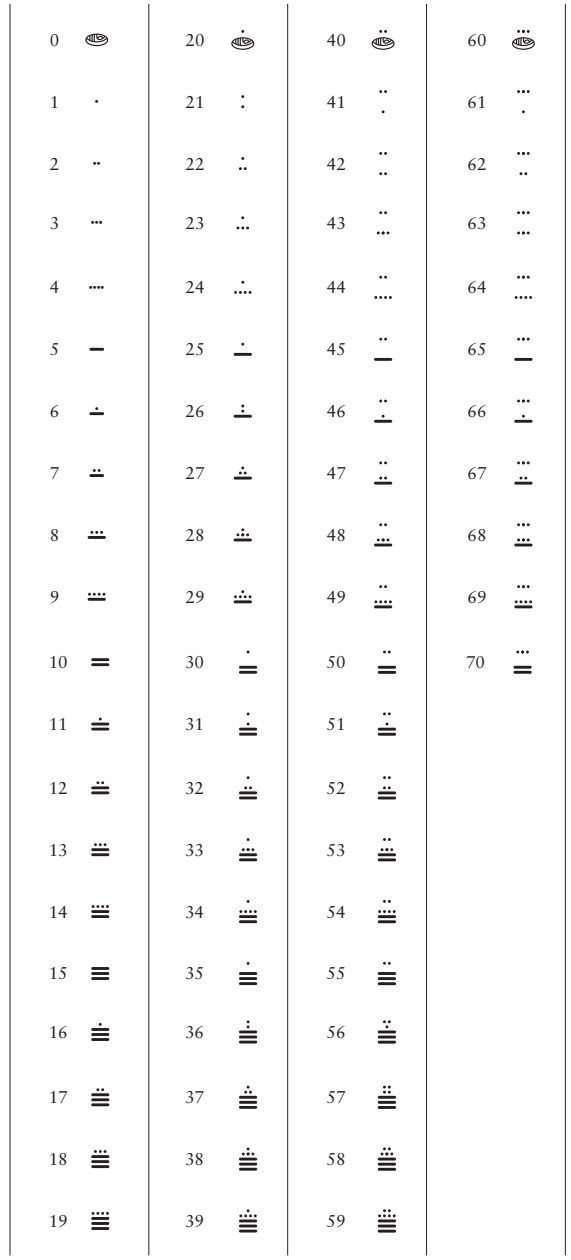
LEGEND

In this thesis, Mayan Hieroglyphs are used as a (visual) numerical reference system. More information about the notation system can be found in The Encyclopedia of Number (non)Sense p. 11.



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