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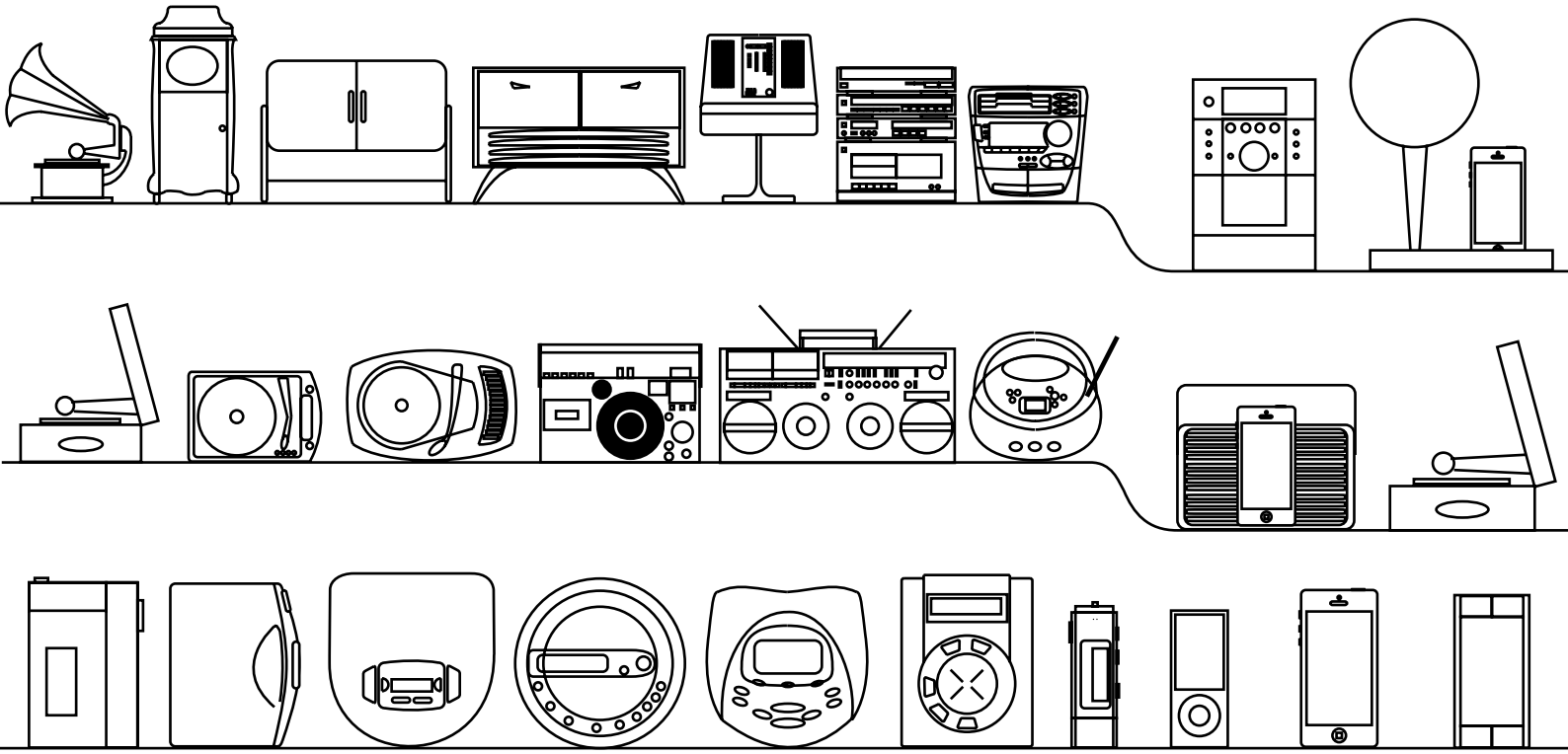

Form evolution

The interplay between product form and technology

Thesis for the degree of Master of Science in Industrial Design Engineering

Mikael Sedlacek

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2014

Department of Product- and Production Development
Division of Design & Human Factors

Master of Science Thesis

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Mikael Sedlacek

SUPERVISOR: Viktor Hjort af Ornäs Ph.D

EXAMINER: Mari-Anne Karlsson Professor

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Chalmers University of Technology
SE-412 96 Goteborg, Sweden
Telefon +46(0) 31-772 1000
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Abstract

When developing a products form concept within a product development process, earlier solutions are often studied in order to either improve upon them or to use them in an innovative way. Therefore knowledge about products design history can be an important aspect for industrial designers, since it represents earlier solutions. When trying to directly apply knowledge about design history to a product concept a problem arises however, which could be linked to the fact that design history often focuses upon the philosophy behind specific designs, rather than explaining how and which properties that changed over time within product categories.

Such a description of how products form changes over time, could be a way to explain how improvements and innovation were achieved, assuming that earlier solutions were improved upon. This type of description can be defined as a trend of evolution, which would bridge the gap between having knowledge of earlier solutions, design history and being able to directly apply it to a product concept.
To fill this knowledge gap the author developed a framework and methodology to evaluate products systematically, considering their technology and form. By using the framework and methodology to analyze over 1000 products, the author identified three cyclic trends of evolution.

1. Creation and depletion of a prototype
2. Composite-integrate-separate
3. Complex-simple-complex

The author proposes that the formulated framework, methodology and trends of evolution can be used as powerful tools to create concepts and aid creative thinking in product design.

Key words: product form, concept design, industrial design, design history, methodology, aesthetics, creative thinking

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This master thesis project involved meeting several people who gave their time to help, guide and give input and for this I am very thankful, as this thesis would not have been possible to take this far without them. I would like to thank Gert Ekström for taking his time to give guidance and lending me a great amount of personal material, and also double checking the historical facts. From Chalmers I would like to thank examiner Mari-Anne Karlsson for supporting the project, Maral Babapour Chafi for her good advice and input. I would especially like to thank my supervisor Viktor Hjort af Ornäs for his never ending stream of good advice. I would also like to thank Anders Warell for discussing the methdology and framework. Cheryl Akner-Koler for having a discussion on epistemology and looking trough my framework. Torbjörn Andersson for discussing the results and Lasse Brunnström for looking trough the framework.

Mikael Sedlacek

Gothenburg, 2014

Glossary

Here some definitions and terms used in the thesis are presented, to give the reader an overview of what the author refers to.

Product form properties – According to the author: The conceptual and semantic properties of a products form.

Semantics – The meaning of a sign.

Conceptual form features – A products conceptual form features are defined by its arrangement of functional elements, system of positioning, ordinance, geometric forms, movement and morphological features. Together they affect the form complexity and integration.

Form complexity - How complex a products form is according to the amount of contrast and rhythm that it contains, in accordance with a defined framework.

Form integration - The surface shape, surface complexity, form elements and how they are intersected in a products form.

Composite form – A unified whole which contains several different form types, with segmented surface intersections.

Prototype – A specific arrangement of technical elements, or a prototypical arrangement, which are used by a majority of manufacturers for the same product category.

Form evolution – The description of how conceptual form features in products develops over time.

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1. Introduction

This chapter goes through the initial hypothesis, the motivation for researching it further, delimits the project, sets the aim and provides a report overview.

1.1. Backround

Mikael Sedlacek came up with the initial idea of this research project by believing to have found what could best be described as a form trend of evolution. The hypothesized trend were that a majority of products form spanning from 1960-2000 seemed to be going from being simple, to complex, to simple - in cycles. For instance a lot of products sold in the 1960s looked to be very minimalistic, while in the 1970s a lot of products instead seemed to have a more complex form, following a post-modernist design philosophy, which in the 1980s looked to be going back to a new type of minimalism, and yet again in the 1990s going back to having a complex form, **FIG 1**.

The problem with this type of description were that it did not define what simple or complex form were, and furthermore only identifying that a couple of products shared vaguely defined properties were certainly not evidence of it being a consistent trend. Therefore the author proposed to conduct his master thesis in Industrial design engineering, as a research project for the division of Design and human factors, at Chalmers University of Technology in Gothenburg. The project were approved and initiated in January 2014, beginning with a motivation for why a knowledge gap off this sort were important to fill.

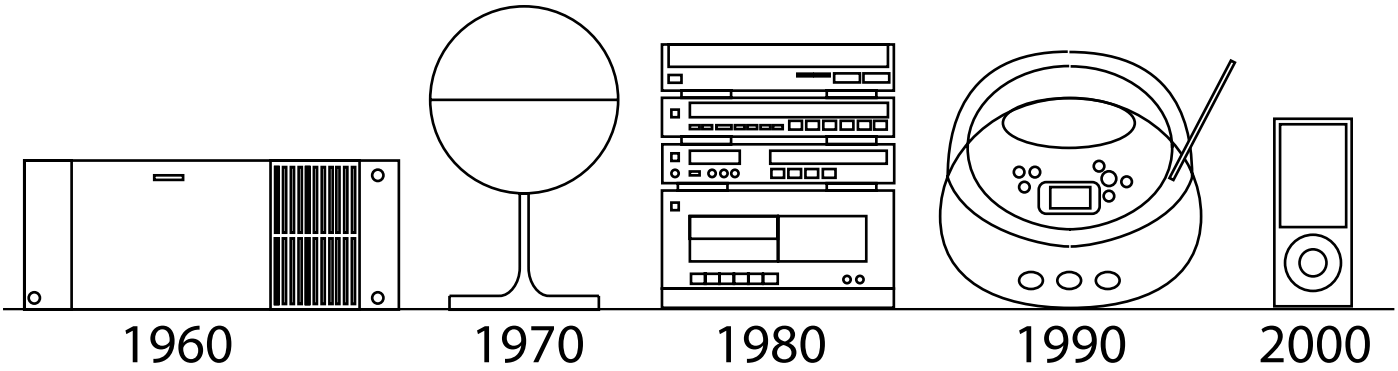


Figure 1. A description of the initial hypothesis, where products form seemed to go from minimalism to complex in cycles.

1.2. Motivation

When developing a product form concept within a product development process, earlier solutions were often studied in order to either improve upon them or to use them in an innovative way. Therefore knowledge about products design history were an important aspect for industrial designers, since it represents earlier solutions. When trying to directly apply knowledge about design history to a product concept a problem arose however, which could be linked to the fact that design history often focused upon the philosophy behind specific designs, rather than explaining how and which properties that changed over time within product categories.

Such a description of how products form changed over time, could have been a way to explain how improvements and innovation were achieved, assuming that earlier solutions were improved upon. This type of description could be defined as a trend of evolution, which would bridge the gap between having knowledge of earlier solutions, design history and being able to directly apply it to a product concept. Since the author believed to have found such a trend, research on the subject could possibly fill an important knowledge gap, and provide a way to directly apply knowledge of trends to product form concepts.

1.3. Rationale & delimitation

An initial rationale and delimitation of specifically which products and properties to research on the subject were needed in order to define a basic outset.

Considering a rationale the viewpoint that every design is a redesign were adopted, which implied that products were iterations of the previous. If each product were an iteration of the previous it meant that if any trends of evolution existed, these would be beyond the individual industrial designer. They would be beyond the individual industrial designer in the sense that any personal touches would be deleted with each new iteration. Because of this an approach of interviewing designers on their thoughts behind their designs were ruled out as implausible.

The same rationale also exposed the reason for the knowledge gap in the first place, since most design history covered the philosophy behind designs, with comments from designers. Next up were to establish which products to look further into. Initially this were discussed with the supervisor and examiner of the project, which lead to a short list of demands.

The first demand were that the products had to have existed at least within time span 1960-2000, since the initial hypothesized trend covered this timespan. Secondly the products had to represent a consistent technological development, because the initial motivation of the project concerned how it were hard to apply design history in a product development process. Since products that involve industrial design engineers often concern a technological development this were of importance. Thirdly a quantity of products to analyze needed to be available.

One product category which fulfilled all the demands were the products within reproduced sound, which concerned products from the phonograph in the late 1800s to the smartphone speakers of 2014. It represented a consistent technological development, since the mediums used and overall technology had been consistently changed and improved. The category also contained a quantity of products to analyze, with products used at home and portable ones, **FIG 2.**

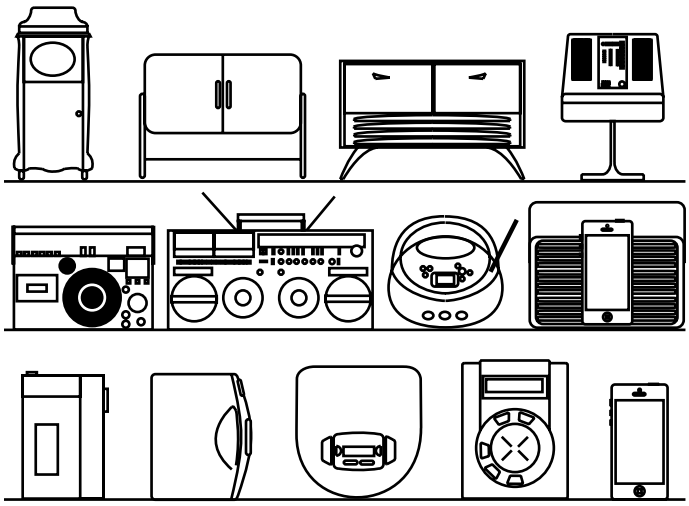


Figure 2. Examples of products within reproduced sound. Furniture gramophones, boomboxes and portable products.

With the product category picked the next step were to establish which overall properties that were going to be further analyzed in the research. The first property set were to establish an overall view of the technological development within the product category. Considering which product form properties to analyze the following ones were picked, based upon which key aspects that are usually presented in design historical research: 'colors, construction, surfaces, materials, position and usage', Brunnström (2006).

1.4. Aim

With the picked product category and properties to analyze an aim of the research were set. The aim of the thesis were to present the exploratory research conducted on products within reproduced sound, concerning their overall technological development, colors, construction, surfaces, materials, positon and usage. With the final research aim to present if there were any form trends of evolution.

1.5. Report outline

With a set aim an approach were needed to start analyzing the product at hand. It were realized that there were no obvious ways of simply starting to analyze data, because the set properties were too basic. Therefore the initial parts of the project consisted of collecting data to understand the basic history of the products. Because of this, the research design, or how to approach the task, were created after an initial data collection and book study.

The report were outlined to present the process and how each part built upon the next. First the initial data collection and a summary on the products history were done. Following with the reserach design, a book study on form frameworks, and a discussion on why they were not directly applicable. After which a synthesized framework were created with formal definitions. From the framework a methodology to apply its definitions were created, from which three cyclic form trends of evolution were discovered. This were followed up with a discussion on the possible applications and conclusions. **FIG 3**.

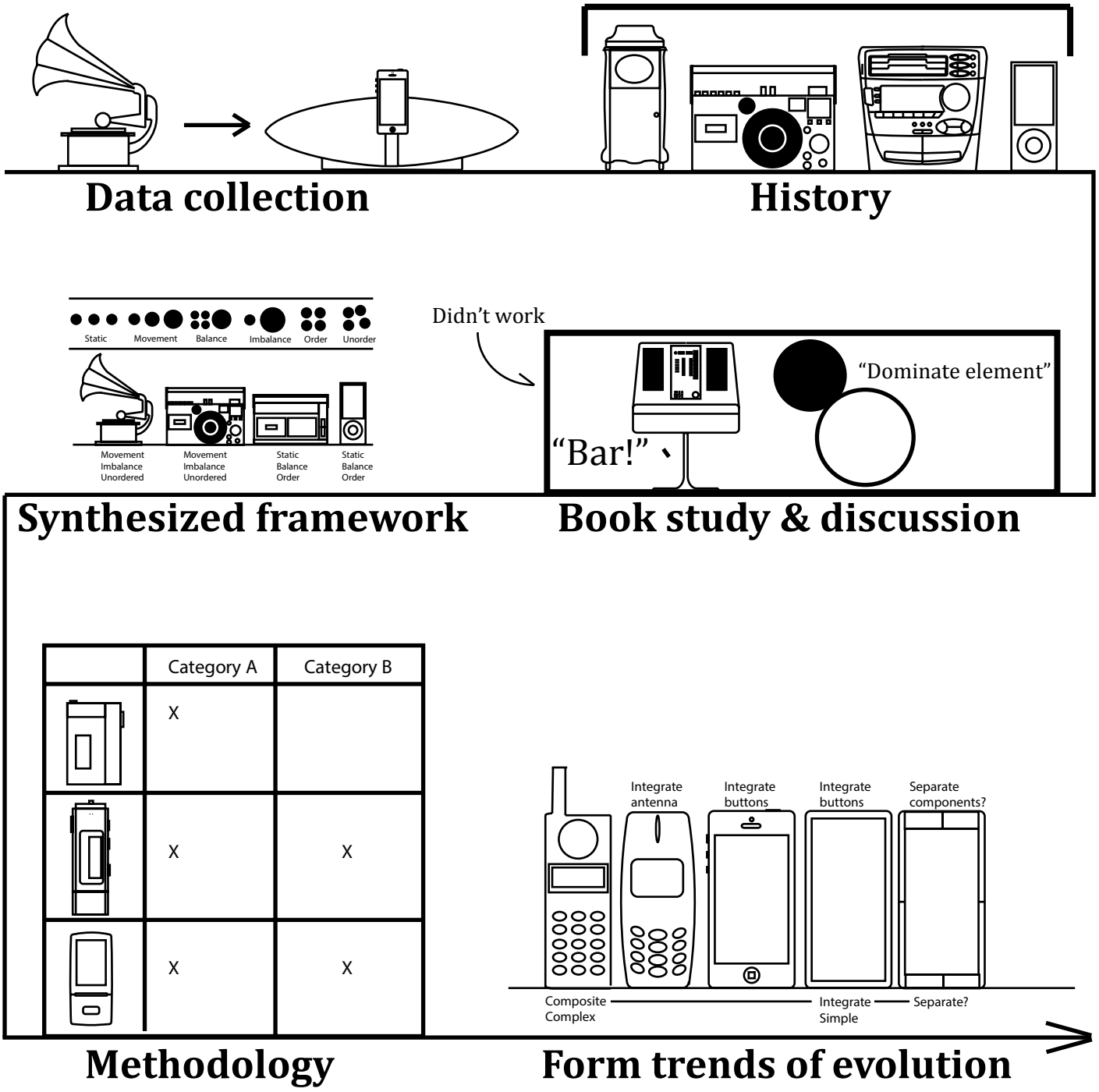


Figure 3. The report outline, data collection, history, book study, new framework, methodology and form trends of evolution.

2. Data collection

This chapter goes through the data collection conducted initally. It covers the study visit, expert intverview and a summary of the products history.

2.1. Preparation

To gain an insight into the history of the products the Swedish National Museum of Science and Technology in Stockholm were contacted, as it were found that they had a big collection of musical products spanning from the years 1800-2000. Upon contacting the museum, the staff were delighted to hear that someone were interested in seeing their collection and a study visit were booked with Kjell Karlsson, a curator at the museum. Karlsson also gave the author the advice to contact Gert Ekström who were formerly a curator at the museum and one of their experts on the field of products within reproduced sound. Ekström were therefore contacted and an interview were booked for the day after the study visit. Before visiting the museum and conducting the interview a timeline of what the author knew about the products history were created, which consisted of presumed years that products existed on the market and when technological shifts took place, such as the introduction of cassette tapes. A simple list with the earlier established properties were also created. Both the timeline and list were created to use as mediators for future interviews, in order to explain what type of information were sought for.

2.2. Study visit

The study visit were conducted in January of 2014 and consisted of the author, together with the curator Kjell Karlsson, looking at, measuring and photographing 24 products within the category. When analyzing the products each of the summarized aspects were discussed with Karlsson and he provided some great insight into how the specific products had been used. A visit to the museums archives were done the day after where a curator had prepared their material on musical products. The material spanned everything from patents, marketing material, newspapers and technical history. Most of the material had been sent in by companies and collectors who wanted it to be stored for future generations. The material were very structured and a lot of useful information were found on the products technical history. During the visit to the archive the subject were also discussed with the archivist Per-Olov Bjällhag who provided some insight into the products technical history. The most valuable information found in the archives were copied to study in detail at a later time.

2.3. Expert interview

The interview with the expert Gert Ekström were held the day after visiting the museum. During the interview a large part of the history of the products were gone through and discussed. The interview were semi structured with the time line and list, but allowing the interviewee to expand on each subject. It were kept semi-structured to avoid missing key aspects of the products history by narrowing the subject down. Ekström also had a collection of material on the products history, containing technical history, marketing material, newspapers and photographs of users with the products. He had collected this material over the span of 20 years and the author were allowed to borrow it to study. A list of manufacturers to collect further data on were also created from the interview, this list can be found in **Appendix C**.

From the study visit, interview and by studying the material provided by Ekström a report on the history of recorded sound were created. This report covered an overview of the aspects concerning manufacturer-, technological, constructional and usage history. The report set the base of the research at hand.

2.4. Summary of the products history

A summary were created to give the reader an overview of the products history, the facts have been checked by Gert Ekström, (2014). The pictres were taken at the Swedish National Museum of Science and Technology.

American inventor Thomas A. Edison invented the first working concept that could reproduce and record sound in 1877, called the phonograph. The phonograph worked by a needle touching a cylinder wrapped with a tin foil sheet, the needle were then attached to a membrane flexed over the opening of a funnel. When the cylinder were rotated the needle followed tracks that had been etched into the tinfoil, and thus sound could be both recorded and reproduced. During the years following 1877 Edison saw competition from Alexander Graham Bell's graphophone, which worked by using wax cylinders instead of tinfoil ones, which produced better sound quality.

While this competition were taking place another American inventor, Emil Berliner, produced a new solution in 1888. Here the cylinder were replaced by a disc, a solution he called the gramophone, **FIG 4 and 5**. All of these products were showcased in so called 'scientific circuses' during the early 1900s and had started to gain some commercial success. It were also around this time that the classic horns were used and the products were given a spring mechanism which were loaded up by a crank.

The three product categories existed on the market until around the year 1913, by which gramophone technology had completely taken over, mainly due to the economic factors of disc production. During the same year the travel gramophone were introduced which were made by combining a suitcase, mechanical components and an internal horn, **FIG 6.** The travel gramophone led to a big breakthrough for the products within reproduced sound, because of its low price and compact size.

Figure 4. A Kämmer & Reinhardt, gramophone from 1898. Completly hand driven.

Figure 5. A Deutche gramophon from 1910. Spring loaded mechanism.

Figure 6. A Swedish Alto, travel-gramophone from 1932.

The invention of internal horns also led to the product category of furniture gramophones, which were essentially cupboards containing a gramophone and storage for discs, **FIG 7.** Around the 1920s electric products were becoming more common and with this came the introduction of the radio. The growing popularity of the radio led to the combination products radio-gramophones, which gained vastly in popularity in the 1930s. At the end of the 1930s a major commercialization took place, with some notable Swedish manufacturers such as Radiola and DUX radio being on the forefront, **FIG 9.** The manufacturing were turned into mass-production with assembly lines and component based constructions. More breakthroughs came around the years of 1950, with the introduction of thermoplastics and stereo sound. During the era the radio-gramophone furniture products saw a big boom in popularity, **FIG 12**. However the introduction of stereo sound led to speakers and turntables being sold as separate products, thus being a new product category. In the 1960s products were made more compact with the introduction of transistor technology, which also led to new ways of constructing the products, **FIG 15**.

Figure 7. A Victor Talking Machine Co. furiture gramophone, from 1921.

Figure 8. A His Masters Voice, HMV, gramophone, from 1925 .

Figure 9. A Swedish Radiola, radio-gramophone, from 1942. An example of a product made with assembly line manufacturing.

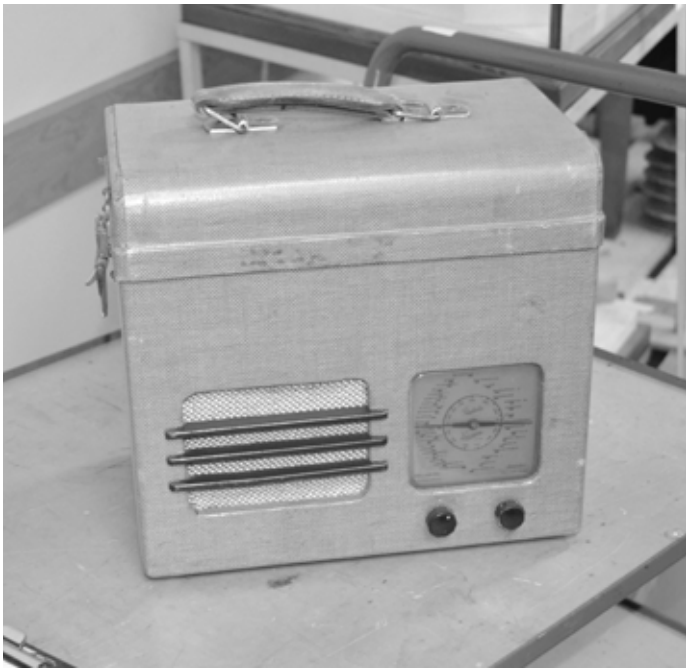


Figure 10. Another Swedish Radiola, travel-gramophone, from 1944. An example of Swedish ingenuity.

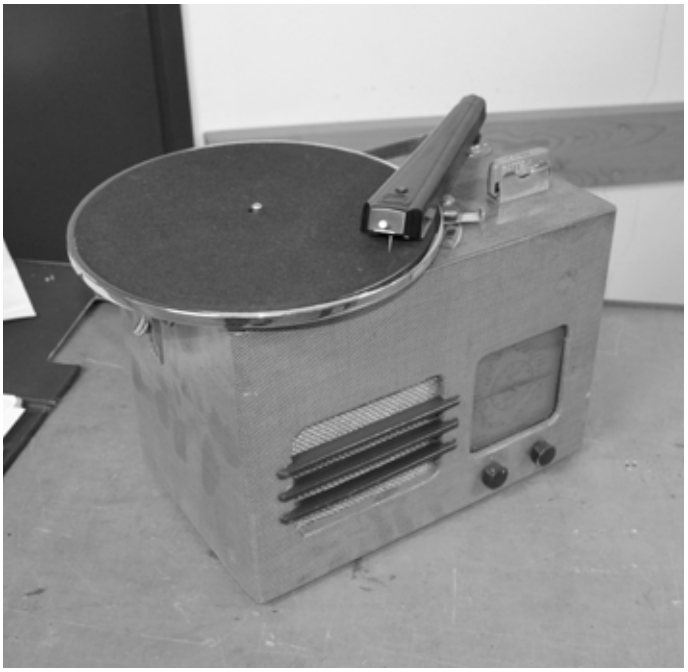


Figure 11. The same Swedish Radiola, travel-gramophone, from 1944. Here put together, as it were used on the beach.

Figure 12. A Telefunken radio-gramophone from 1952 An example of a massive 1950s radio-gramophone.

Figure 13. A Philips turntable from 1956.

Figure 14. A Philiphs travel-gramophone from 1954. An example of the use of thermoplastics.

Figure 15. A Braun radio-gramophone from the 1960s. Dieter Rams design.

During the 1970s another breakthrough took place, with the introduction of the compact cassette. It had been developed by Philips since 1963 and were a major breakthrough for the industry within reproduced sound because it had almost the same sound quality as gramophone discs but with a much smaller size. This also led to the new products category of portable cassette players, which in a similar fashion as the travel gramophones, changed the market because of their low price and compact size. During the 1980s a major product category, which changed the whole industry were developed by Sony, namely the Sony Walkman, a personal cassette player, **FIG 17**. It were a major change since users where able to listen to music on their own while walking, running or in any other setting.

Figure 16. A Panasonic portable cassette player from 1971.

During the same era compact disc (CD) were developed in a collaboration between Philips and Sony. The popularity of CD technology rose in popularity during the 1990s where portable CD players competed with portable cassette players for a market share. In the late 1990s and early 2000s the digital format called mp3 gained in popularity, which saw the rise of another industry changing product, the Apple iPod, **FIG18**. Other manufacturer also had mp3 players, but the iPod were unique because of its ease of use and ability to store a big amount of music.

The digital format later led to music players being integrated with cellphones, which by around the year 2009 became smartphones. Smartphones had a multitude of functions, among those the ability to play streaming, downloaded and radio music. The smartphones also had the ability to be connected to a docking station where another device could control the functions of the phone. Among those available devices were smartphone speakers, to which the phone could either be connected via wireless methods or be placed within. This summed up the basic history of the products, going from hand cranked phonographs using tinfoil, to smartphones connected wirelessly with a pair of speakers.

From this an interesting pattern could be spotted in how the products technology evolved over time. For instance it seemed like products basic functionality were going from being simple, with for instance the phonograph working by simply cranking the handle, to being complex, with the radio-gramophone products featuring an array of different functions and buttons, to becoming simple again, with the smartphones working by simply pressing play on the touch screen. One might say that their **functionality** were going from simplicity-complexity-simplicity, being a technological trend of evolution. This basic understanding moved the project forward to the research design.

Figure 17. The first Sony Walkman from 1979. Personal cassette player.

Figure 18. An Apple iPod from 2004.

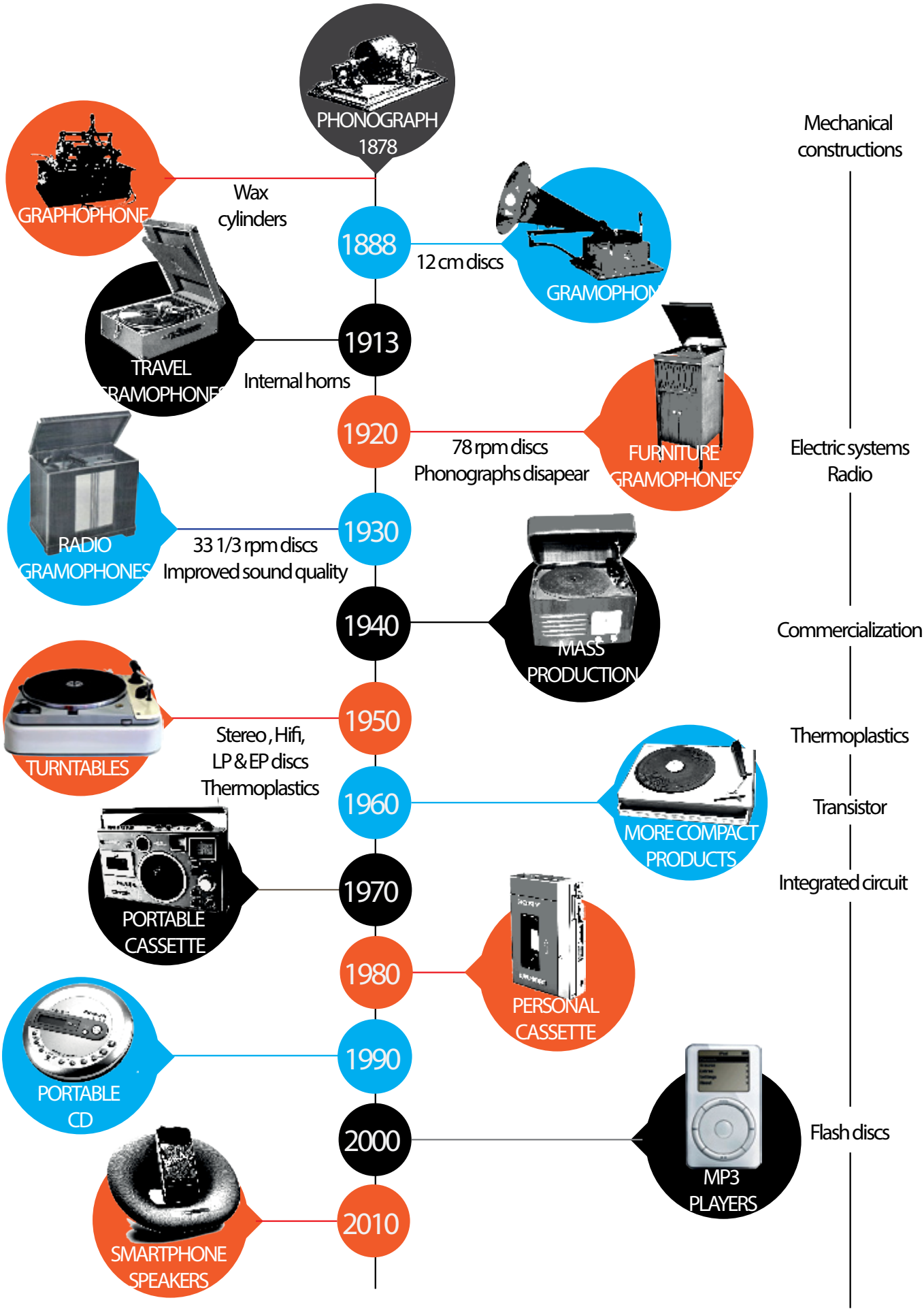


Figure 19 A time line of the development with some of the more important product groups of each century. On the right side of the figure are the technological developments which affected the product groups possible to makde.

3. Research design

This chapter goes through the basic approach of TRIZ and inital idea to solve the task at hand.

3.1. Theory of inventive thinking

In the beginning of the project the supervisor suggested to the author to look up TRIZ, or the theory of inventive problem solving. TRIZ can be defined as an engineering problem solving toolkit, primarily based on the work of Genrich Altschuller. He developed the toolkit by 'researching over 400 000 patents', and finding that problems often are solved following the same basic principles, Gadd (2010). Among the tools are 40 principles to solve engineering contradictions, creativity triggers and the technological trends of evolution. The technological trends of evolution can be described as a way of finding future products, based around eight basic trends, Gadd (2010). One of these trends were the trend found when analyzing the products history, simplicity-complexity-simplicity, which states that – a products basic functionality first is simple, it then increases in complexity and is then simplified again, moving in a cyclic pattern, Gadd (2010). The knowledge of such a trend could have great potential in the hands of an industrial design engineer, because earlier solutions could be analyzed to see if the basic functionality of the product were moving towards simplicity or complexity. The trend also could provide means of being innovative, by figuring out how to actually make the products functionality more simple or complex. This were also an example of how to bridge a gap similar to that which were being sought to fill, since such a trend proved knowledge about technological history, and making it possible to apply directly to a product concept. Therefore the approach of systematically analyzing a quantity of products based on properties were adopted.

Technological trends

Eight technolgical trends, describing how a products technology evolves over time.

1. Increase in ideality

$$\frac{\text{Benefits}}{\text{Cost+Harms}} = \text{Ideality}$$

The system (product) becomes better and cheaper, achieves more benefit/functionality, while costs (inputs) and harms (outputs) decreases.

2.Follow S-curves

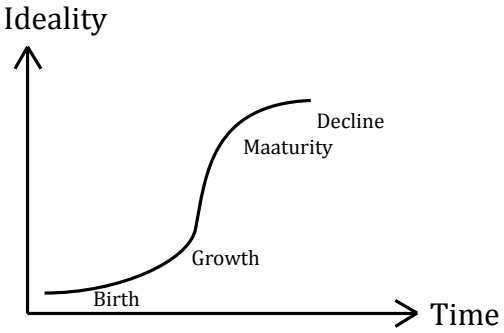


Figure 20. The S-curve of evolution.

Follow S-curves – After being invented new systems improve slowly at first while being developed (birth). After they come onto the market there are normally many improvements both in functionality and how they are made, accompanied by a reduction in cost. This is shown as a rapid increase in Ideality (growth). Eventually this tails off until no further improvement is possible (maturity), and new systems are needed (decline) – with their own new S-curves.

3.Increase in automation

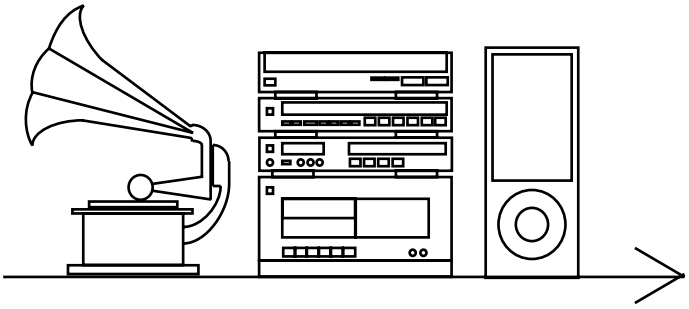


Figure 21. The automation increased from the gramophone to the iPod.

Need less human involvement – The automation increases.

4. Non - uniform development of parts

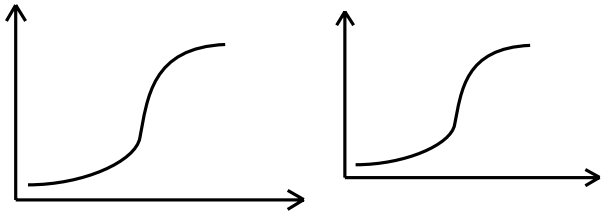


Figure 22. Parts developed at different rates.

Have non uniform development of parts- Some parts of the system develop faster than others.

5.Simplicity-complexity-simplicity

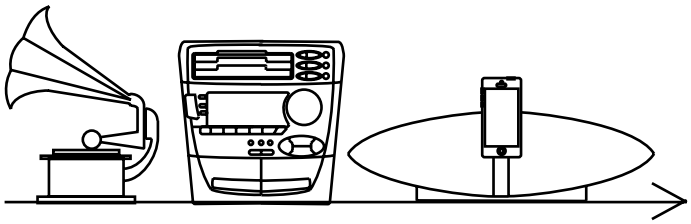


Figure 23. The gramophone were a simple solution; put a disc in, crank handle, put on needle= play. The multisystems were complex; three CD players, two cassette players, an array of buttons. The smartphone speakers were simple; put phone in the speaker, press play.

Simplicity-complexity-simplicity – The first solution to a function is simple, it then increases in complexity and is then simplified again (a cyclic pattern).

6.Increase in dynamism

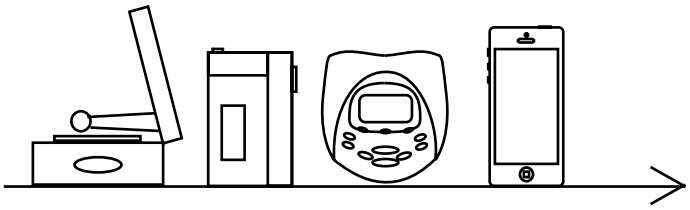


Figure 24. From the travel-gramophone, to the smartphone, the products became more dynamic and flexible.

Increasing dynamism, flexibility and controllability – Products become more segmented, and as they become more segmented they have more parts and therefore need more control.

7. Increase in segmentation

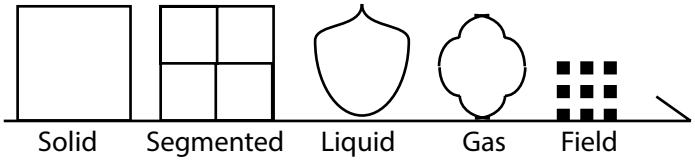


Figure 25. Products use smaller parts and turn into a field

Increasing segmentation and use of fields- The usage of smaller and smaller parts until the parts are so small that together they have become a field effect (also called Transition to Micro-levels and Increased Use of Fields).

8. Matching & miss-matching parts

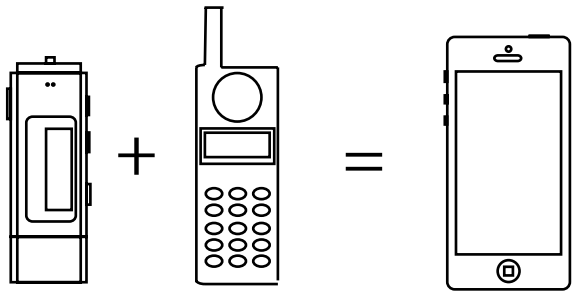


Figure 26. An example of a matching and missmatching of parts. An mp3 player put together with a cellphone, became a smartphone.

Matching and mismatching of parts- Matching function and functionality to all requirements not just the prime output to produce a system which finally delivers everything wanted instead of just some of the requirements.

3.2. Inital idea

There were an immediate challenge with this task however, because the properties of *colors, construction, surfaces and materials* needed to be defined in such a way that they were representative of a change, and in the best of world falsifiable. For instance if products constructions went from being made out of wood to being made out of thermoplastics, it could not simply be stated that a trend were that constructions were going from wood to thermoplastics. Therefore the first thing needed were a framework that defined the named properties. Secondly a methodology to apply the framework and being able to systematically evaluate the properties were needed.

In essence what the author wanted to do were to place the products in a table, with a chronological order, and make a 'product specification', **FIG 27**. This product specification would then be based on the framework, so that the results would be strictly defined. When this categorization would have been completed, how the products properties changed over time could be analyzed, since they would be placed in chronological order. With this research design and basic idea of how to evaluate the products, the research were continued by a book study and synthesizing of form frameworks.

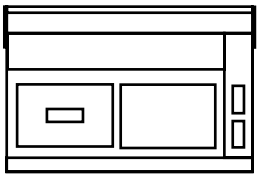
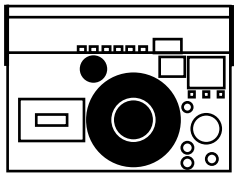
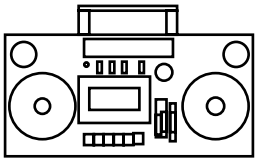
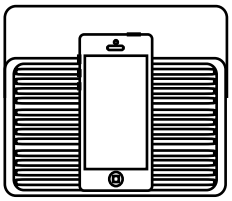
	Year	Colors	Construction	Surfaces	Materials
	1970				
	1975				
	1980				
	2014				

Figure 27. The inital idea of how to evaluate changes in properties over time. The categories were too general and not applicable at this stage. However it gave an idea of how to continue.

4. Book study

This chapter goes through the book study and attempts to apply the found definitions. It were found that few definitions worked out of the box, and therefore a discussion on why can be found after. Lastly a view on epistemology and form can be found, based around the discussion of why the books definitions did not work.

4.1. Book study on form frameworks

The book study were conducted to find possible ways of defining the properties: colors, construction, surfaces and materials with categories. When studying each book/paper, **TAB 1**, it were attempted to apply the categories to the initial idea, with ordering a sample group of products in a chronological order and categorizing them with the definitions. The goal were to find out if the categorization would be strict enough to actually be applicable. With the highest rank of applicability being that the results could be classified as falsifiable. Furthermore it were of importance to see if obvious changes in the products colors, construction, surfaces and material, would be represented by the definitions. The categories would also have to be universal towards all products within the category.

Book	**Author**
1. Universal principles of design	Lidwell (2003)
2. Systematic design of industrial products	Tjalve (2003)
3. Order and meaning in design	Muller (2001)
4. Three dimensional visual analysis	Akner-Koler (1994)
5. A universal grammar for visual composition	Stebbing (2004)

Table 1. The books studied to find possible ways of defining the named properites. Universal principles of design were a book containing a lot more than form and were used for defining colors. A universal grammar for visual composition were a paper that proposed four universal articulations on aesthetic experssion: contrast, rythm, balance and proportion. The rest of the books, systematic design of industrial products, order and meaning in design, and three dimensional visual analysis were more oriented towards product form.

Universal principles of design

The book could be described as a cross-disciplinary collection of principles. These principles covers guidelines, human biases and general design considerations. One of the chapters covered general guidelines in how colors could be used. Following the guidelines were a definition of warm/cool colors, and of four main color combinations.

- **Analogous** Colors that are next to each other on the color wheel
- **Triadic** Colors that are at the corners of an triangle placed in the color wheel
- **Complementary** Two colors that are directly across from each other in the color wheel
- **Quadratic** Colors that are at corners of a square placed in the color wheel

The definitions were seen to be directly useful for the application, as they could easily be placed in a table and used to categorize changes in colors and color combinations, **FIG 28**.

Systematic design of industrial products

The book covered an array of examples of how to systematically develop and understand product form. One of the numerous examples given were called quantified structures, which covered how technical parts can be structured in a product, **FIG 29**. It were presented as a way to evaluate different structures during concept design by moving around their technical elements. An example of this were of how the motor, dust container and nozzle of a vacuum cleaner could be arranged, and how the arrangement affected the products construction.

Tjalves way of defining quantified structures were seen as a potential way of defining specific construction categories, based around the arrangement of elements. However specific arrangement categories needed to be created if it were going to be used.

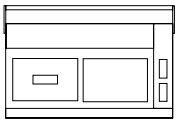
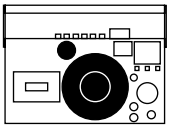
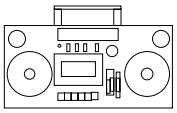
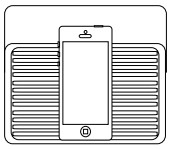
	Year	Colors
	1970	Warm Analogous
	1975	Cold Quadtratic
	1980	Warm & cold
	2014	Warm Analogous

Figure 28. An application of the definitions of colors found in universal principles of design.

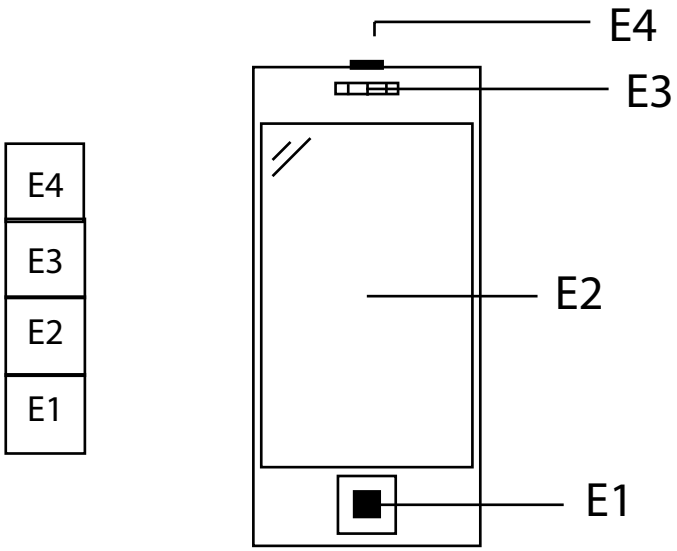


Figure 29. An example of quantified structures of a cellphone, made by the author. E1 were a button, E2 a screen, E3 a speaker and E4 an addition button. These could be moved around by switching their order.

Order and meaning in design

Muller's book can be defined as a structured approach to discuss, understand and develop products form. Three main feature categories are specified, which according to Muller constitute order and meaning within product form: prototypical features, behavior typical features and solution typical features.

Prototypical features

Prototypical features were defined as: 'Products are ascribed a function when a user associates certain properties of an artifact with a goal that is reached with it thus a semantic feature constituting meaning and a solution principle', Muller (2001).

Behavior typical features

Behavior typical features are described as a categorization that is bound to certain form features. These form features are then linked to certain types of usage, for instance an office-chair, a relaxing chair or a kitchen chair.

Solution typical features

The solution typical features could be described as the form, material and ordering of a product. They were divided into three sub-categories: topological ordering, typological ordering and morphological ordering. For each of the three sub-categories Muller gave furthered articulations.

Topological ordering

Topological order were defined as the position of form elements in relation to one another. The sub-category contained four defined positioning systems, linear, radial, central and orthogonal. For each positioning system Muller also gave visual examples concerning chairs.

Typological ordering

Typological ordering were defined as the form type of specific elements, which Muller identified as: circles, polygons, sphere, cylinder, cone, torus and cube. It were explained that since very final form can be seen as a derivative of these formally defined geometrical forms, they constitute the basis of understanding all form types. Within the category Muller also defined what were called composite form and integrated form. Where composite form were articulated as being a unified whole, in which every part had their own form, and integrated form being one totally formed whole.

Morphological ordering

Morphological features were defined as the spatial quality of the embodied elements, which mainly involved the material properties. Here three types were articulated as: linear-, flat-, and massive matter.

Application

The prototypical and behavior typical features were deemed to be completely useless for this application, because they were based upon perceived properties. The topological orderings categories were seen as potential ways of describing differences in construction, but the definitions were vague. The form elements and articulations of composite and integrated form were seen as being useful to analyze the products surfaces, but needed a more clear definition. The morphological features were seen as useful for analyzing the products materials and possibly also surfaces, but needed a more understandable definition. **FIG 30.**

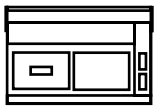
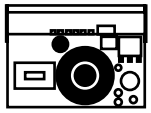
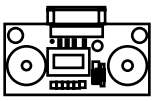
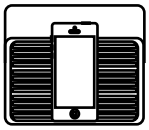
	Year	Prototypical feature	Behaviour typical feature	Topological ordering	Form elements	Composite form	Integrated form	Morphological features
	1970	'Cassette player'	'Boom box'	Orthogonal	Cylinder Cube	-	-	Flat
	1975	'Cassette player'	'Boom box'	Central?	Cylinder Cube	-	-	Flat
	1980	'Cassette player'	'Boom box'	Orthogonal	Cylinder Cube	-	-	Flat
	2014	'Cassette player'	'Boom box'	Orthogonal?	Cylinder Cube	-	-	Flat

Figure 30. An attempt to apply Mullers definitions to the inital idea. All categories except the form elements needed to be adapted if they were going to be used. The prototypical features and behaviour typical features were useless for the application, because they were based perception.

More solution typical features

Within the chapter of solution typical features five more categories of ordering features were defined by Muller: disposition, ordinance, plasticity, constructivity and materiality. These were presented in tables with element, ordering feature and an articulation. The articulations were presented as a way of expressing the differences between the features.

Disposition were presented as: 'Articulation of conditions in phenomenal space as a result of differ-ences in space distribution', Muller (2001). The category could be used to analyze the products surfaces, **TAB 2**.

Element	Ordering feature	Articulation
Symmetry	Symmetrical/asymmetrical	Stillness/Movement Orientation/Lack of orientation Balance/imbalance
Gradua-tion	Regular/irregular Rhythmic/arrhythmic	Ordered/unordered Static/dynamic Boring/lively Harmonic/disharmonic

Table 2. The disposition of elements according to Muller.

Ordinance regarded the symmetria and eurhythmy. Where symmetria were presented as being: 'ratios of sizes describing the same direction in space', Muller (2001). Whereas eurhythmy were described as: 'sizes describing different directions in space', Muller, (2001), **TAB 3.**Here the both the definitions of symmetria, eurhythmy, and their ordering features, were of interest as ways of analyzing the products construction.

Element	Ordering feature	Articulation
Symmetria	Lare/small Importan/unimportant	Narrow/wide High/low
Eurhythmy	Lean/stocky Heavy/light	Elegant/clumsy Stable/unstable Fragile/sturdy

Table 3. The ordinance according to Muller.

Plasticity referred to the overall integration of the product, the surfaces complexity, its size and shape, **TAB 4**.

Element	Ordering feature	Articulation
Size, shape	Space-filling/space-structuing Organic/geometric	Closed/open Rough/elegant Voluminous/compact Natural/artifical
Surface complexity	Uniform/multiform	Simple/complex

Table 4. The plasticity according to Muller.

Constructivity were described as the surface intersections and surface shape, **TAB 5**.

Element	Ordering feature	Articulation
Surface intersection	Single/composite Segmented/un-segmented	Simple/complex Closed/open Connection/separation
Surface shape	Angular/rounded Flat/curved Continous/dis-continous	Hard/soft Tension/without tension Gradual/abrupt Integration/differentiation

Table 5. Constructivity according to Muller.

Verdict

Overall the solution typical features presented were possible ways of analyzing the products construction, surfaces and materials. However a problem were that lot of the articulations were based around perceived properties, and therefore needed to be adapted to be applicable, **FIG 31**.

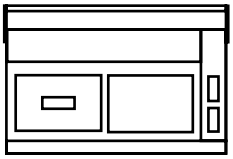
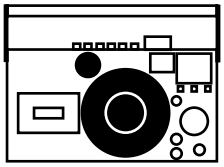
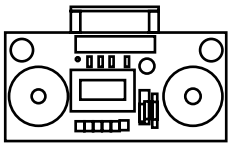
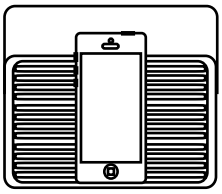
	Year	Disposition	Ordinance	Plasticity	Constructivity
	1970	'Stillness'	'Small'	Uniform Geometric	Cylinder Cube
	1975	'Movement'	'Small'	Multiform Geometric	Cylinder Cube
	1980	'Unordered'	'Large'	Multiform Geometric	Cylinder Cube
	2014	'Balance'	'Small'	Multiform Geometric	Cylinder Cube

Figure 31. An attempt to apply Mullers furthered solution typical features. Most were based on percieved properties, thus were not applicable. It ought not be forgotten that these articulations can be useful when discussing form in general. It were for this specific application that they could not be used.

Three dimensional visual analysis

Akner-Koler:s book took a similar approach to product form as Mulllers. Within the book she defined four main categories which product form can be evaluated from: elements and their properties, movement and forces, relationships, and organization. For each category she provided visual examples and articulations to discuss, understand and evaluate form.

Forces were defined as a way to 'induce structural asymmetry', which were 'expressed in bending or curving of the inner axis of a form and the elements parts', Akner-koler (1994).

Three different axis:s were defined: straight, bent and curved, **FIG 33.** A straight axis involved a one-dimensional movement, without any forces acting upon it. A bent axis were defined as: 'incorporating two activities from different directions…; the movement of the axis and the force that abruptly changes the course of the axial, movement creating a sharp bent angle', Akner-Koler (1994). A curved axis were articulated as: 'two or more activities from different dimensions: axial movement, and the force(s) that gradually change the course of the axis', Akner-koler (1994).

Curves were then split up into three sub-categories: mono-, bi- and compound curve, **FIG 34**. Where a mono-curve were defined as: 'a rectangular plane which is changed by a curved plane with the two end edges remaining straight', Akner-Koler (1994). A bi-curve being articulated as 'the combination of two curves which are bent in two different directions', Akner-Koler (1994), and a compound curve: 'the combination of three or more curves which are bent in different directions', Akner-Koler (1994).

The category of movement and forces were seen as a potential way of analyzing products surfaces, but problems arose when trying to strictly define if movement could be seen in the products. Therefore an adaption were needed if the category were going to be used. The definitions of curves did present the highest grade of applicability by being falsifiable, but needed to be simplified in order to be understandable, **FIG 35**.

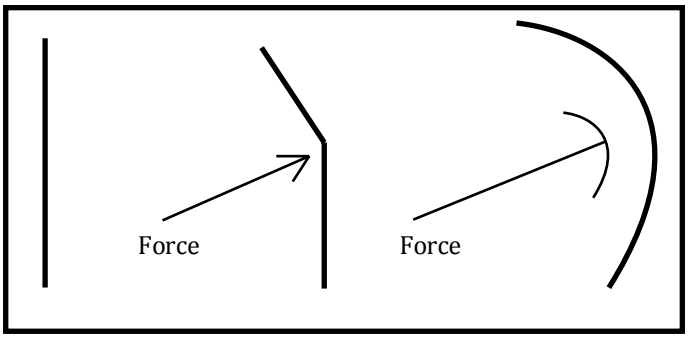


Figure 33. Three axis:s, straight, bent and curved. Figure by the author.

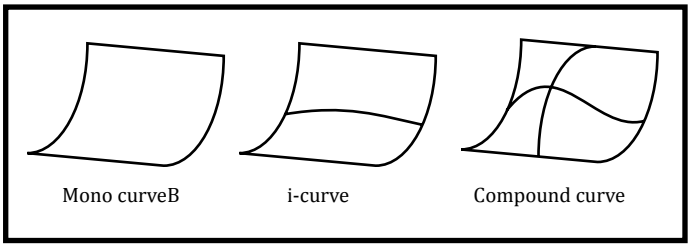


Figure 34. Three curve-types: mono-,bi- and compound curve. Figure by the author.

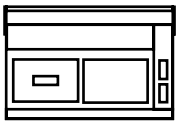
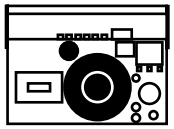
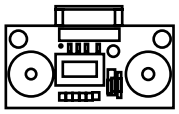
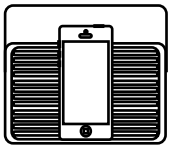
	Year	Forces	Curves
	1970	'No movement'	No curves
	1975	'Movement'	No curves
	1980	'Movement'	No curves
	2014	'No movement'	Mono curves

Figure 35. An attempt att applying the definitions to the original idea. Curves were highly applicable, but forces needed adjustments.

A universal grammar for visual composition

A universal grammar for visual composition were a publication, based on the research of 50 books on visual composition. The publication concluded that four terms were used frequently in each book; 'contrast, rhythm balance and proportion', Stebbing (2004). Because of their frequent use Stebbing proposed that the terms could be used a universal grammar to discuss and articulate aesthetic expressions.

- **Contrast** Any element of color contrasting one another
- **Rhythm** The results from the repetition of a contrast
- **Balance** The relationship between contrast and rhythm
- **Proportion** The measured relation between the components of a design

From the paper the definitions of contrast and rhythm had a potential use to analyze the products surfaces and what would be named form complexity, - how complex the form were according to the amount of contrast and rhythm. With the aid of visual examples from the paper and Stebbings explanation of what contrast and rhythm were, it were determined that strict categories could be created, **FIG 36**. Furthermore these categories could also be falsifiable.

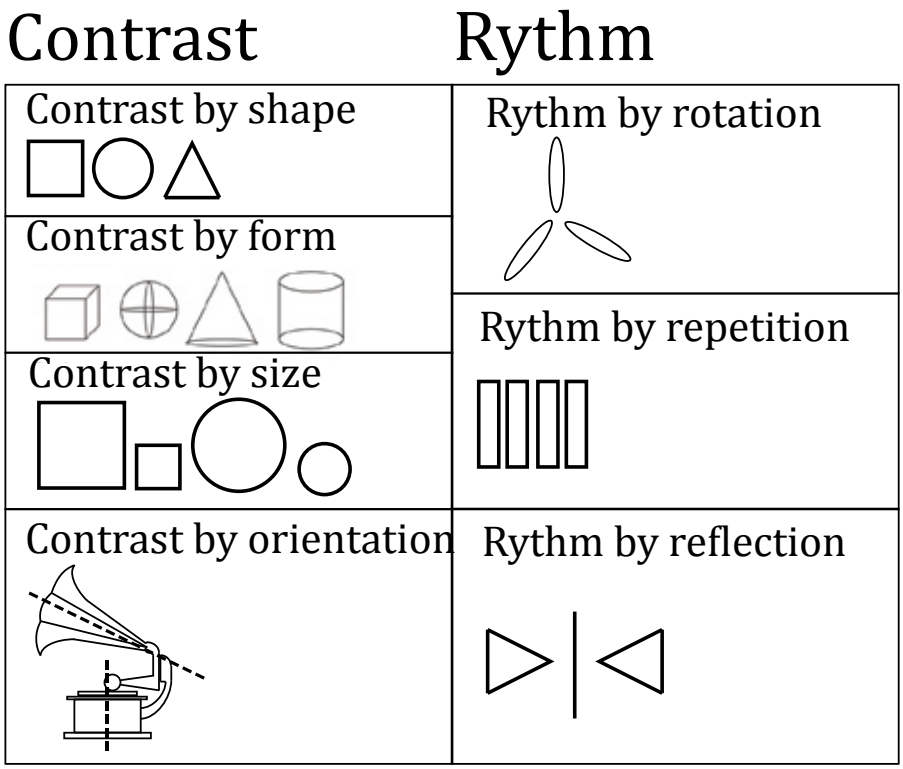


Figure 36. The authors definitions of what were found in the paper by Stebbing.

4.2. Discussion on book study

Considering the books studied on form, a pattern were emerging which concerns current definitions of meaningful properties and aesthetic properties. Specifically the book 'Order and meaning in design', Muller (2001) were linked to this pattern. The pattern were that a lot of categories mixed what can be defined as meaningful properties, and aesthetic properties, in a way where it seemed like they were trying to measure meaning. With measuring meaning the author refers to trying to measure perceived qualities. For instance Muller (2001) described that prototypical- and behavior typical features were linked to semantic features constituting meaning. These feature categories could only be used to discuss form with others, not measure it, because they were linked to perceived qualities and were even defined as such. However within the feature category solution typical features, a great mix of meaningful and aesthetic properties could be found, with for instance symmertia (the measurement in one direction) defining an articulation of 'important/unimportant', Muller (2001). The articulation were linked to a perceived quality (meaningful property) but the element were a falsifiable one: the measurement of an artefact in one direction.

Another example could be found in the definition of 'movement and forces', Akner-Koler (1994), where a force were acting upon a bent or curved axis, creating movement. This type of definition could be useful in a discussion about form, but were also close to being a definition on how to measure meaning. When conducting the study, these patterns were initially hard to grasp, but were simplified when the categories were put in tables, and trying to see if the results could be questioned without ending up in a circle argument. The importance of having strict results were linked to the end goal of the framework, which were: to be able to categorize products based around clearly defined properties, and seeing if these properties changed consistently over time. If the properties were perceived ones, then they would have been useless for this application. An example of why such results would be useless, could be found by analyzing a current portable stereo and its form properties, **FIG 37.**

Its basic geometric form of a cylinder and the way that it were carried, made it closely resemble a bazooka (anti-tank weapon). Thus a user might associate a "macho" or "explosive" image with the product. Thus one would have a measurement: the basic geometric form, and an articulation: macho, or explosive. If one now hypothetically would have found a product from the year 1878, with the same basic geometrical form of a cylinder, one could now compare it to the portable stereo of 2014, and believe that it were associated with a "macho" image in 1878 as well. Problems would arise with that type of conclusion however, because bazookas did not exist in 1878. Thus one could not know if a user would have associated the same image with the product, because one could not know what the users had experienced prior. One could say that an eminent little problem had arose. This eminent little problem were linked to that it were an attempt at measuring meaning, or a perceived quality. This led the author to the subject of epistemology.

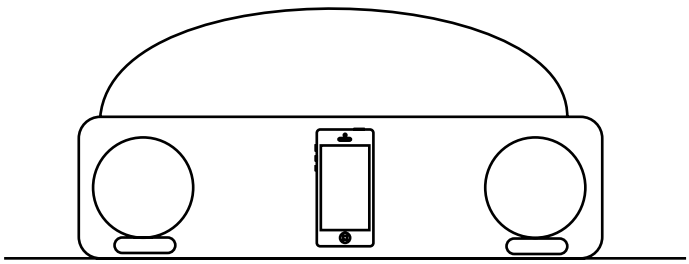


Figure 37. A boombox, which could be compared to a bazooka, in the way that it were carried, and form properties.

4.3. Epistemology and form

In an attempt to understand the problem from a broader point of view the author took inspiration from Immanuel Kant, and his definition of analytical and synthetic propositions, found in 'Critique of pure reason', Kant (1787). An analytical proposition were for instance: "An oak is a tree", and a synthetic proposition were for example: "All oak trees are tall".

The analytical proposition were a truth in itself, because within the concept of oak it could be found that it were a tree. The synthetic proposition however, were neither true nor false and it could only be defined within a framework. So by for instance saying: "all oak trees are tall in comparison with rose bushes", the synthetic proposition were objectively measurable considering the presented framework. Another synthetic proposition were for instance 5+5=10. Which were only objective within the framework of addition.

For a framework this meant that either defined opposites or measurable properties must have been presented in order to propose that a product form could be placed within a certain category.
For instance if one wished to measure the "movement" of a selected group of products, the only way to go about this would have been to define what movement were and what "no movement" were, and then place the products in relation to one another. If one takes this argument further, it could be said that the products only could contain movement in comparison with one another, which also meant that what was being measured were only "true" within the framework presented and thus were not a perceived meaning.

The distinction of analytical and synthetic propositions can be linked to the view that human experience were based on perception, which were interpreted with concepts. These concepts were defined by frameworks. This distinction also meant that the world as it is, were unknowable, and the only thing that can be known were other peoples concepts, **FIG 38.** Thus referring to that product form, as it is, were unknowable. Therefore one could not measure the meaning of things, because meaning were based upon perception. Thus the only thing that could be done were to propose a framework to define concepts, because the framework makes the proposition measurable.

An example of this would be to define the complexity of form. The only thing that could be proposed were that a products form had a certain complexity according to a framework. However it could not be proposed that it thus had a certain visual complexity, because visual complexity, from this point of view, were based on perception. Thus visual complexity would be subjective. This epistemological view sums up what was being sought for when defining a synthesized framework, which were the next part of the project.

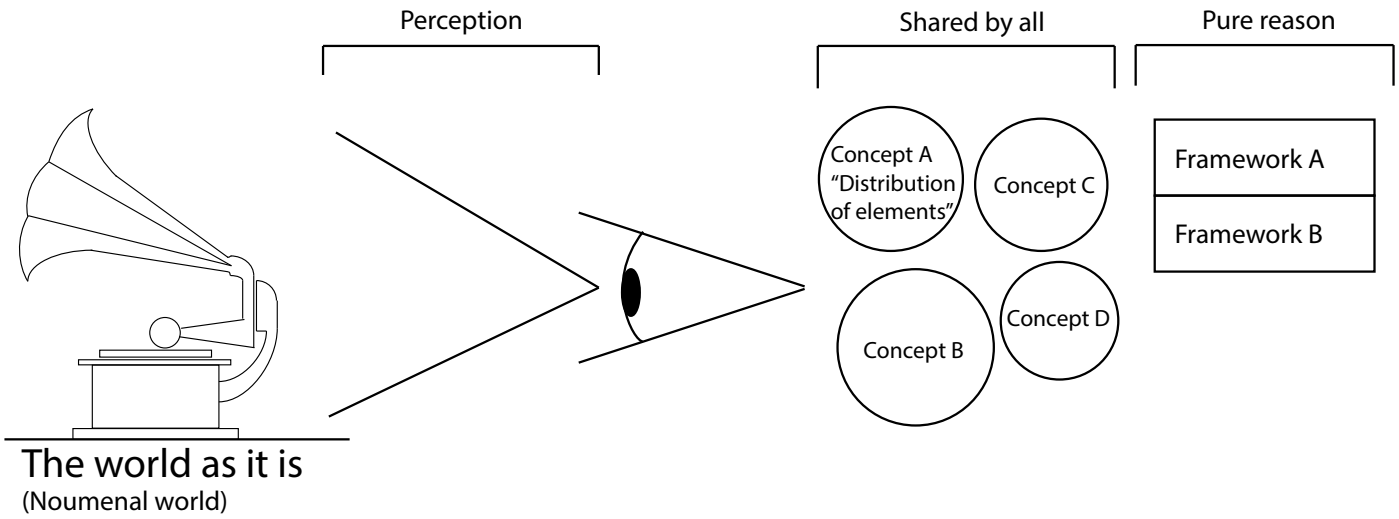


Figure 38. The authors view upon human experience: human experience were based on perception, which were interpreted with concepts. These concepts were defined by frameworks. This distinction also meant that the world as it is, were unknowable, and the only thing that can be known were other peoples concepts,

5. Synthesized framework

This chapter goes trough the created framework, based upon the earlier book study and epistemological view. It finishes with a discussion.

5.1. Framework

From the attempts at applying the original frameworks, and looking into epistemology, a synthesized framework were created by analyzing more sample data. The goal were to create a categorization that would be strict enough to actually be applicable. With the highest rank of applicability being that the results could be classified as falsifiable. Furthermore it were of importance to see if obvious changes in the products colors, construction, surfaces and material, could be represented by the definitions, **FIG 39.**

The framework created featured ten classes with formal definitions. The classes were split up into three levels of abstraction where each level represented a deeper level of understanding, **FIG 40.**

The first level covered the products colors and part of the products construction by determining how elements in the product were distributed. In the second level it were determined how the elements were positioned in relation to one another and covering the second part of the products construction. The third level covered the products surfaces by analyzing their movement, materials, form integration and form complexity. Each class then had set categories with given articulations. The order of the classes and abstraction levels were based upon how abstract the concept were, with the rationale that if one asked what color a specific product had, most people would be able to answer, but if one asked in witch positioning system certain elements were following within a products form, the concept would likely be more abstract for someone unexperienced. It were also a way to split up the properties in a coherent manner.

Figure 39. The process of adapting the frameworks against sample data. The data were analyzed with the orignal frameworks definitions, it were then detirmined if any obvious changes could be detirmined with the definition. If not it were adpated.

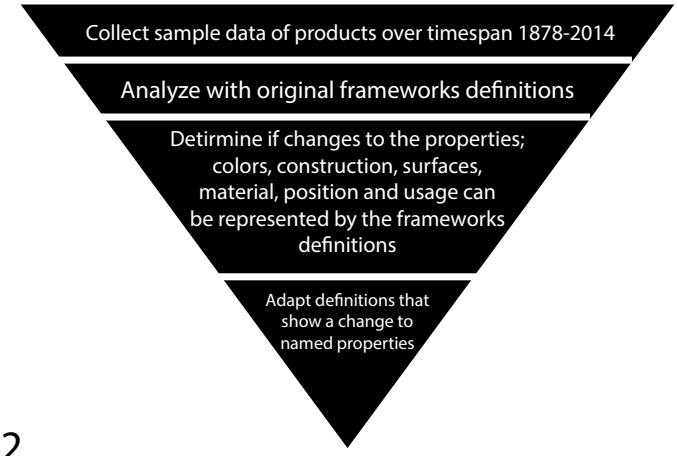
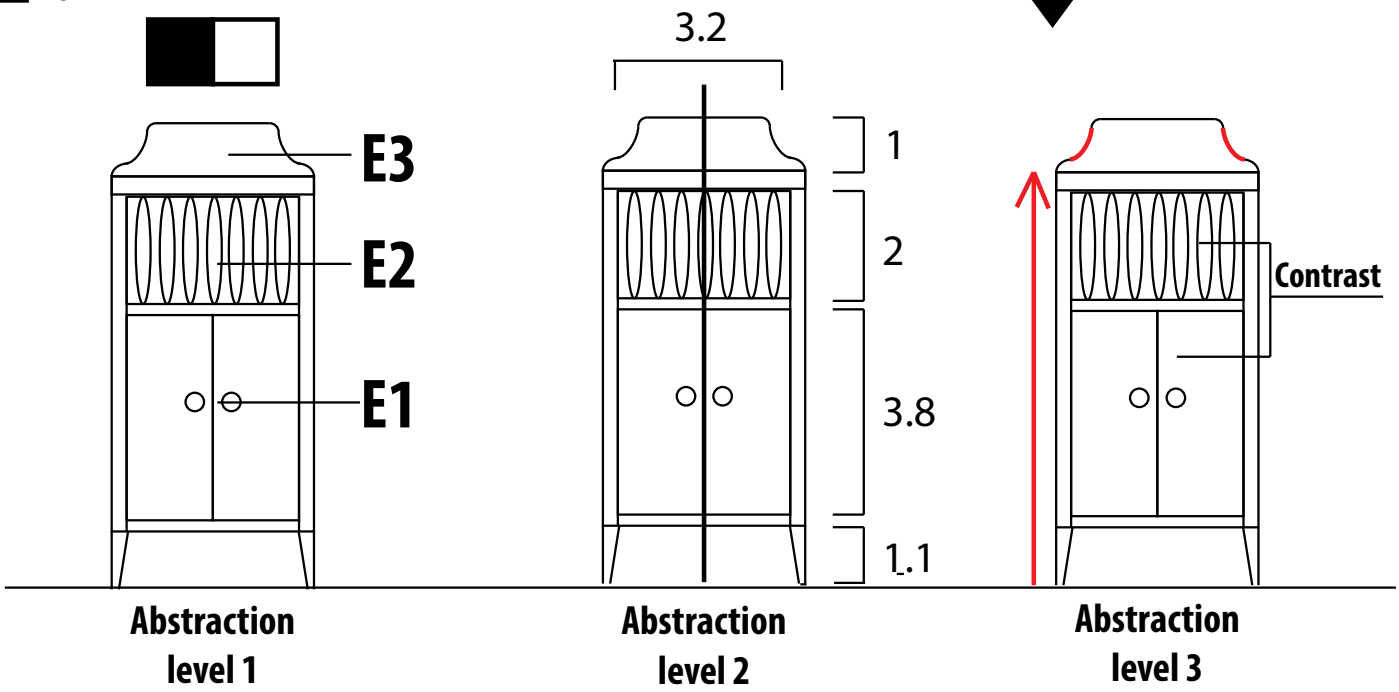


Figure 40. Three abstraction levels.



1. Colors

The first class in the framework involved the colors of the product and categorizing them from the following criteria, **FIG 41**.

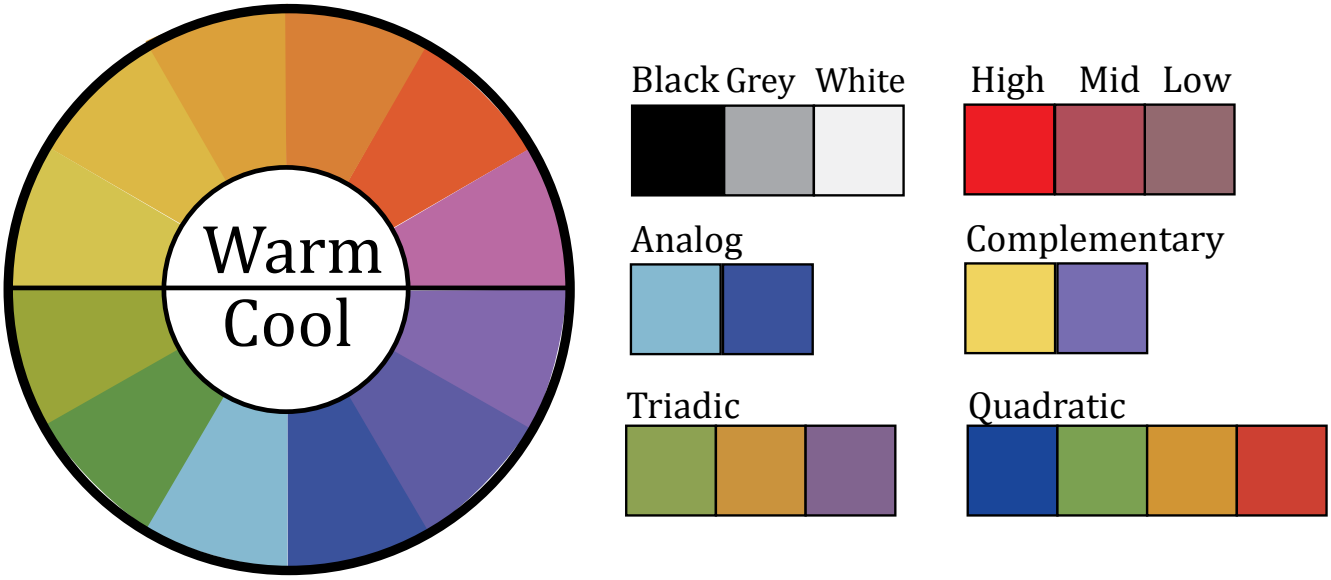


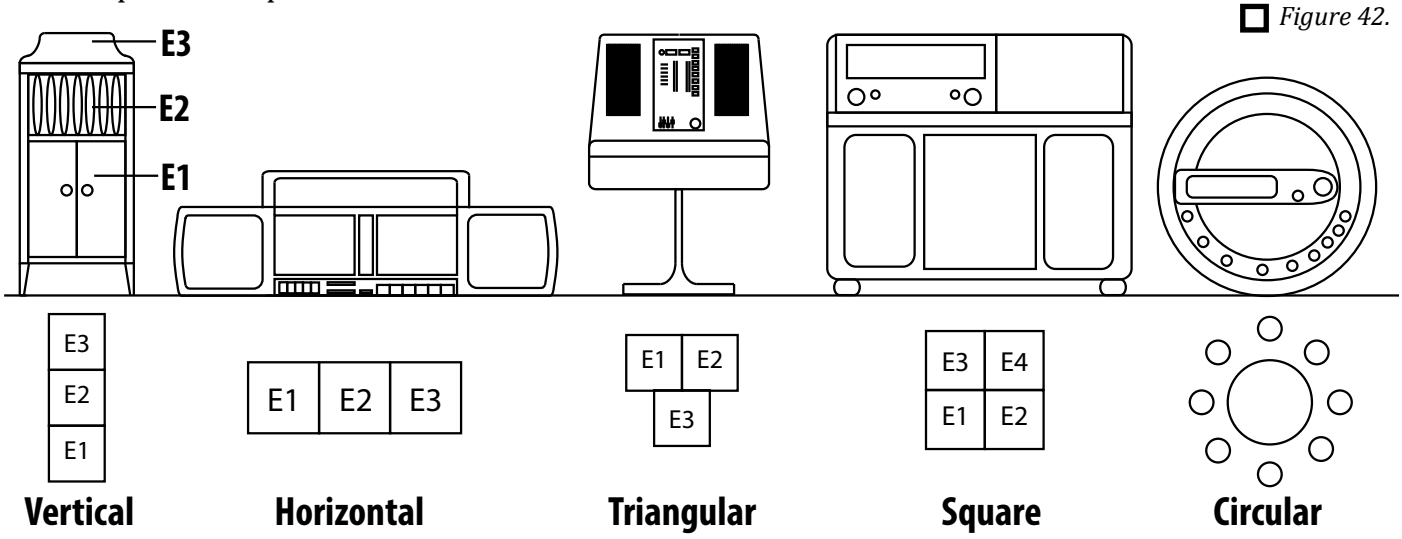
Figure 41. The definitions of colors within the framework.

- Warm and cool colors
- Black, grey white
- High-, medium-, and low saturation
- **Analog** Colors that were next to each other on the color wheel
- **Triadic** Colors that were at the corners of an triangle placed in the color wheel
- **Complementary** Two colors that were directly across from each other in the color wheel
- **Quadratic** Colors that were at corners of a square or rectangle placed in the color wheel

2. Arrangement of functional elements

The second class of the framework were invented by using Tjalve,(2003) visual examples of quantified structures and defining formal categories from what were found in the products. A functional element were seen as any part of a product that fulfilled a technical functionality, and therefore the category covered part of the products construction. **FIG 42**.

Figure 42.



- **Vertical** Each functional element were displaced vertically from the next
- **Horizontal** Each functional element were displaced horizontally from the next
- **Square** The functional elements were placed within a square or rectangle
- **Triangular** The functional elements were placed in a triangular arrangement
- **Circular** The functional elements were placed in a circular pattern

3. Positioning system

This class covered two parts in defining how form elements were positioned in relation to one another. The first part involved categorization using four definitions from Muller (2001) book, which were adapted and simplified for this application, **FIG 43**.

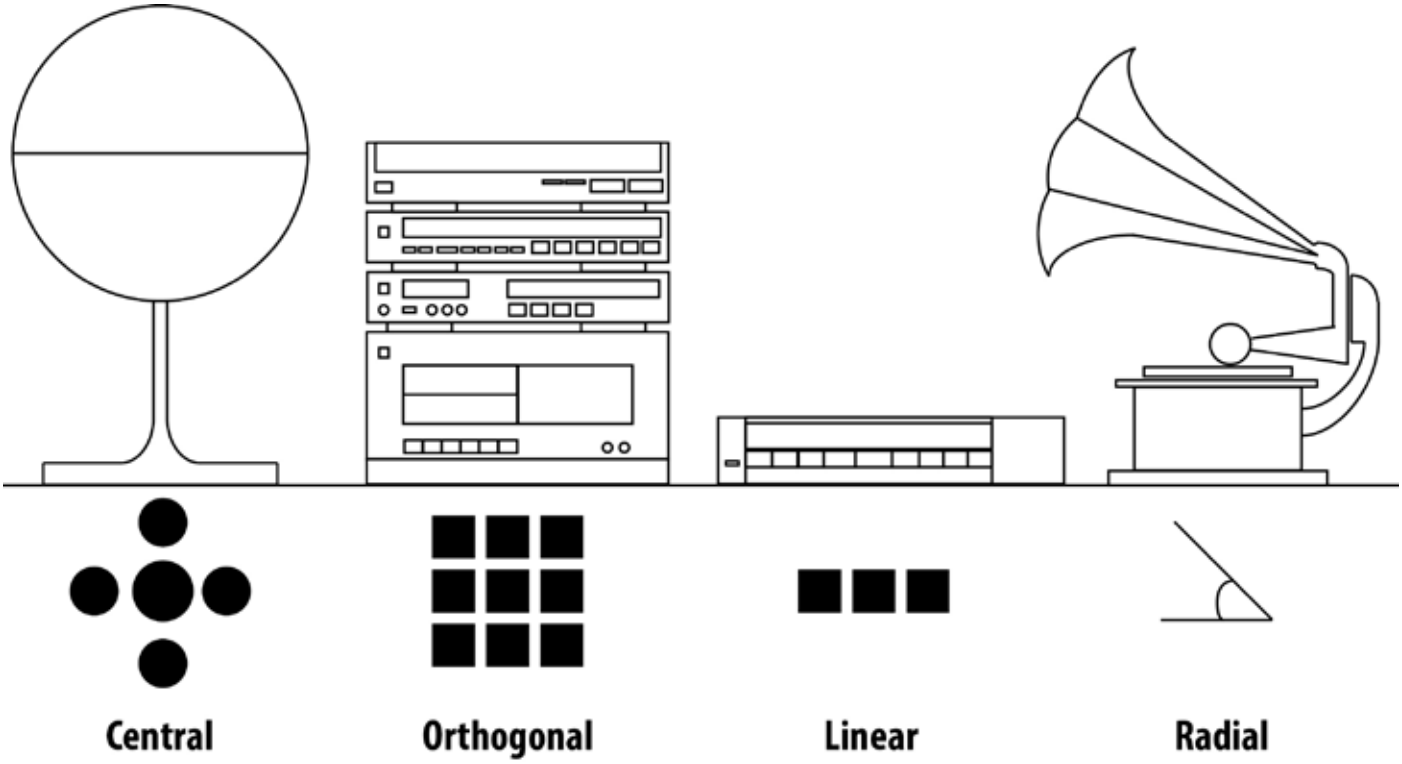


Figure 43. The positioning systems: central, orthogonal, linear and radial.

- **Central** Form elements were positioned around or towards a central axis of the product
- **Orthogonal** Form elements were placed in a square or rectangular positioning system
- **Linear** Every extension or form element were placed along a line or curve
- **Radial** An extension or form element were placed at an angle form another

The second part involved determining if the positioning system were formal or informal, where an informal positioning system were defined as containing elements which were displaced from the coordinate system, **FIG 44.** The class dealt with both constructions and to some extent user interfaces, independent of which the four definitions were applicable.

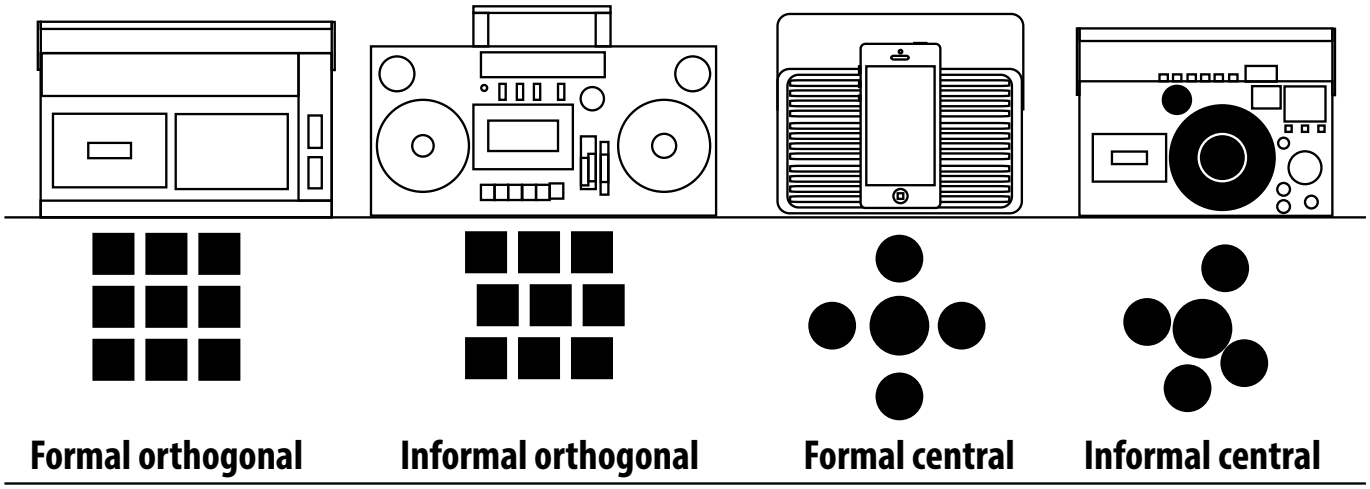


Figure 44. Examples of formal and informal positioning systems.

4. Ordinance

Ordinance were the measurements and proportions of a product with the definitions adapted and simplified from Muller (2001). Ordinance were split up into two subclasses, symmetria and eurhythmy, where symmetria were the measurement in one direction and eurhythmy the ratio between height and width. Categorizing the products with symmetria involved a comparison of products within the same product category with the defining opposites: high/low and narrow/wide, **FIG 45**. The articulations were only possible to define within a comparison and were used to understand how the products constructions changed over time.

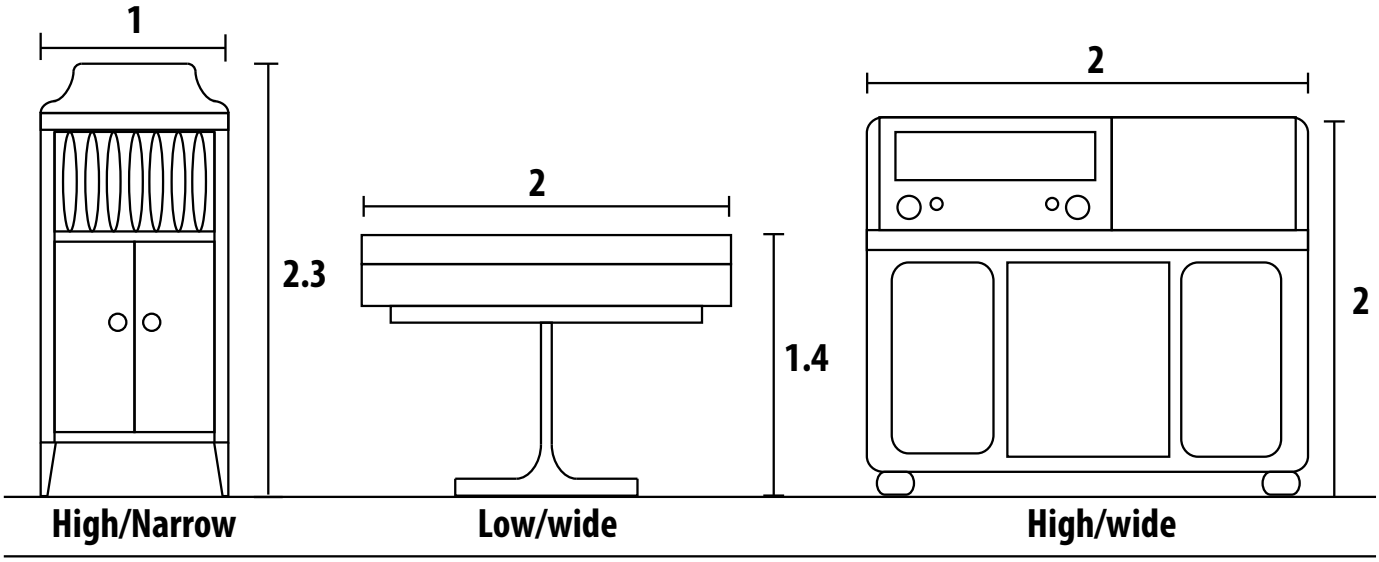


Figure 45. Examples of measurements of ordiance, and comparison of products.

5. Geometric forms

The first part of analyzing the products surfaces were to determine which geometric forms they could be identified to contain. The elements categorized were limited to: sphere, cube, cylinder, cone and torus, **FIG 46**.

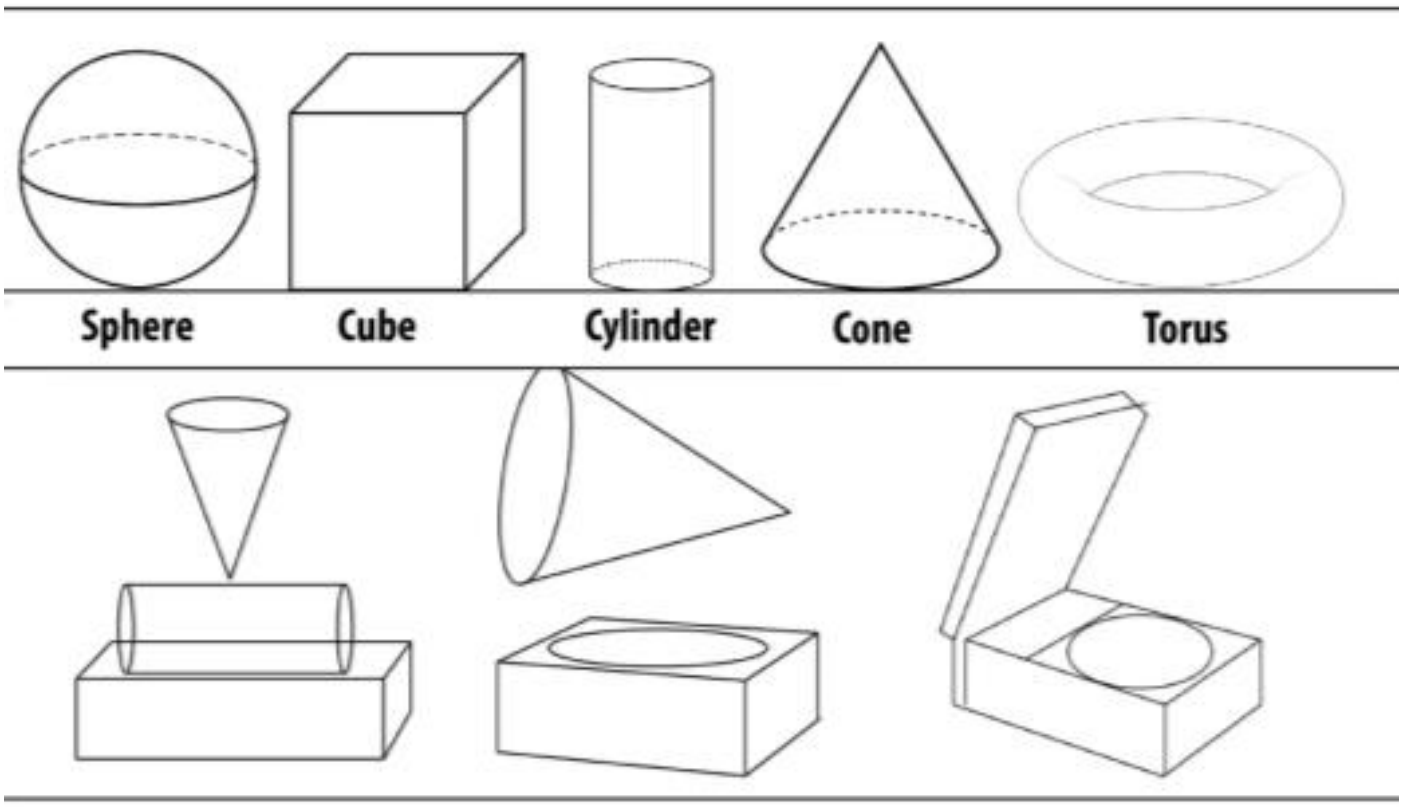


Figure 46. Geometric forms used to categorize the products.

6. Movement

The second part of analyzing the products surfaces featured simplified definitions of forces and visual balance from Akner-koler (1994) and a definition of disposition from Muller (2001). The category dealt with curves, axis orientation and disposition which could create 'movement' if they were unbalanced (asymmetrical). The first part of analysis involved categorization with three defined curve-types, **FIG 47**. The class also concerned if the products contained movement trough axis orientation and/or forces, both of which were recognized by looking for asymmetrical curves and axis:s, **FIG 48**.

Axis orientation – Movement (in direction)/balanced. **Forces** – Movement (in direction)/balanced

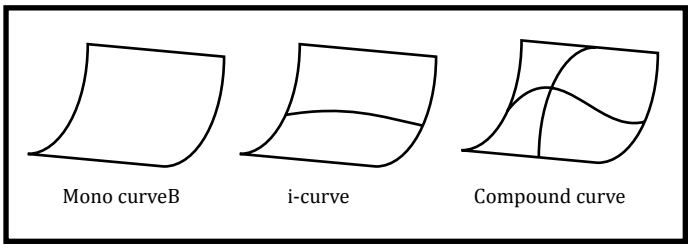


Figure 47. Three types of curves, mono-,bi-, and compound curve.

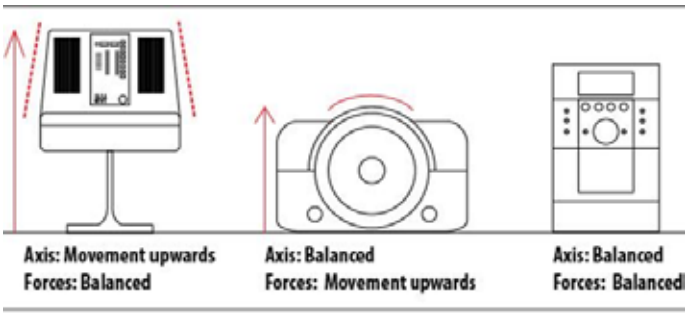


Figure 48. Movement trough axis orientation or forces.

The disposition of elements were instead a comparison of form elements sizes and position in relation to one another, with six defining articulations adapted and simplified from Muller, (2001). Categorizing products with the six definitions were only possible within a comparison and were used to compare constructions, surfaces, and to determine if there were any movement created by form elements disposition, **FIG 49**.

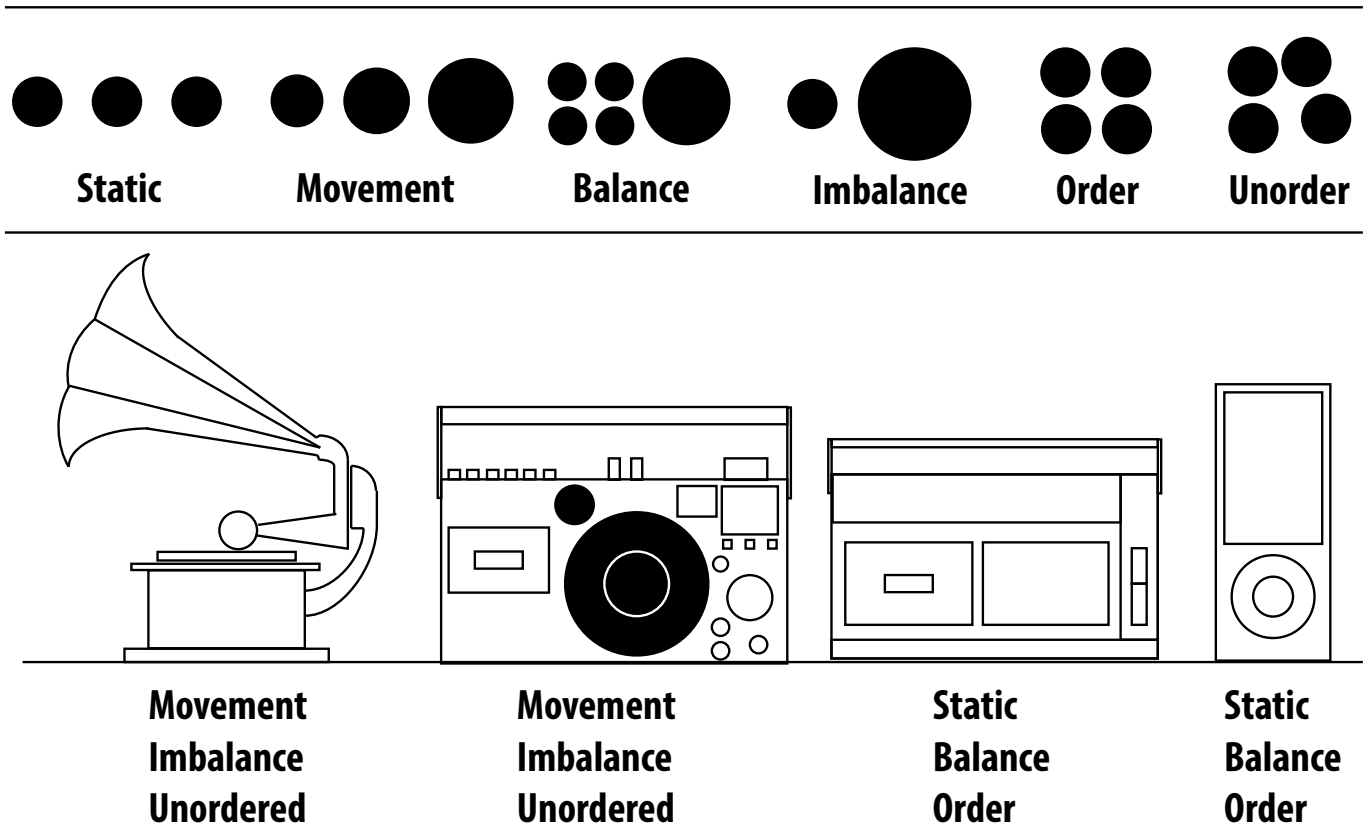


Figure 49. Three opposites concerning disposition: static/movement, balance/imbalance and order/unorder.

7. Materials

Within this class the basic materials were noted down, **FIG 50** and **FIG 51**.

Figure 50 A Philips turntable from 1974. Made out of thermoplastics and alumnium.

Figure 51. A Radiola radio-gramophone from 1951. Made out of a classical scandinavian, bent wooden frame. With thermoplastic buttons.

8. Morphological features

The last part of analyzing the materials were to categorize the products with simplifications of Muller (2001) three definitions of morphological features. The category were used to define how surfaces were built up and a way to determine manufacturing aspects (plastics were often made from massive matter, wood from flat matter and so forth), **FIG 52** and **FIG 53**.

- **Linear matter** Open frames of wire or tubes
- **Flat matter** Flat shaped matter, such as wooden boards
- **Massive matter** One solid piece, such as molded plastic pieces

Figure 52 A Philips travel-gramophone from 1969. Made mostly out of flat plasic pieces, and massive plastic pieces.

Figure 53 A HMV gramophone from 1925. The tonearm were linear matter, while the wooden boards were flat matter.

9. Form integration

The basis of this category were an adaption from (Muller, 2001) categories constructivity, plasticity and typological features, with a simplified definition created for this application. Form integration deals with the surface shape, surface complexity, form elements and how they were intersected. When for instance a technological element such as a button, were integrated or taken away, the named factors were also affected. In essence the category deals with defining a relationship between technology and form, since technological elements also have a form. Composite and integrated form were defined as two opposites, and in simple terms composite form could be described as consisting of many different form types with segmented surface intersections and an integrated form consisting of a few coherent forms with un-segmented surface intersections, **FIG 54** and **TAB 4**.

Composite ——————————— Integrated

Form elements	Geometric, organic	Geometric	Geometric
Surface complexity	Uniform and multiform	Uniform	Multiform
Surface intersections	Angular, segmented	Angular, segmented	Rounded, un-segmented
Surface shape(s)	Dis-continuous, flat	Continuous, flat	Continuous, rounded

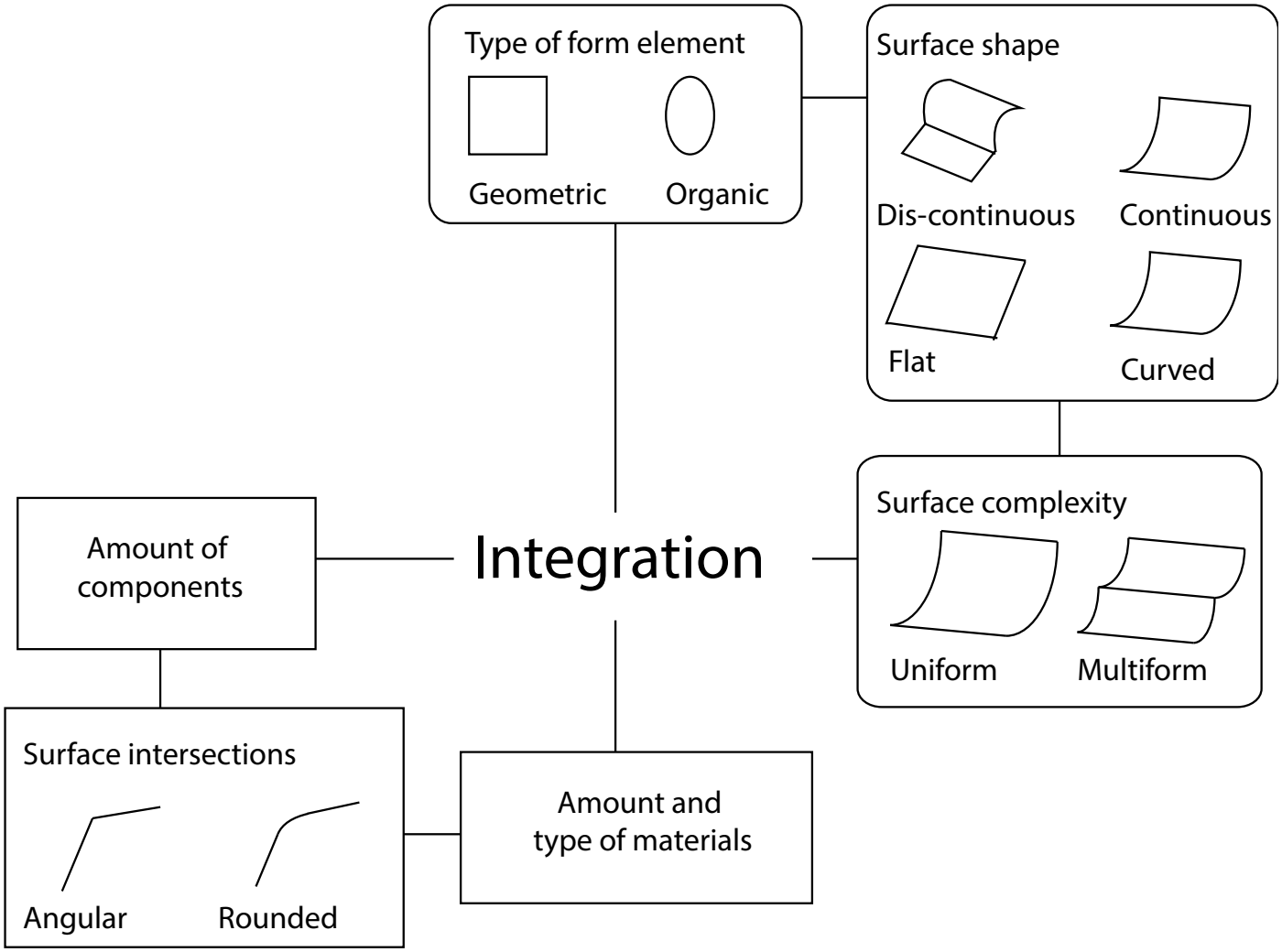
Figure 54. The form integration, dependent on the form elements, surface complexity, surface intersections and surface shape(s).

Category	Articulation
Form elements	Geometric/organic
Surface complexity	Uniform/multiform
Surface intersection	Segmented/un-segmented
Surface intersection	Angular/rounded
Surface shape	Continuous/dis-continuous
Surface shape	Flat/curved

Table 4. The properties affecting the form integration. With defining opposites.

The relationship between the categories and how they affected the form integration were dependent on the type of form elements and surface complexity which together affected the surface shape. The amount of components and type of materials, which together highly affected the surface intersections.

The coherency of the factors: type of form elements, surface complexity and shape highly affected how integrated a form were, with more coherency leading to higher form integration. The amount of components, materials and surface intersections affected the integration, where a lesser amount led to a higher form integration. This category were considered to be one of the key aspects of the framework.
See FIG 55 next page.



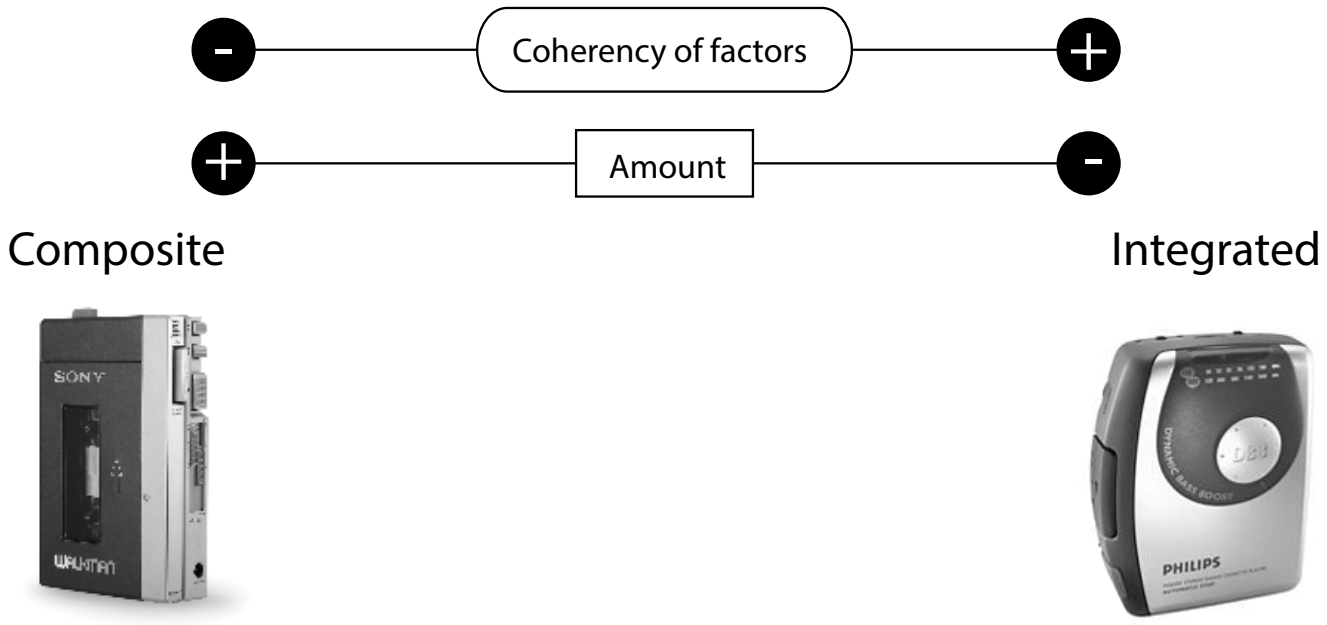


Figure 55. The form integration were a factor dependent on coherency and amount of- form elements.
Two opposites were placed in the figure, with a Sony Walkman from 1979 and a Philips from 1993. Notice how the surface intersections were affected by the amount of elements, with the Philips having less.

10. Form complexity

The last category within the framework dealt with the products form complexity in terms of contrast and rhythm. Four definitions of contrast and three definitions of rhythm were created based mainly upon visual examples from Stebbing (2004) publication, **FIG 56**. A link were also found between contrast, rythm, and movement, integration. More movement, with less integration led to higher form complexity, and vice versa, **FIG 57.**

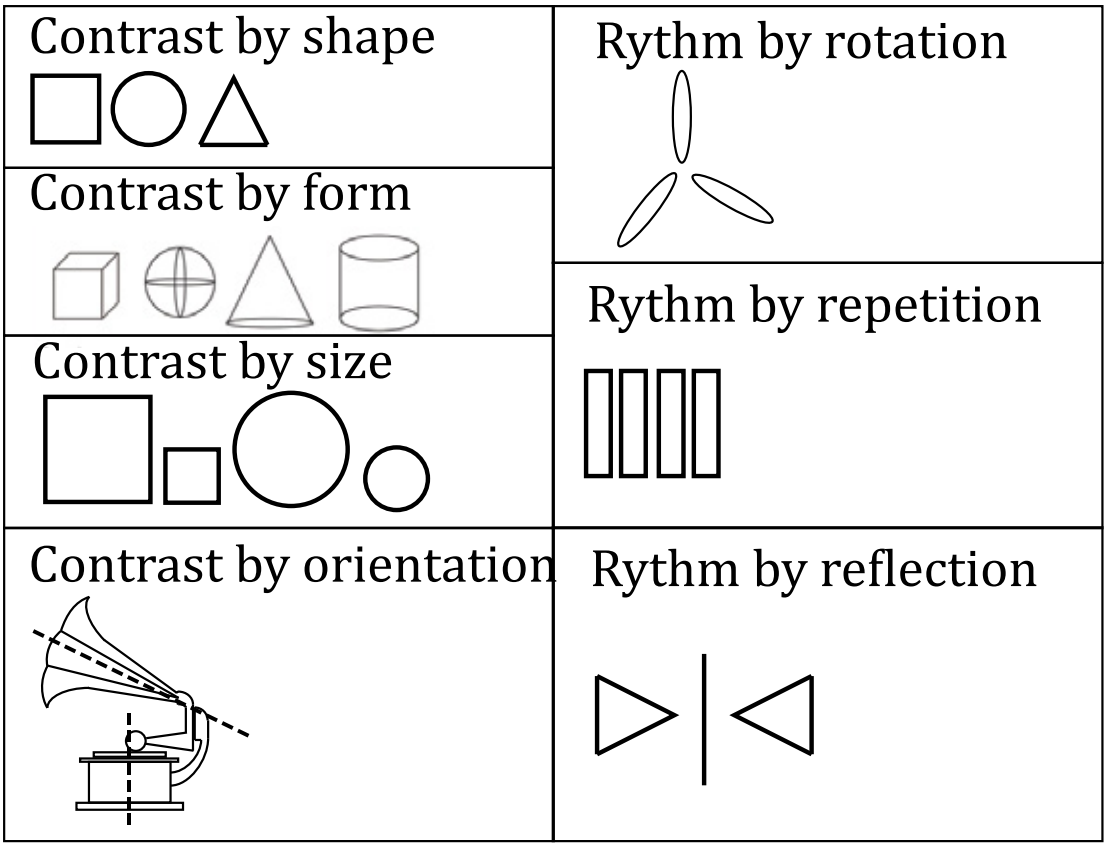


Figure 56. Four different types of contrast and three different types of rythm. Defining form complexity.

- **Contrast by shape** — Two or more opposing shapes within a product, where a shape is a two dimensional element created by being enclosed. An enclosed element is simply an element that is placed within another element
- **Contrast by form** — Two or more opposing forms that were not enclosed
- **Contrast by orientation** — Two or more axis's elements following different coordinate systems
- **Contrast by size** — Two or more elements of the same type having different sizes

- **Rhythm by repetition** — A repeating pattern in a linear direction
- **Rhythm by rotation** — A pattern rotated around a common axis
- **Rhythm by reflection** — A pattern reflected over a common axis

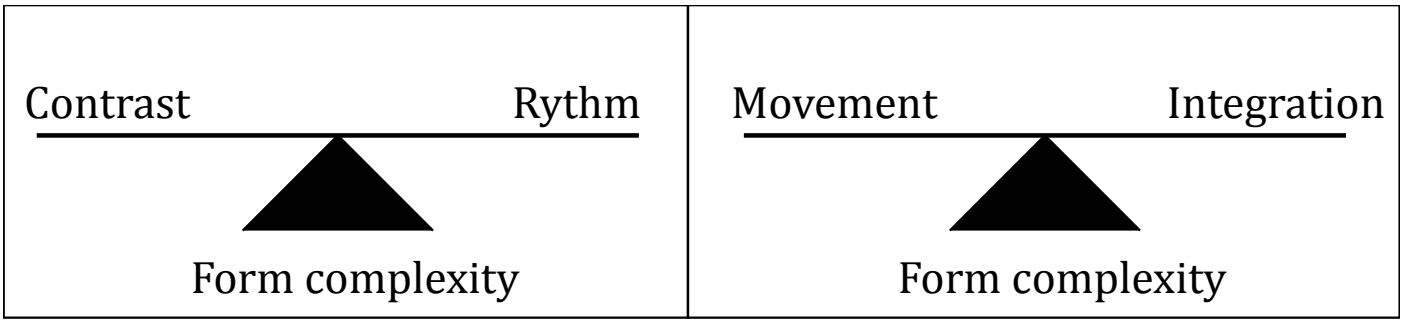


Figure 57. A relationship between contrast rythm and form complexity. This relationship were related to the relationship between movement, integration and form complexity.

5.2. Discussion on the synthesized framework

The goal of the framework were to be able to define changes in the products properties: colors, construction, surfaces and materials, with strict enough results. Considering being able to see changes in the properties, it were applicable and universal towards the sample products. It were also possible to achieve falsifiable results with the classes: colors, arrangement of elements, geometric forms and form complexity. Thus these classes fulfilled the highest rank of applicability.

The class of form integration produced what could be called strict results, which only worked in a comparison. Thus products could only be compared against the articulations and each other to define which form were more integrated than the other. Essentially the class were somewhat diffused by how abstract it were, and therefore it could not be defined as falsifiable in the sense of the word.

The classes of positioning system, ordinance, movement and morphological features were applicable enough to produce data that showed obvious changes in the products properties. They could be classified as strict in their definitions, and falsifiable in the sense that one could compare any results against the framework. However they to, as with form integration, were somewhat diffused by how abstract the definitions were.

Also important were that the framework did not try to measure meaning, which as stated earlier, would not be possible. The framework could be said to achieve this in that all categorization made always could be referred back to the definitions in the classes. For instance, if a product were categorized as containing movement, it would be said to: "have movement according to the framework", and not "users will perceive movement in the product because of this". Thus avoiding the earlier discussed problems.

This discussion could be somewhat abstract to understand for an unexperienced reader, and therefore the author made a short example to present the problem. For instance if an industrial designer were creating a product from a rectangle **FIG 58**, and "wanted to make the product look lighter", a classical way would have been to put an angle to the corners at the bottom of the rectangle **FIG 59** From the point of view presented in this thesis, it would not be possible to determine if "the product looks lighter", because that would be based on perception. It could however be stated that "movement trought axis orientation has been created", which would be according to the framework. Thus one would only state the measurement, not the meaning, because meaning would be based on perception and users experiences. This summed up the framework, next up in the project were to create a methodology to apply the classes.

Figure 58. A rectangular product, which a designer wants to make "look lighter".

Figure 59. The rectangle supposedly made to "look lighter". According to the author this can not be established. Only that a movement trough axis orientaion had been created.. Thus a measurement, not a perception.

6. Methodology

The goal with the methodology were to evaluate how form properties in the products changed over time. The initial idea of placing the products in chronological order to analyze changes were at first used as the only tool of analysis. But after realizing the vast complexity of analyzing a large number of products the method were split up into a quantitative- and qualitative analysis. The goal of the quantitative analysis were to identify if certain properties were shared within certain time frames, called form eras. When and if these form eras had been identified, a fewer amount of products were going to be picked from these eras and analyzed in greater detail, called qualitative analysis. Thus the quantitative analysis would identify when products shared properties, and the qualitative analysis would identify how. From these two parts a system analysis were conducted upon the results.

6.1. Data collection

With use of the supplied list of manufacturers from the initial data collection, a major data collection were done from museum, auction and manufacturer websites in order to find a quantity of products. A majority of the data were collected from the websites: bukowskis.com, radiohistoriska.se and radiomuseum.org. From the websites data on years in manufacturing, materials, measurements and pictures of the products were collected. In order to verify that the data were correct it were cross-referenced with the provided material from the expert Ekström and archive information. In total the data of 1021 products were collected within the product categories, all of which were stored in separated excel spreadsheets based on product category, **FIG 60** and **FIG 61**. A list of the manufactures and product categories can found in **Appendix C.**

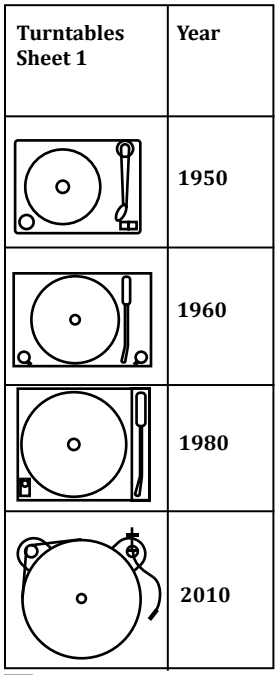


Figure 60. Example of a chronologically ordered sheet.

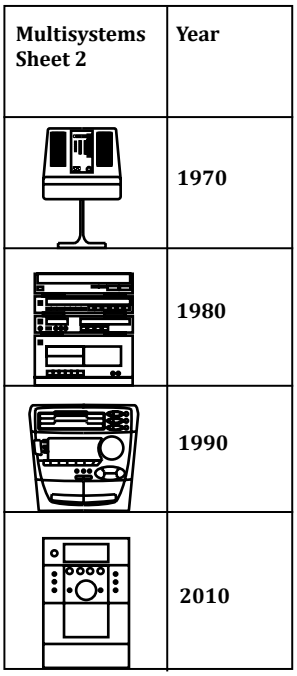


Figure 61. Example of a chronologically ordered sheet.

6.2. Qualitiative analysis

The aim of the qualitative analysis were to identify when and if certain properties were shared. Because of the big number of products that were going to be analyzed, the amount of categories from the framework were limited to: colors, arrangement of functional elements, positioning system, geometric forms, curves, materials, morphological features, form integration and form complexity, **TAB 5** and **FIG 62.** Some categories were also marked on a scale from 1-2, following the basics of 'Design format analysis', Warell (2001). Where one (1) referred to that the product contained the trait less and two (2) that it contained it a lot. For instance if a product contained a small sphere it were marked with a (1) and if it contained one big or several small spheres it were marked with (2). Each of the product categories were placed into separate sheets and when all products had been categorized a cluster analysis were conducted.

Class	Categories	Marked with
Year	-	
Colors	Warm, cold, black, grey, white analog, triadic, complementary, quadratic.	X
Arrangement of functional elements	Vertical, horizontal, triangular, square, circular.	X
Positioning system	Central, orthogonal, radial, linear	X
Geometric forms	Sphere, cylinder, cube, cone, torus	1-2
Movement	Mono-curve, bi and compound curve.	X
Material	-	Material type
Morphological features	Linear, flat, massive.	1-2
Form integration	Composite and integrated form	1-2
Form complexity	Contrast by shape, contrast by form, contrast by orientation, contrast by size, Rhythm by repetition, rhythm by rotation, rhythm by reflection.	X

Table 5. The classes and categories used from the framework, in the quantiative analysis.

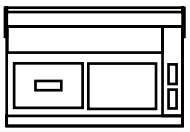
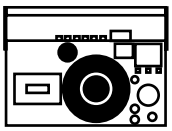
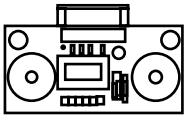
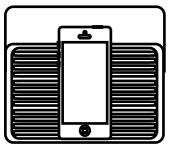
	Year	Colors	Distribution of elements	Positioning System	Geometric forms	Curves	Material	Morphological features	Form Integration	Form complexity
	1970	Warm	Square	Orthogonal	Cube 2	-	Thermo-plastics	Flat 2	1	Contrast by shape, size
	1975	Warm	Square	Central	Cube 2, cylinder 2	-	Thermo-plastics	Massive 1 & flat 2	1	Contrast by shape, size & form
	1980	Warm	Square	Orthogonal	Cube 2 cylinder 1	-	Thermo-plastics	Massive 1 & flat 2	1	Contrast by shape, size & form
	2014	Cold	Horizontal	Central	Cube 2	Mono	Thermo-plastics	Massive 2	2	Contrast by size, rythm by repetition

Figure 62. How the categorization took place. Each class had a separated subcategory, such that for instance cylinder and cube had their own column. The sheets were too massive to print as they were in the report.

6.3. Cluster analysis

The cluster analysis were conducted by printing the excel sheets on A0 papers. What were sought for were shared properties within certain time frames, or form eras. A form era were seen as a big number of products having the same features within a time frame, and then those feature were not represented as much or not at all in products following the years after. The same process were repeated for each product category and then the different product categories were cross-referenced with one another to see if the same eras would be recognized. For instance if it were found that portable cassette players shared properties within the years 1975-1980, **FIG 63**, the next task would be to see if multi systems shred properties within the same time frame. If that were the case, then it could be defined as a form era. The cluster analysis could thus provide insight if form eras existed, and either support or discard the initial hypothesized trend.

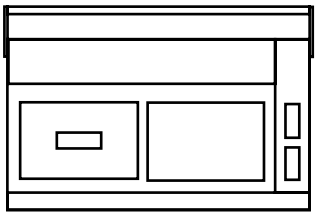
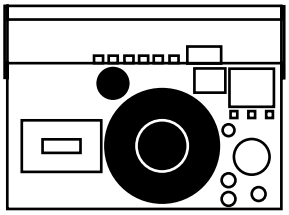
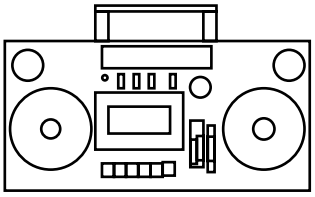
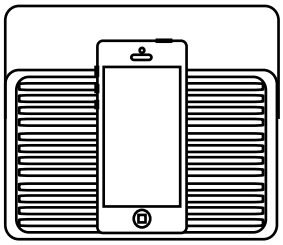
	Year	Colors	Geometric forms	Morphological features	Form complexity
	1970	Warm	Cube 2	Flat 2	Contrast by shape, size
	1975	Warm	Cube 2, cylinder 2	Massive 1 & flat 2	Contrast by shape, size & form
	1980	Warm	Cube 2 cylinder 2	Massive 1 & flat 2	Contrast by shape, size & form
	2014	Cold	Cube 2	Massive 2	Contrast by size, rythm by repetition

Figure 63. How the cluster analysis were conducted. The goal were to find enought matching features, or clusters, that did not exist prior or after to it. For instance here it had been found that a form era could be 1975-1980. The clusters were based around finding a majority, because there were products that did not fit into the clusters, or so called outliners. These are mentioned in the following chapters.

6.4. Results from the quantitative analysis

The quantitative analysis showed that ten separate form eras existed for the products, based upon the analysis of 1021 products with roughly 100 products within each identified era, TAB 6. The main identifying features were based upon form complexity, which separated the form eras. From the quantitative analysis form era specifications were created with the identified defining features which can be found in **Appendix B.**

Years	**Product categories**
1878-1913	Phonographs, (graphophones), gramophones
1913-1938	Travel gramophones, gramophones, phonographs
1938-1950	Radio-gramophones, gramophones, travel gramophones
1950-1960	Turntables, radio-gramophones, travel-gramophones
1960-1970	Turntables, radio gramophones, hi-fi systems, travel-gramophones
1970-1980	Turntables, hi-fi systems, multisystems, travel-gramophones, boomboxes
1980-1990	Multisystems, turntables, boomboxes, personal cassette players, personal cd-players
1990-2000	Compact systems, boomboxes, personal cd-players, personal cassette players, personal mini-disc players
2000-2010	Compact systems, home theaters, mp3-players, mobile phones(limited amount), boomboxes
2010-2014	Turntables, sound bars, compact systems, smartphone speakers, boomboxes, mp3-players, smartphones, travel gramophones

Table 6. The ten form eras identified, and product groups within them.

6.5. Qualitative form analysis

When the qualitative analysis were going to be conducted, an important delimitation were needed. The delimitation regarded which products to select for further analysis. What had been found within the quantitative analysis were clusters of products that that shared properties. However there were examples of products that did not have the defining properties, so called outliners. Outliners could be found by which properties they diverged with. Some of these outliners contained properties that were not represented in the previous form era, but not in the era where it had been manufactured either. Or in simple terms, properties that made the outliner diverge from any earlier and current products.

A motivation for not looking at the outliners, were found concerning the knowledge gap stated at the beginning of the thesis. Which were that design history often focus upon the philosophy behind specific designs, rather than explaining how and which properties that changed over time within product categories. Such a description of how products form changed over time, could be a way to explain how improvements and innovation were achieved, assuming that earlier solutions were improved upon. This type of description could be defined as a trend of evolution, which would bridge the gap between having knowledge of earlier solutions, design history and being able to directly apply it to a product concept. Thus it were sought for which basic properties of form, where being changed in a majority of products. In other words, looking for how iterations of products were developed. Therefore outliners were not of importance for this application, but not forgotten in terms of future work.

From that motivation a total of 204 products were selected from the clusters that defined the eras. Pictures of these products were then ordered according to the identified form eras, within an illustrator document, and analyzed with the frameworks ten classes. Next in the project were to conduct a system analysis on the results.

6.6. System analysis

Using the illustrator document with all parts of the frameworks classes and products, patterns were sought for, by looking for converging and diverging features within product categories, **FIG 64**. This task were vastly simplified by having the classes from the framework, since each of the features could be analyzed separately. The earlier created form era specifications were also studied to not get blinded by the vast amount of data in the document. From the document, form era specifications and the earlier created report on the history of recorded sound, the system were analyzed to see both how features changed and if they were interrelated with technological development.

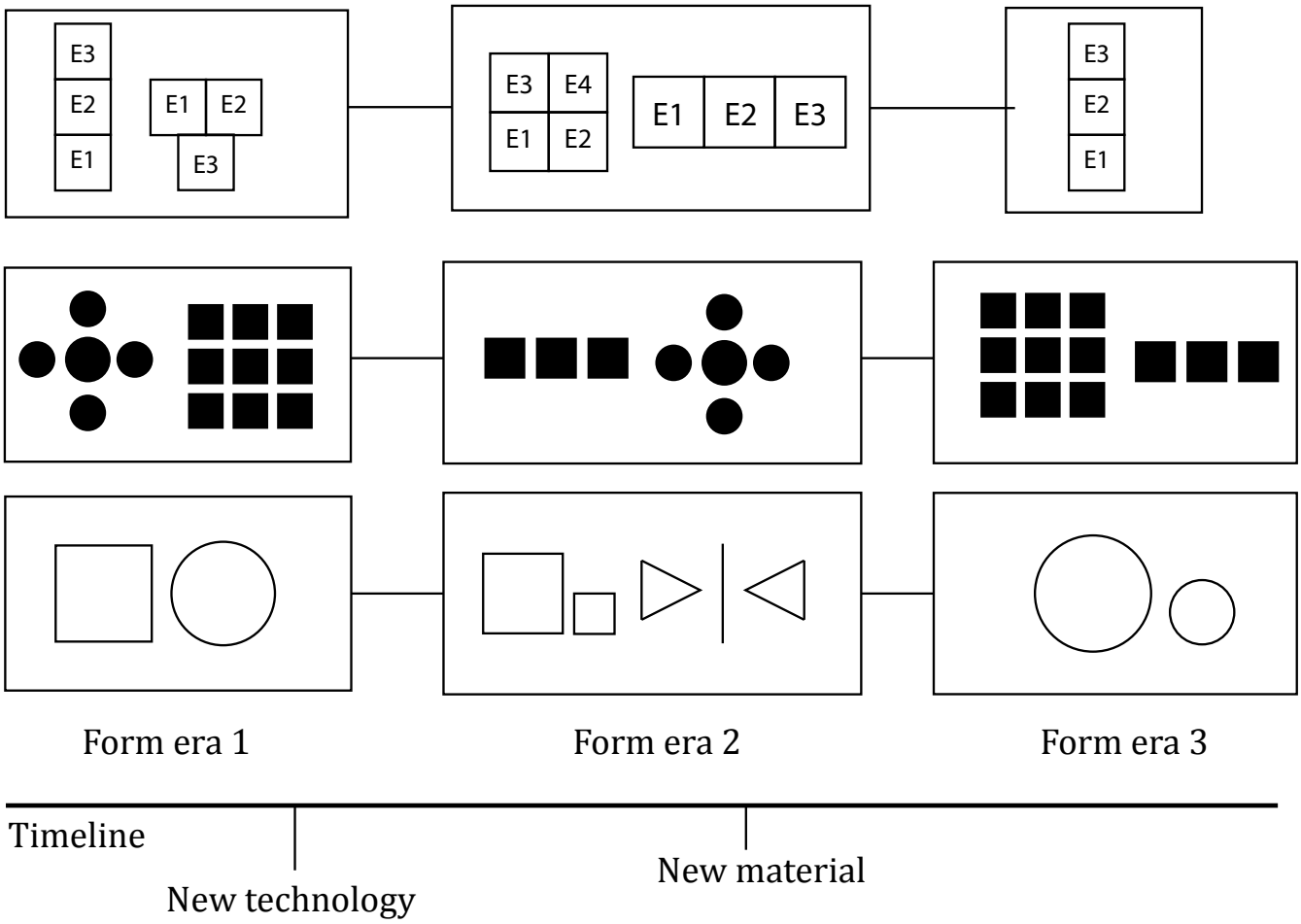


Figure 64. A basic sketchup of how the analysis were conducted. By looking at how and if categories changed in patterns, or likewise, and then comapring it against the technological development it could be concluded if changes happend systematically.

6.7. Discussion on the methodology

The methodology used were in a sense quite basic and simplistic. Essentially it can be described as ordering products in tables based on features, and then analyzing how features change. However it were realized quite early on, that looking at form features of products were an exhausting task. This were aided with the help of the frameworks classifications. The classifications made it possible to analyze singular form properties, which of course were there in the products, but were abstracted by the amount of properties to look at, if the framework had not been used.

An essential point of the quantitative analysis were of how product categories were analyzed separately, and then cross referenced against each other. The reason for conducting the analysis in this manner were to identify changes that were specific for product categories. It were also because products main building blocks may have varied, in the sense that for instance a furniture gramophone could have been constructed with different features than a travel gramophone. They could still have shared features such as form complexity however, and thus the reason for cross referencing the clusters against each other. The motivation can be found in that products may, or may not have shared certain properties following a certain aesthetic. If they did, then this would be found when cross referencing the products against the defined time frames. Essentially it were inspired by the initial hypothesis about a complex-simple-complex cycle. This were of course a danger however, because if patterns were looked for, then they might also have be found, following too much assumptions. The motivation then, were that if enough data could be collected, this would not pose a problem. Because all results could be checked with the framework.

Another important issue were that of using a scale of 1-2 for certain categories in the quantitative analysis. This were motivated on the basis of the aim of the quantitative analysis, which were to find where products shared features, not to specify precisely how. Another fact were that these categories could not be used as the basis for a falsifiable analysis, only to get an overview of how these specific features changed. Thus the classes of geometric forms, morphological features and form integration could not be used for anything else than understanding the overall system.

In the end the main identifying features for the form eras where that of form complexity, which were based around falsifiable definitions, thus the results of the quantitative analysis were well defined. This could also be a lesson for future use of the same methodology, which would be to only use the class of form complexity for a quick quantitative analysis. However it ought to be underlined that an overall understanding of the system were aided with the scaled categories as well, so thus it would depend on the field of application.

The selection of products that were in the clusters, and not analyzing outliners, were based around the definition of the knowledge gap and the aim of the project. Initially some outliners were identified, and it were speculated that these outliners could be the definers of the form era following. However after realizing that the amount of outliners grew with the amount of product categories, this analysis were scraped. Analyzing the initially found outliners with the framework unfortunately gave no reliable results, in terms of if they actually defined the next form era. Thus commenting any further upon them would be pure speculation. Future work on analyzing outliners could be potentially fruitful, but were beyond the scope of this project.
The system analysis in itself were essentially dependent on the previous methodology, and report written on the technological development. Thus critiquing the system analysis were hard, but for any future use of the method, using a database could be useful to analyze meta-data faster. From the system analysis came the results of the project, the form trends of evolution.

7. Form trends of evolution

This chapter goes trough three discovered cyclic trends of evolution, follwed by a discussion on the possible applications and a conclusion.

7.1. Trends

Through the system analysis three cyclic trends of evolution were discovered, all of which were of high interest for innovating concept creation and bridging the knowledge gap.

1.Creation and depletion of a prototype
2.Composite-integrate-separate
3.Complex-simple-complex

The first trend dealt with singular product categories, and of how specific arrangement of elements converged or diverged, dependent on the technological development, **FIG 65**. The second trend dealt with how elements in a products form were integrated, and then separated with each new iteration, **FIG 66**. The same trend were also dependent on technological development, and involved how new product categories were created. The third trend dealt with how a majority of products form complexity, within all categories, went from complex-simple-complex in cycles, **FIG 67**.

Three general trends were also discovered, which involved: how colors were changed, how products systems of positioning went from informal to formal; and the consistent addition and removal of materials. They can be found in **Appendix A.** These trends were more general and not as highly applicable as the three cyclic. Never the less the trend of how colors changed were of importance, especially if it would have had a co-relation with the trend of complex-simple-complex. This were because if one for instance could link highly saturated colors with a high form complexity, or vice versa, it potentially could have been a co-relationship. An analysis of both trends showed that there were no relationship between the two. Following the discovery of the trends came creating a description for each.

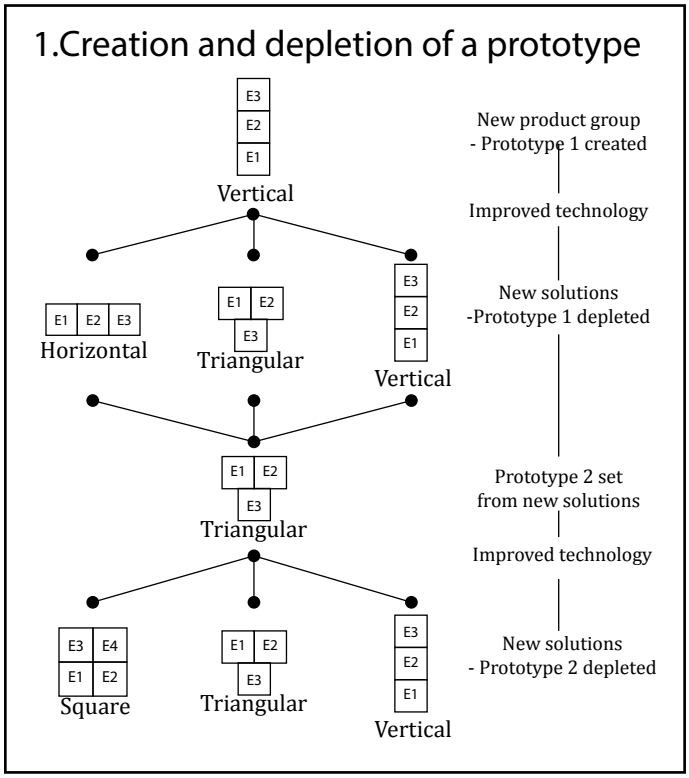


Figure 65. The creation and depletion of specific arrangments of elements(prototypes), because of technological development.

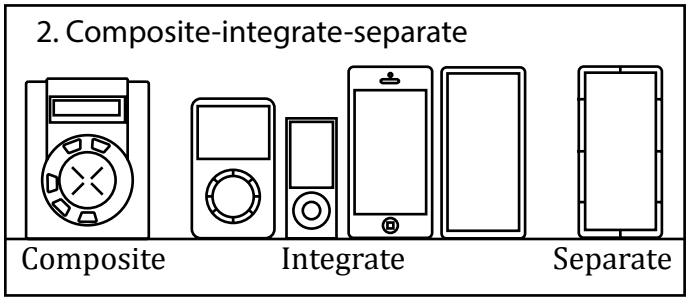


Figure 66. Elements such as buttons were consistently being integrated, then separated, both to increase dynamism.

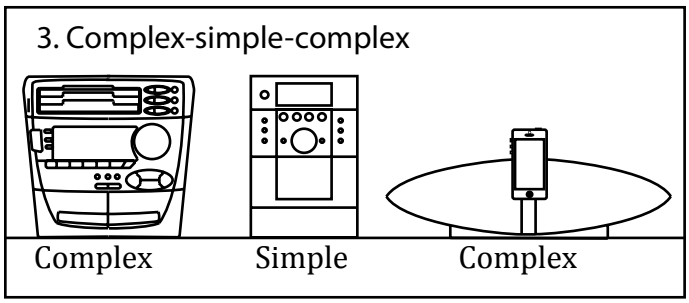


Figure 67. Products within the the whole category of reproduced sound had a form complexity going in cycles; complex-simple-complex, linked to each form era.

1. Creation and depletion of a prototype

A prototype were defined as a specific arrangement of technical elements, or a prototypical arrangement, which were used by a majority of manufacturers for the same product category. An example of a prototype were the arrangement of elements in portable music players. Which had the medium placed in the center of the product and speaker on each side **FIG 68.**

The first prototype in a category were created by the initial product launched on the market, were other manufacturers copied the arrangement. Following the initial launch on the market, significant technological advances usually took place, which meant that manufacturers tried to find new ways of arranging the elements. This led to the prototype being depleted, because all manufactures had different ways of using the improved technology. From the diverging group of arrangement a new prototype were formed if no significant technological advances took place, **FIG 69.**

The creation and depletion of a prototype had a strong link to the S-curve of ideality, where prototype 1 were created during the birth of the system, depleted during growth because of rapid improvements in technology, and a new prototype being created from the diverging solutions during growth, prototype 2, **FIG 70**.

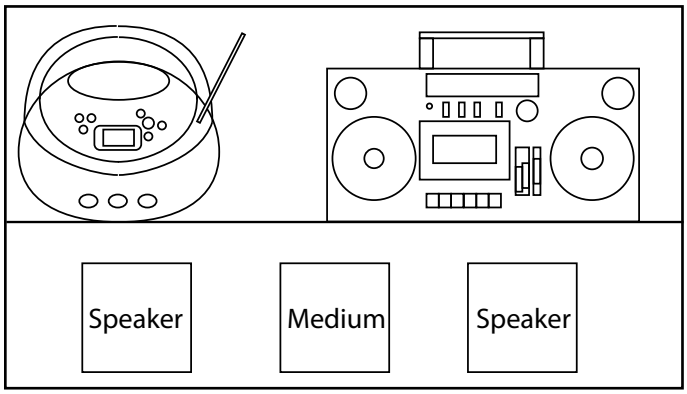


Figure 68. An example of a specific arrangment, also called a prototype. The medium used, independent of technology in this case, were placed in the middle, with one speaker on each side of it.

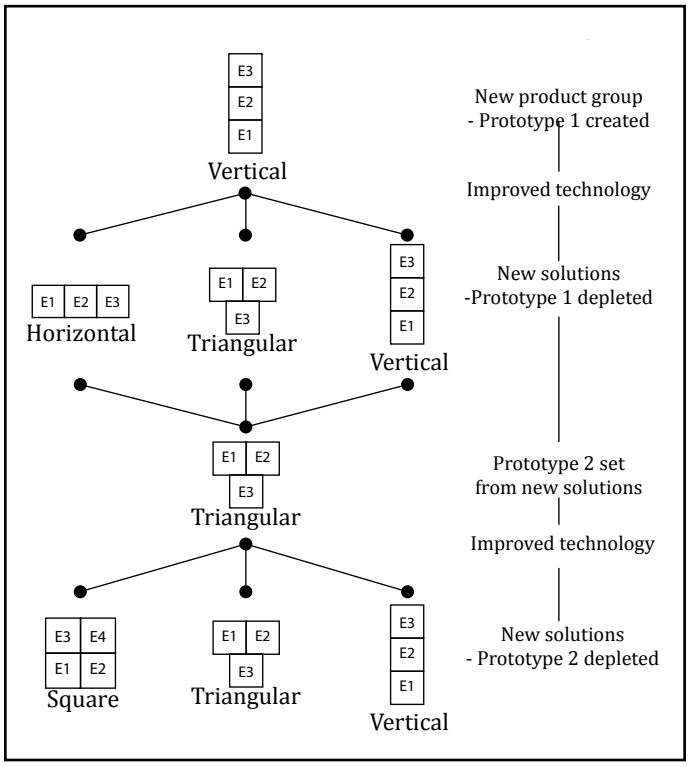


Figure 69. Specific arrangments being created and depleted. Initiated with the first product on the market creating prototype 1. Prototype 1 were then depleted by a significant technological development, which led to divereging solutions in how to use the technology. From this group of diverging constructions, prototype 2 were created.

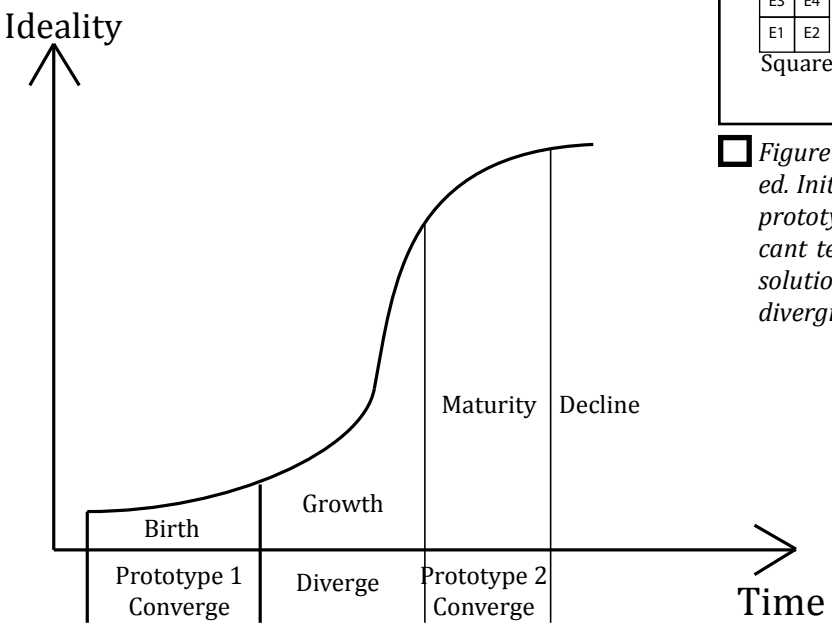


Figure 70. The trends strong link to the S-curve of evolution. Furthering the use of the S-curve as a tool for analysis of products prototypical arrangments.

An example of the pattern were the development of radio-gramophones during 1930-1970, **FIG 71**. The initial products were made like towers (prototype 1), which were essentially copies of the earlier gramophones without a radio. With the introduction of assembly lines in 1940 new ways of arranging the elements were created by the manufactures, which led to the prototype being depleted. With no significant improvements in technology during 1950s, prototype 2 were created. With the introduction of transistor technology during the 1960s, new ways of arranging the elements were yet again being created and thus prototype 2 were depleted.

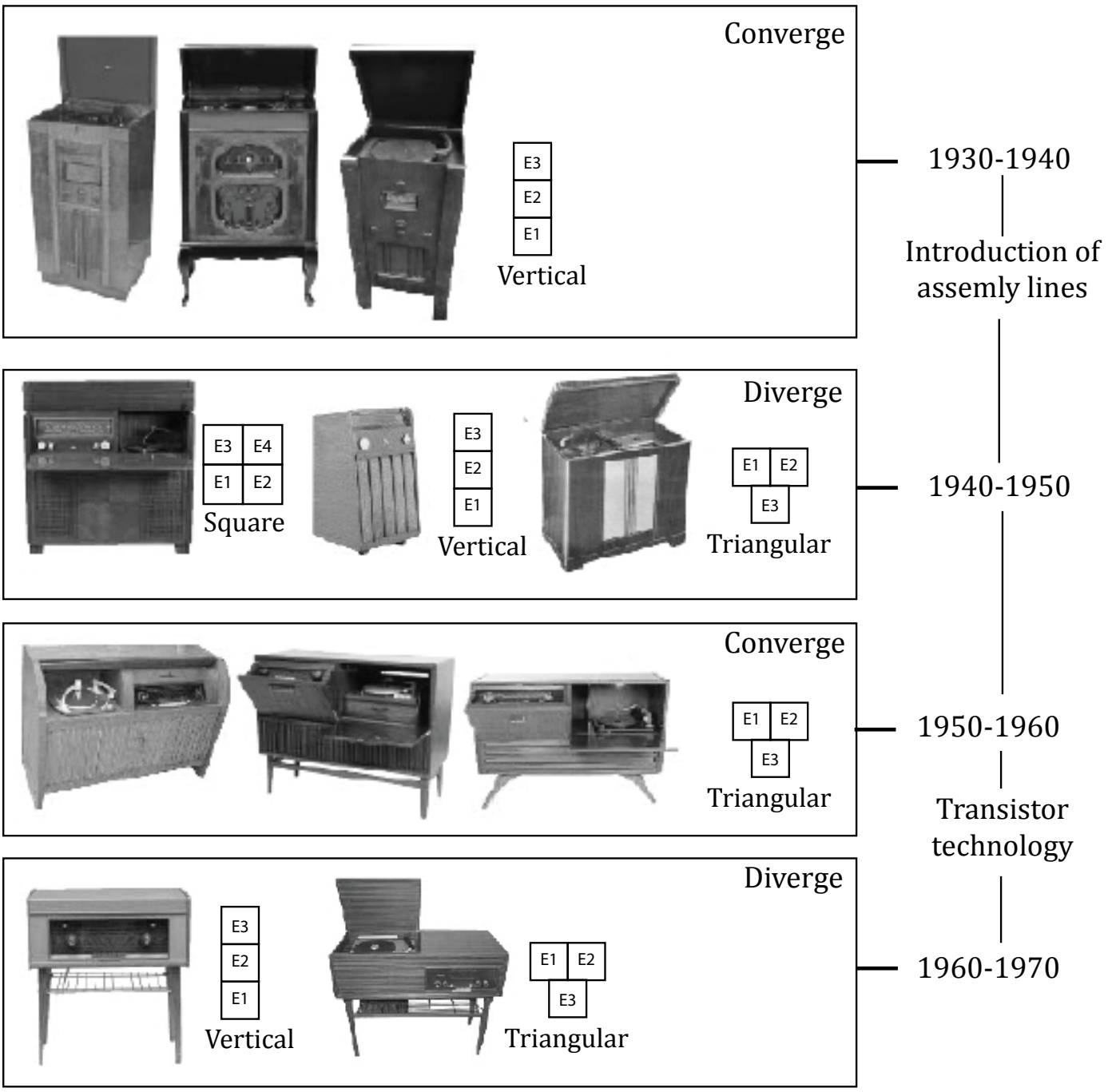


Figure 71. The creation and depletion of a prototype for radio-gramophones. From 1930-1970, following consistent converege-diverge pattern, in coherency with significant technological advances.

A more modern example were the development of mp3 players from 1997-2014, **FIG 72.** The initial mp3 players launched during 1997 were given the same arrangement as the CD-players before them, prototype 1 were created. With the increased manufacturers on the market and gain in popularity, the technology were significantly improved. This led to the introduction of flash discs during the years 2000-2010 and new ways of arranging the elements, thus prototype 1 were depleted. With no significant improvement in technology prototype 2 were created around the year 2010. This development of mp3 players likely had a relation with the usage and position of the products. Considering that the initial arrangements made them hard to store in a pocket, which were solved with the new constructions made in 2000-2010.

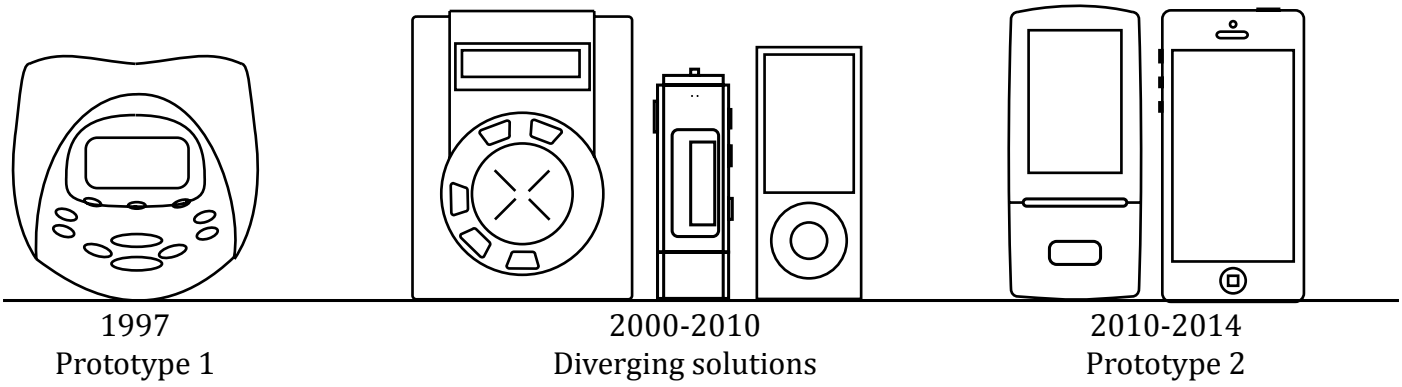


Figure 72. The development of mp3-players from 1997 to 2014. The first mp3-players were copies of the current CD plyaers, in terms of arrangment of elements. Upon the introduction of flash discs new solutions were created, and thus diverging constructions. During 2010-2014 a new prototype were created from the diverging group.

Another example could be found in the development of furniture gramophones in 1913-1950, **FIG 73**. The different arrangements had an effect on the products possible position in a home, and also how vinyl records could be stored.

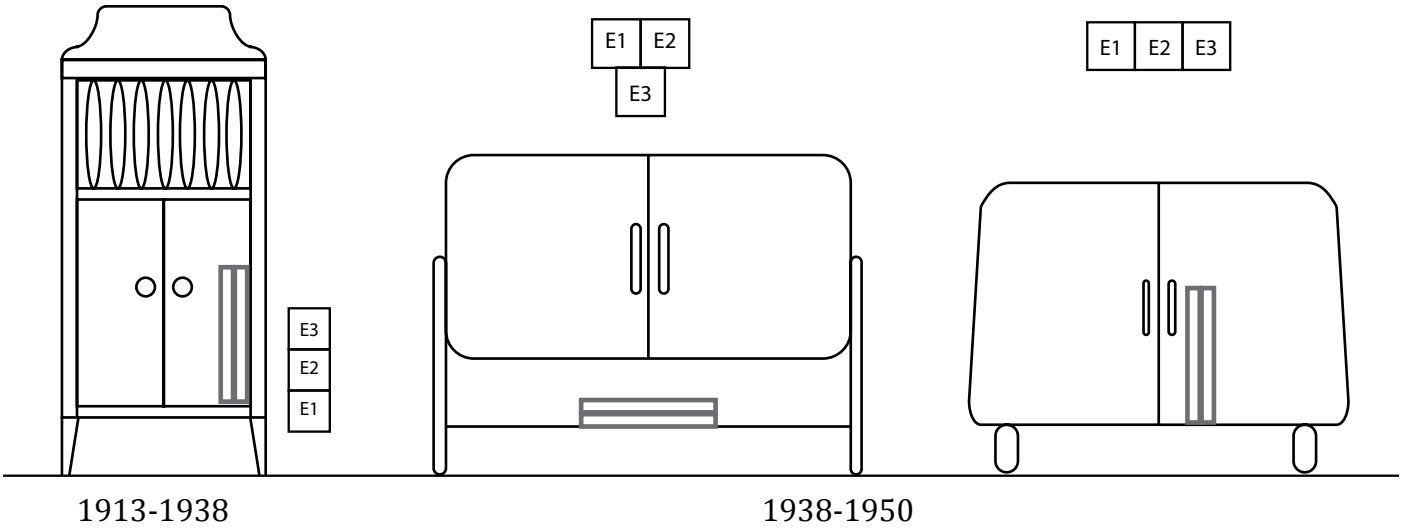


Figure 73. The effects that the arrangment of elements had on usage. Here the way that the discs could be stored were highly affected. Further motivation can be found in Tjalves 2003 book, Systematic design of industrial products. This were an example of a combination of design history, and current ways to develop product concepts, briding that gap.

2. Composite-integrate-separate

This evolutionary involved how products at their birth, were constructed by placing elements on top of each other. Thus being composite constructions, or constructions consisting of many different form types. Following a technological development, the elements were integrated, or merged, with each other. Following yet another technological development the elements were then either further integrated or separated from each other.

An important distinction in understanding the trend were the definition of elements and integration. Elements were regarded as any element in the products that had a form, thus referring to buttons, speakers, screens and more. Integration referred to the earlier set definition of form integration in the framework, **FIG 74.** So if for instance a button were integrated, the products form also became more integrated, because the amount of components were lessened. This would also have an effect on the coherency of the form elements. Thus the products form became more integrated considering that factor as well.

An example of the trend were the consistent integration of buttons of mp3-players in the years 2000-2010, **FIG 75**. The products in 2000 were constructed like boxes with a bigger number of buttons placed on top of the box. Upon the introduction of the iPod, several buttons were integrated, making the form integration higher. With further development of the technology used came further integration, with the iPod of 2005 having even fewer buttons. This development were taken even further with the introduction of touch screen in 2010.

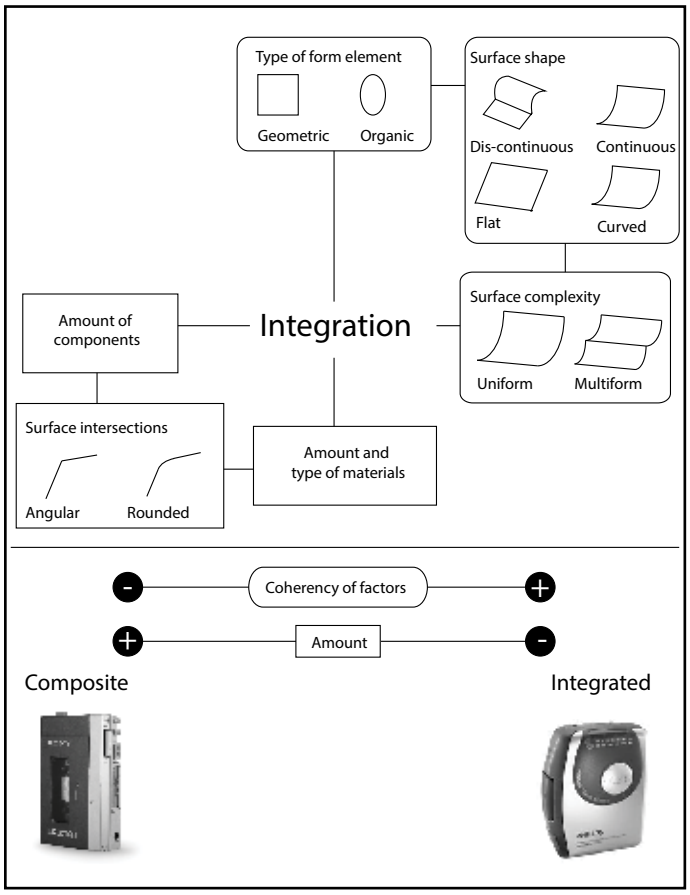
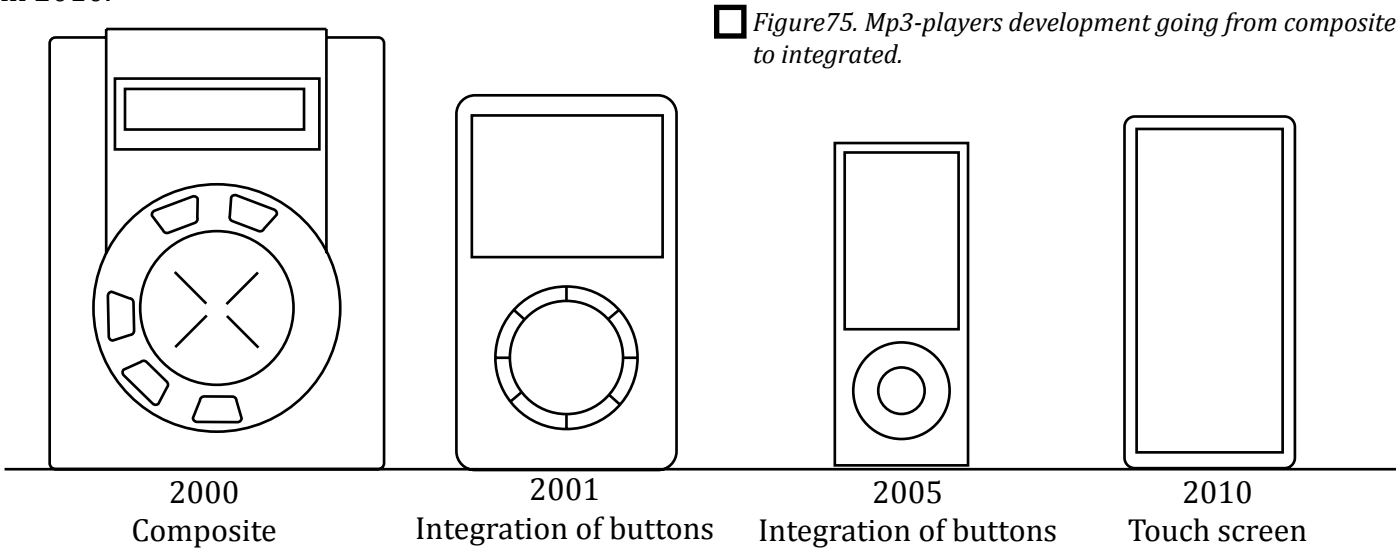


Figure 74. The form integration were a factor dependent on coherency and amount of- form elements. Two opposites were placed in the figure, with a Sony Walkman from 1979 and a Philips from 1993. Notice how the surface intersections were affected by the amount of elements, with the Philips having less.

Figure75. Mp3-players development going from composite to integrated.



Another example of the trend, were the development of travel gramophones from 1920-1975, **FIG 76**. The initial travel gramophones were built by placing a spring mechanism, turn table and horn inside of a suitcase. Therefore being a composite construction. Upon the introduction of thermoplastics, the components were merged with each other, and thus furthering the form integration. The form integration were then furthered again in the 1960s. Then in the 1970s a separation of elements occurred, where the speakers could be separated from the product.

The trend had close relations to usage, position and manufacturing. Its relation to usage were due to the fact that integrating elements, such as buttons, led to a simplified user interface. An integration of elements were also related to that the system became more automated over time, since fewer elements to interact with, meant a higher automation. The trend also led to the creation of several product categories.

Examples of product categories that were created because of an integration of separation of elements were: the travel-gramophone, turntables, personal cassette players, component systems and smartphones.

Travel-gramophones were invented with the introduction of internal horns, thus being an integration from the old gramophone horns, **FIG 77**.

Turntables on the other hand, were invented by separating the furniture and turntables, mainly because of the invention of stereo sound, **FIG 78**. One of the most important products in the category, the Sony Walkman, were created by separating the cassette player and speaker from a portable cassette player, **FIG 79.** Component systems were also an example of a separation of elements, where the radio, cassette player and turntable were made into separate components, **FIG 80.** Smartphones on the other hand were essentially a result of an integration of buttons, and also functions, of mp3-players and cellphones,

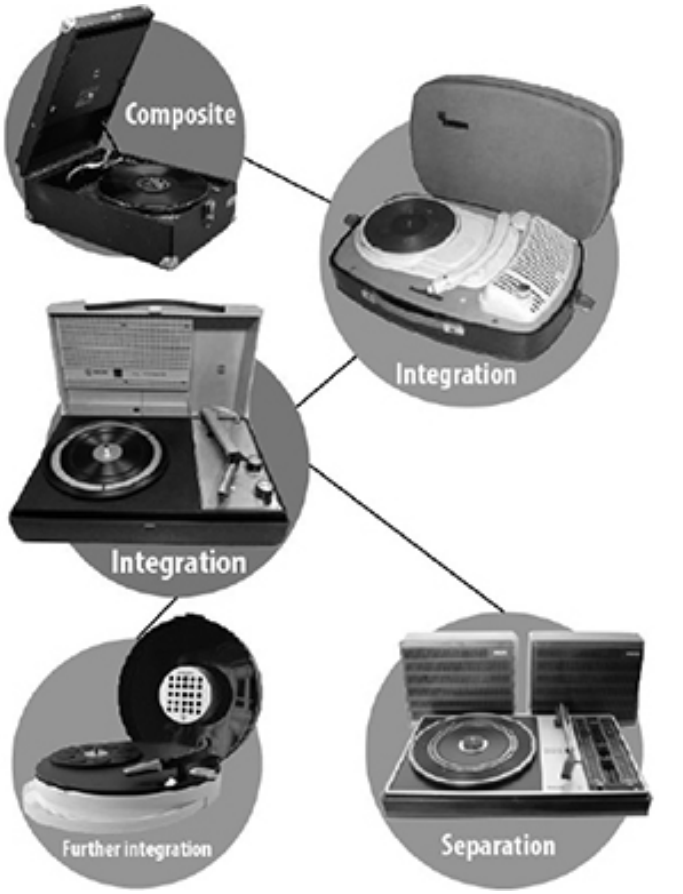


Figure76. The development of travel-gramophones from 1920 to 1970. Ending with a separation of the speakers, leading to increased dynamism and flexibility.

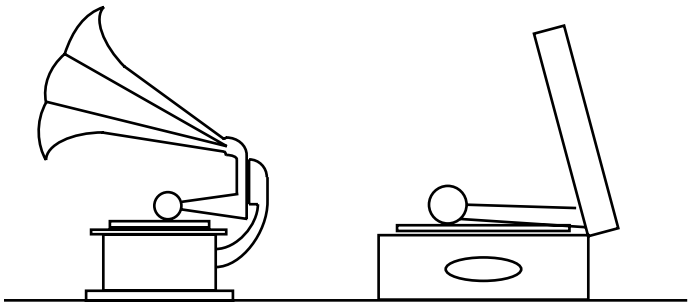


Figure 77.

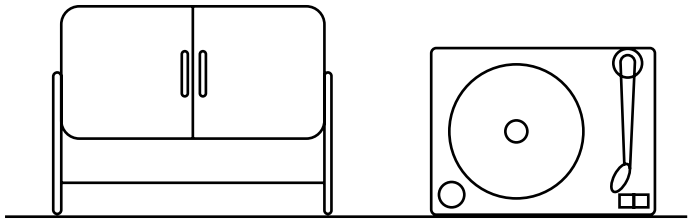


Figure 78.

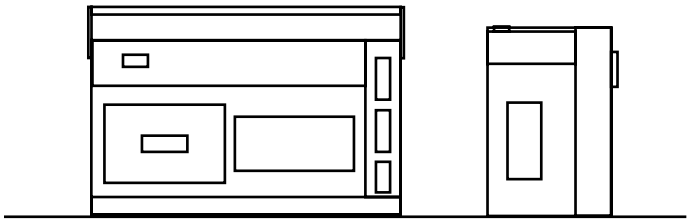


Figure 79.

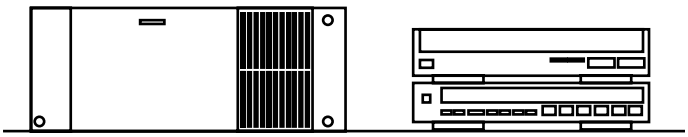


Figure 80.

A common trait with the creation of the product categories mentioned, were that they all represented increased dynamism and flexibility of the system. For instance the popularity of the Sony Walkman were due to the fact that it were portable in a new way. The same could be said for smartphones, which integrated a number of functions.

It were of importance to remember that this trend represented a fuse in understanding of the relationship between form and technology. For instance it were closely related to the technological trend of increased segmentation. The main difference being that form integration in this research were defined. Thus the discovery filled an important knowledge gap that could bridge the understanding of technology and form in a new way.

3. Complex-simple-complex

Moving back to the hypothesized trend that started the research, it were discovered that the form eras found represented two consistent patterns. The first pattern were that products form were going from containing movement, to no movement, between the eras and in cycles. For instance the horn gramophones of the early 1900s contained a lot of movement, with the invention of furniture gramophones around 1913, less movement were seen, and in 1938 the products almost contained no movement, this cycle then continued on until 2014, **FIG 81** and **FIG 82**. The definition of movement within the framework were however lacking, especially in terms of being falsifiable. Support of the claim were found in the second pattern, which were that products were going from containing more types of contrast, to less, to more, in the same cyclic pattern as movement were, **GRAPH 1** As contrast and rhythm were related to form complexity, and were falsifiable, they were seen to support the initial theory.

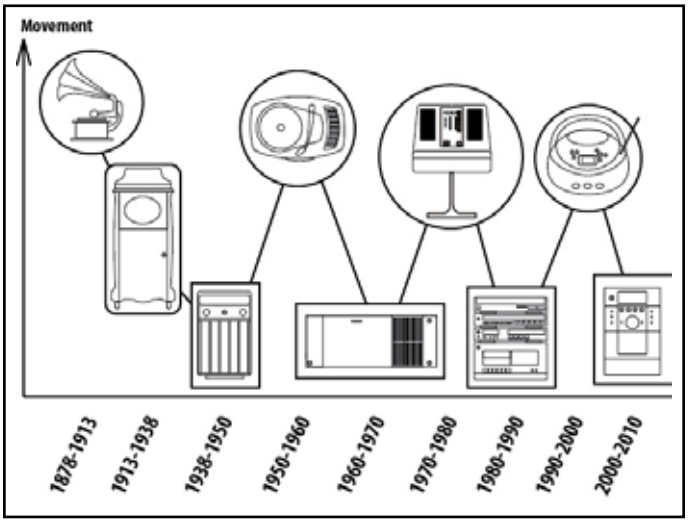


Figure 81. How products movement changed between the eras in a simple graph.

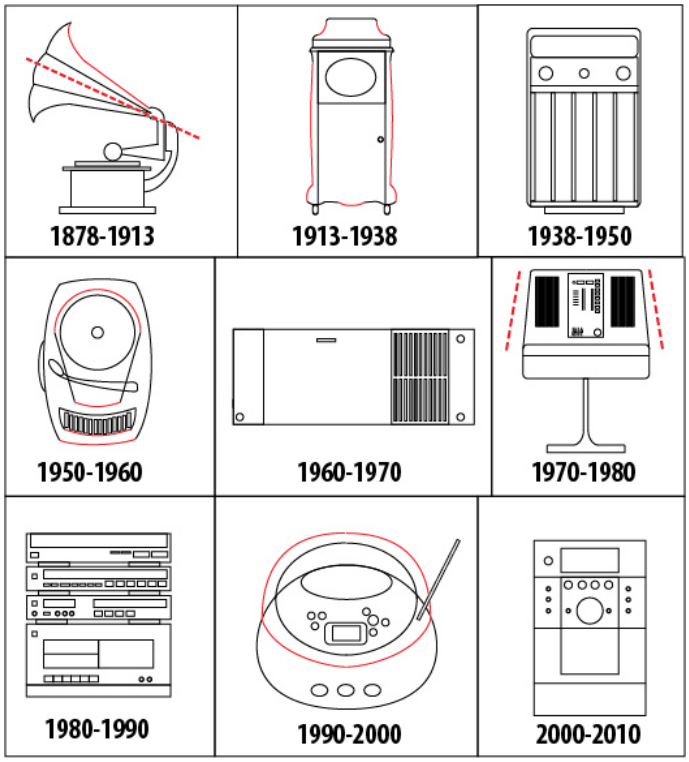
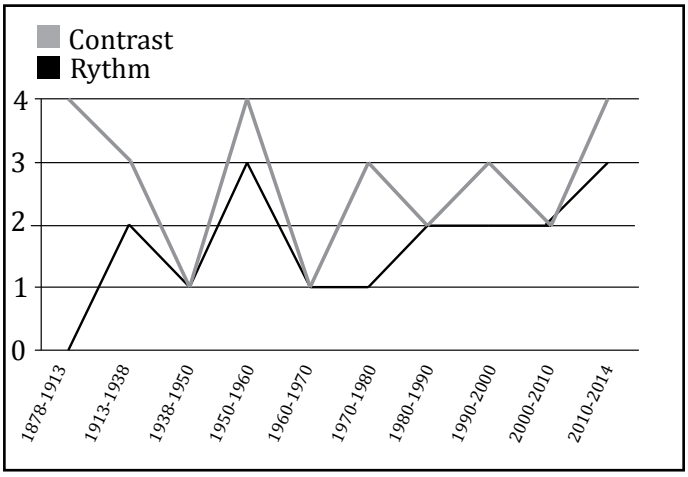


Figure 82. How products movement changed between the eras more specifically.



Graph 1. A look at how many types of contrast and ryhtm each eras products contained. There were four types of contrast and three types of rythm. Here it can be seen that the products form complexity goes in cycles; complex-simple-complex.

Thus a majority of the products researched were going from having high form complexity to low, in cycles between the eras, **FIG 83**. An important aspect considering the products form complexity were to remember that it represented how complex the products form were according to the framework only. Thus it ought not to be mistaken for visual complexity, which were earlier established to be based on perception and subjective. Considering the reasons why the trend existed could not be answered, because the amount of variables that could have had an effect were too great. Moreover form complexity did not represent all aspects of the products form, since contrast and rhythm were used in different ways. The discovery of the trend were still seen to fill a knowledge gap in terms of how products form complexity in general changed over time, and moreover could prove useful if used together with the frameworks definition of form complexity. The final part of the project were to discuss possible applications of the framework, methodology and trends of evolution

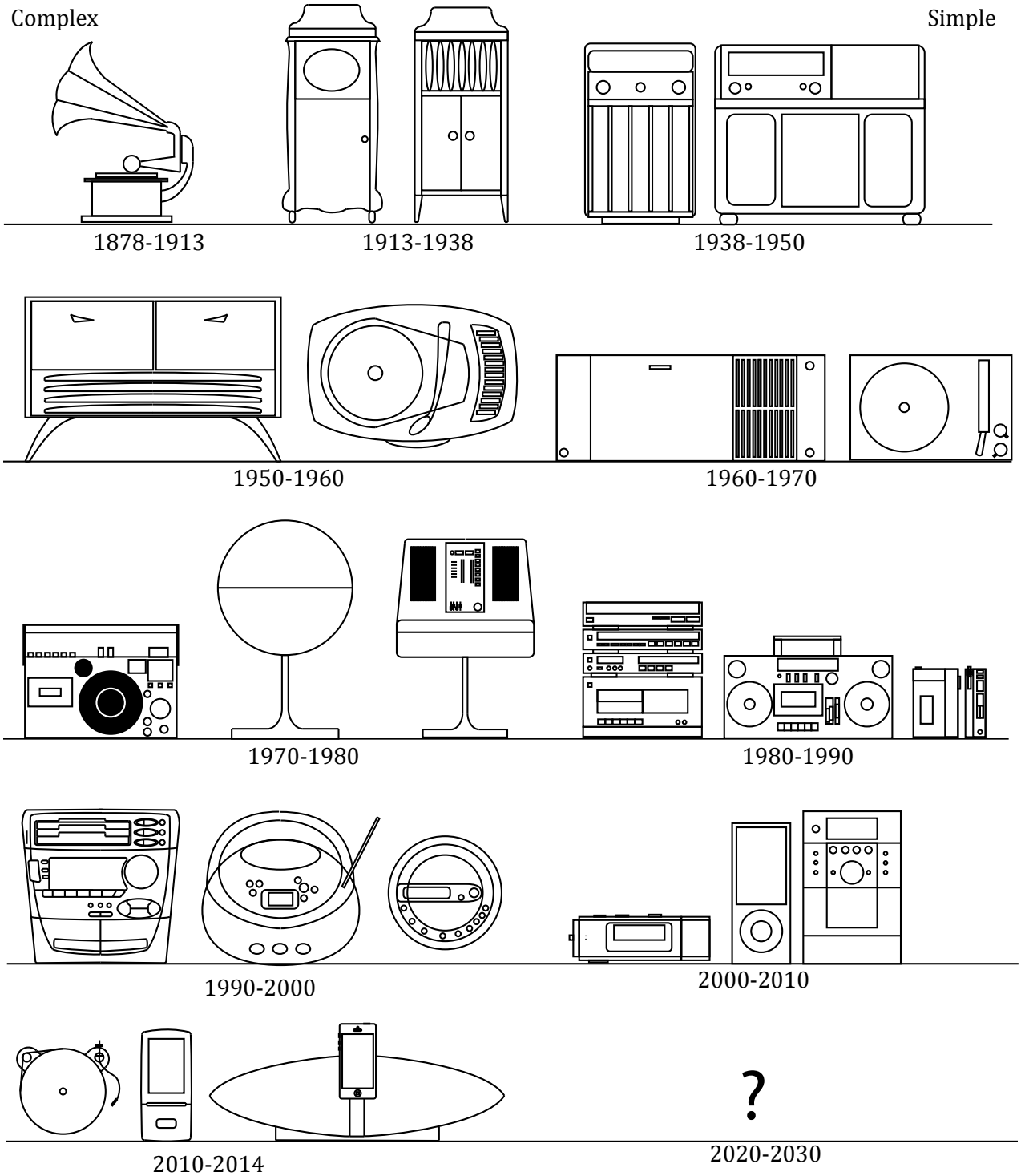


Figure 83. A figure of how the products form went in cycles from complex-simple-complex. The products on the left have a high form complexity, while the products on the right have a low form plexity (simple).

7.2. Discussion on possible applications

The project started out with an initial hypothesis about form cycles and the knowledge gap that could be filled if such were discovered. The work to reach a conclusion upon the subject featured a lot of unexpected problems however, which resulted in the creation of the framework and methodology. Creating a framework were not in the original intentions of the project, but proved to be essential in being able to analyze how form features changed over time. It also led to questioning how form properties and meaning were mixed within the books. Which also were the reason for why the frameworks found had to be synthesized, and adapted.

Furthermore, as the framework were developed with sampling against a quantity of data, its applicability likely reaches beyond the original intentions. For instance it could be used as a creative tool to develop a product concept by defining the: colors, arrangement of functional elements, positioning system, ordinance, geometric forms, movement, materials, the form integration and complexity. In the end a whole product concept could be designed with combinations of the defined opposites within the framework and then be directly comparable with the same definitions. This would also imply that the combinations could be compared against user studies on form meaning.

The methodology used together with the framework could be applicable for analyzing the visual brand identity of product groups. The strength would be because of the frameworks definitions, in terms of specifying the products form properties. The weakness would stem from the fact that the frameworks classes does not deal with all properties important for visual brand identity. Used in combination with other established methods however, it could provide an extension.
Considering the evolutionary trend: the creation and depletion of a prototype, it could be of high interest from a concept creation point of view. This were because it could enable designers to analyze the current development and possibly forecast when to diverge or converge. Essentially a way to know when to be creative with arrangement of elements, and when to follow the mainstream. Thus if a manufacturer would not bring a new technology to the product, then the arrangement ought not to be changed. It could also be a way to know when to be creative with the arrangemens.

Out of the three discovered cyclic trends, composite-integrate-separate, were seen as the most useful considering concept creation. This were because it combined an understanding of the relationship between form and technology. It could prove useful in experimenting with integrating or separating elements when developing a concept. Furthermore it could also be used to understand how products in history were developed, following the same trend. Thus filling the knowledge gap originally sought to fill. Considering the applicability to other product categories, the trend were also applicable to cellphones, **FIG 84**. Where buttons were consistently being integrated, resulting in a touchscreen, and later likely will be separated into components, such as a phone made out of blocks. Which would increase the dynamism of the product.

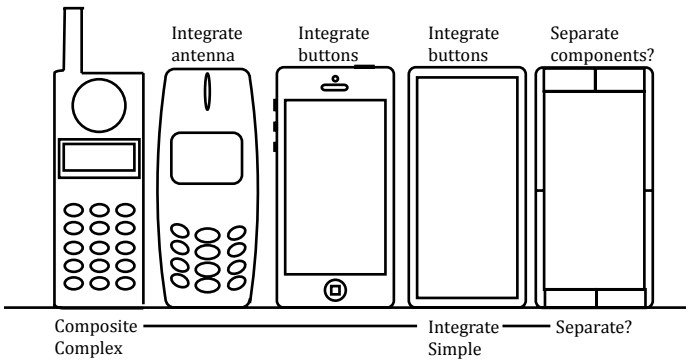


Figure 84. The development of cellphones and what will likely be done next; a separation of elements.

Considering the trend complex-simple-complex, its applicability would lie mostly in the fact knowing that products form complexity generally goes up and own in cycles. However further studies on why the trend existed in the first place would be needed. For instance an important aspect were the general lack of logic in how colors were used when the form complexity changed between the eras. It were thought that there would be a link, but no link could be found. Essentially trying to rationally deconstruct the trend without more data would only lead to illusions. This also related back to the earlier thoughts behind epistemology and form.

7.3. Conclusion

The aim of the thesis were to present the exploratory research conducted on products within reproduced sound, concerning their overall technological development, colors, construction, surfaces, materials, positon and usage. With the final research aim to present if there were any form trends of evolution. The report presented the exploratory research conducted and thus this aim were reached. Furthermore three cyclic form trends of evolution were discovered and presented, thus this aim were also reached.

All in all the research resulted in the discovery of three cyclic form trends of evolution, which were related to the aspects earlier established. The framework, methodology and trends of evolution could provide powerful tools for concept creation, and bridging the gap between knowledge of earlier solutions, design history and being able to directly apply it. The power of the tools stems from their simplicity and practicality. They could result in innovative concepts within seconds of redesigning a product. One would go; establish prototype, integrate or separate, complex or simple. These would then be directly identifiable with the framework, thus not based on perception; rather a defined concept.

Future work were split up into three directions. The first would be to develop the descriptions within the framework and trends of evolution with user studies, in order to make it more understandable and applicable. The second would be to dig deeper into each form trend, and mainly look into the outliners effect on form complexity. The third would be to look into further product categories with an equal approach.

8. References

Akner-Koler, Cheryl. (1994), *Three dimensional visual analysis.* KTH
Brunnström, Lasse. (2006), *Telefonen: En designhistoria.* Atlantis tekniska museet
Ekström, Gert. (2014)
Gadd, Karen. (2010) *TRIZ for engineers: enabling inventive problem solving*. John wiley & sons
Jordan, Patrick. (2000) *Designing Pleasurable products.* Taylor and Francis
Krogrud, Svein. (1993) *Volund*. Norsk Teknisk museum
Labadie. (1927) *Fonografens historia*. Vetenskapen och livet
Lidwell, William. (2003) *Universal principles of design.* Rockport publishers inc.
Lundberg, Börje. (2013) *Entreprenören i centrum.* Premium publishing
Magnusson, Lars. (2010) *Svergies ekonomiska historia*. Norstedts
Miegel, Fredrik. (2002) *Kultursociologi*. Studentlitteratur AB
Muller, Wim. (2001) *Order and meaning in design*. TU delft
Stebbing, Peter. (2004) *A universal grammar for visual composition*. HFG
Strandh, Sigvard. (1977) *100 år med inspelat ljud*. Tekniska museet Stockholm
Tjalve, Eskild. (2003) *Systematic design of industrial products*. Institute for Product Development, Technical University of Denmark
Tekniska museets arkiv, Museivägen 7, 115 93 Stockholm
Wahlström, Sten. (2003) *Ljudteknik och historia*. Karlstad
Warell, Anders. (2001) *Design syntactics.* Chalmers reproservice

Appendix

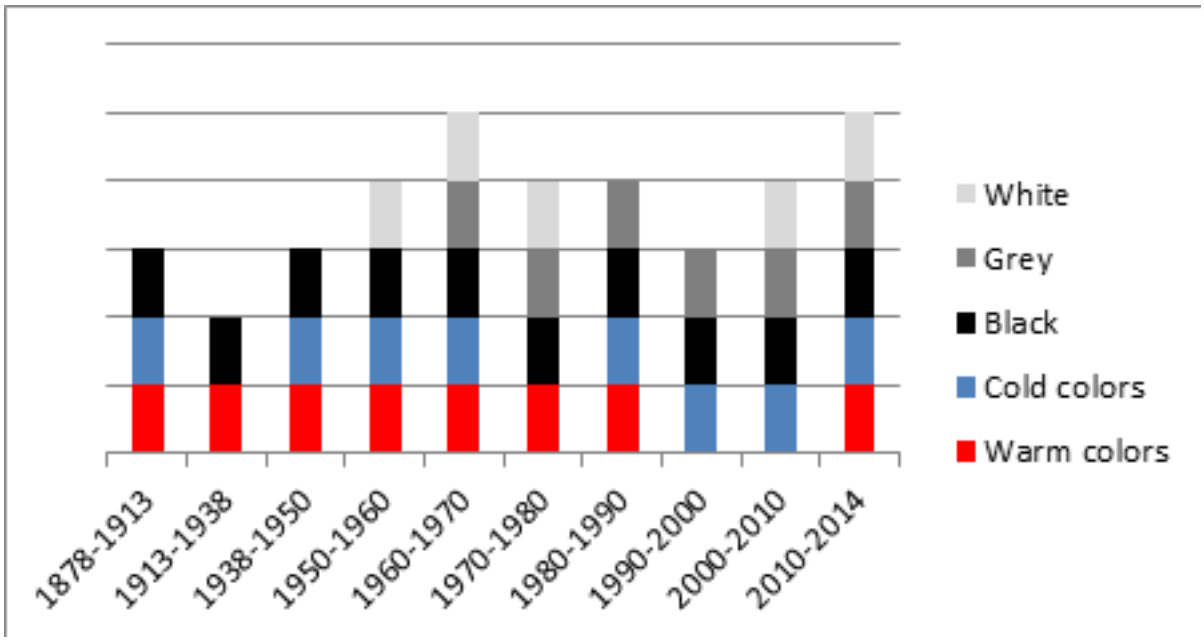
This chapter covers the general trends found, form era specifications and provides the list of manufacturers used, which could be useful for anyone interested in the history of reproduced sound.

A. General trends

Three general trends were also discovered, which involved: how colors were changed, how products systems of positioning went from informal to formal; and the consistent addition and removal of materials.

Colors change

The usage of colors the same color combinations in the products generally converged within the product categories and eras independent of manufacturers. The usage of colors also changed consistently between the eras as displayed in the comparative chart below created from the results of the quantitative analysis with all product categories included, **GRAPH A**. In general home products featured analog color combinations, where a consistent change from warm lowly saturated colors towards black/grey color combinations was seen from 1878-2014. The portable products in general featured both analog and complementary color combinations, with more saturated colors than the home products within the years 1913-2014. An important aspect considering the colors used, were that their change was inconsistent with how the products prototype, movement, integration and materials were changed over time. Considering any systematic change no real conclusions could be drawn other than the fact that products within eras consistently had coherent colors and color combinations within product categories.



Graph A. A graph of how colors were being used over time. No real consistency could be seen in how they changed. Only concluding that they were coherent within the eras.

System of positioning (informal to formal)

When a new product category was introduced the products often had an informal system of positioning, where certain elements did not follow any specific coordinate system. When the products within the category were developed the elements were placed in a formal system of positioning, **FIG A**. It can be linked to the form trend Composite-integrate-separate, where new products had a composite construction thus when the products where made more integrated the systems of positioning were made formal. A general pattern found considering the link between product form and system of positioning was that products with a lot of movement often had a central positioning system, whereas products which were static often had an orthogonal or linear positioning system, **FIG B**. Thus the systems of positioning changed much in the same way as the movement. As the systems of positioning regarded all functional elements within a product form, they also referred to the user interfaces of the products, and since the initial products within a new category often had informal systems of positioning their user interfaces were often unordered. Upon development their systems of positioning were made formal and thus the user interfaces became more ordered

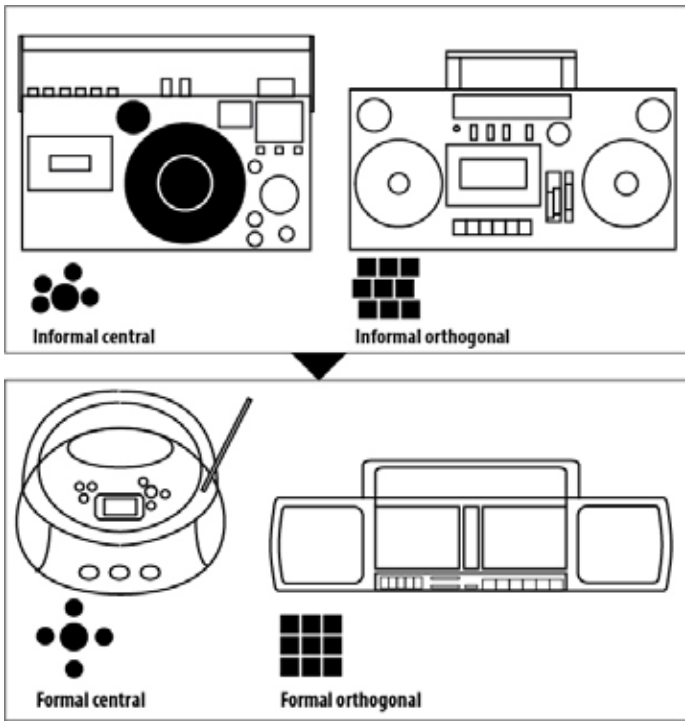


Figure A. How the products system of positioning were changed with new iterations of the products.

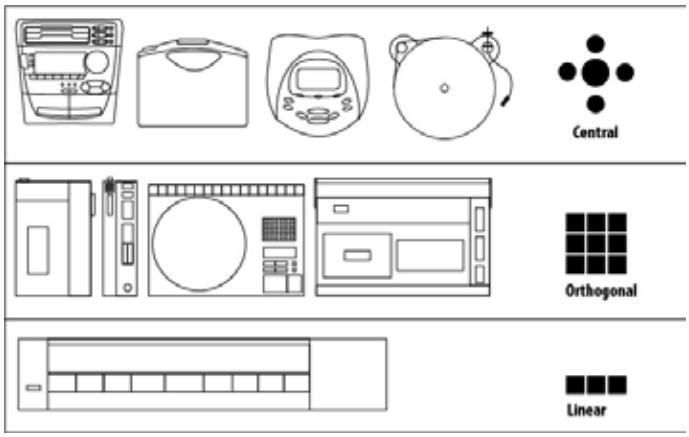


Figure B. How the products system of positioning were linked to the products movement and form complexity.

Consistent addition and removal of materials

The separation of materials could also be described as a consistent pattern with the addition and removal of materials over the time span 1878-2014. There was a transition from wood and iron to thermoplastics and later composite materials during the timespan and through the qualitative analysis an interesting pattern was found concerning how the actual transitions took place. The pattern consisted of how materials were consistently added and removed in relation to one another. So when a new material was used in the products the amount of the new material was relatively small in comparison to the earlier used ones. Upon further development this new material was then used in greater scale and the usage of other materials lessened, and finally resulting in some materials being removed entirely. An example of this is the development of common products used at home, spanning from the early 1900 mechanical gramophones, to the radio-gramophones in 1938-1970 and the component systems of the 1980s, **FIG C**.

Figure C. The consistent addition and removal of materials in products from 1913-1980

B. Form era specifications

This chapter provides the form era specifications for all ten eras found.

Years	Product category	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
1878-1913	Phonographs, graphophones, gramophones	Vertical	X	Central		Contrast by shape	
		Horizontal	X	Orthogonal	X	Contrast by form	X
		Triangular		Radial	X	Contrast by orientation	X
		Square		Linear		Contrast by size	X
		Circular				Rhythm by repetition	
		Warm colors	X			Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	
						Sphere	
						Cylinder	2
						Cube	2
						Cone	2
						Torus	
						Mono-curve	2
		Black colors	X			Bi –curve & compound curve	
		Grey colors				Composite form	2
		White colors				Integrated form	
		Analog colors	X			Linear matter	
		Triadic				Flat matter	2
		Complementary				Massive matter	1
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
1913-1938	Travel gramophones, gramophones, phonographs	Vertical	X	Central	X	Contrast by shape	
		Horizontal		Orthogonal		Contrast by form	X
		Triangular		Radial		Contrast by orientation	
		Square		Linear		Contrast by size	
		Circular				Rhythm by repetition	X
		Warm colors	X			Rhythm by rotation	
		Cold colors				Rhythm by reflection	X
						Sphere	
						Cylinder	1
						Cube	2
						Cone	
						Torus	
						Mono-curve	1
		Black colors	X			Bi –curve & compound curve	2
		Grey colors				Composite form	2
		White colors				Integrated form	1
		Analog colors	X			Linear matter	
		Triadic				Flat matter	2
		Complementary				Massive matter	1
		Quadtratic					

Years	Product categories	Abstrac-tion level one (1)		Abstrac-tion level two (2)		Abstrac-tion level three (3)	
1938-1950	Ra-dio-gram-ophones, travel gramo-phones	Vertical	X	Central	X	Contrast by shape	X
		Horizontal	X	Orthogo-nal		Contrast by form	
		Triangular	X	Radial	X	Contrast by orienta-tion	
		Square	X	Linear		Contrast by size	
		Circular				Rhythm by repetition	X
		Warm colors	X			Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	
						Sphere	
						Cylinder	1
						Cube	2
						Cone	
						Torus	
						Mo-no-curve	2
		Black col-ors				Bi –curve & com-pound curve	
		Grey col-ors				Composite form	2
		White colors				Integrated form	2
		Analog colors	X			Linear matter	
		Triadic				Flat matter	2
		Comple-mentary				Massive matter	
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
1950-1960	Turntables, radio-gramophones, travel-gramophones	Vertical		Central	X	Contrast by shape	X
		Horizontal	X	Orthogonal	X	Contrast by form	X
		Triangular	X	Radial	X	Contrast by orientation	
		Square		Linear		Contrast by size	
		Circular				Rhythm by repetition	X
		Warm colors	X			Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	X
						Sphere	
						Cylinder	1
						Cube	2
						Cone	
						Torus	
						Mono-curve	2
		Black colors	X			Bi –curve & compound curve	1
		Grey colors				Composite form	2
		White colors	X			Integrated form	2
		Analog colors				Linear matter	
		Triadic				Flat matter	2
		Complementary				Massive matter	2
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
1960-1970	Turntables, hi-fi systems, travel-gramopones	Vertical		Central	X	Contrast by shape	
		Horizontal	X	Orthogonal	X	Contrast by form	
		Triangular	X	Radial		Contrast by orientation	
		Square		Linear	X	Contrast by size	X
		Circular				Rhythm by repetition	X
		Warm colors	X			Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	
						Sphere	
						Cylinder	1
						Cube	2
						Cone	
						Torus	
						Mono-curve	
		Black colors	X			Bi –curve & compound curve	
		Grey colors	X			Composite form	2
		White colors	X			Integrated form	2
		Analog colors	X			Linear matter	
		Triadic				Flat matter	2
		Complementary				Massive matter	
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
1970-1980	Turntables, hi-fi systems, multisystems, travel-gramophones, boomboxes	Vertical	X	Central		Contrast by shape	X
		Horizontal		Orthogonal	X	Contrast by form	
		Triangular	X	Radial		Contrast by orientation	
		Square	X	Linear		Contrast by size	X
		Circular				Rhythm by repetition	X
		Warm colors	X			Rhythm by rotation	
		Cold colors				Rhythm by reflection	
						Sphere	
						Cylinder	2
						Cube	2
						Cone	
						Torus	
						Mono-curve	
		Black colors	X			Bi –curve & compound curve	
		Grey colors	X			Composite form	1
		White colors	X			Integrated form	2
		Analog colors				Linear matter	
		Triadic				Flat matter	1
		Complementary				Massive matter	2
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
1980-1990	Multi-systems, turntables, cd-players – home, boomboxes, personal cassette players, personal cd-players	Vertical	X	Central	X	Contrast by shape	
		Horizontal	X	Orthogonal	X	Contrast by form	
		Triangular		Radial		Contrast by orientation	
		Square	X	Linear		Contrast by size	X
		Circular				Rhythm by repetition	
		Warm colors	X			Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	X
						Sphere	
						Cylinder	
						Cube	2
						Cone	
						Torus	
						Mono-curve	
		Black colors	X			Bi –curve & compound curve	
		Grey colors	X			Composite form	1
		White colors				Integrated form	2
		Analog colors				Linear matter	
		Triadic				Flat matter	
		Complementary				Massive matter	2
		Quadtratic					

Years	Product categories	Abstrac-tion level one (1)		Abstrac-tion level two (2)		Abstraction level three (3)	
1990-2000	Compact systems, boom-boxes, personal cd-players, personal cassette players, personal mini-disc players	Vertical	X	Central	X	Contrast by shape	
		Horizontal	X	Orthogo-nal	X	Contrast by form	
		Triangular	X	Radial		Contrast by orientation	
		Square	X	Linear		Contrast by size	X
		Circular	X			Rhythm by repetition	
		Warm colors				Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	X
						Sphere	
						Cylinder	
						Cube	2
						Cone	
						Torus	
						Mono-curve	
		Black col-ors	X			Bi –curve & compound curve	
		Grey col-ors	X			Composite form	1
		White colors				Integrated form	2
		Analog colors				Linear matter	
		Triadic				Flat matter	
		Comple-mentary				Massive mat-ter	2
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
2000-2009	Compact systems, home theaters, mp3-players, mobile phones, boomboxes	Vertical		Central	X	Contrast by shape	X
		Horizontal	X	Orthogonal		Contrast by form	
		Triangular		Radial		Contrast by orientation	
		Square	X	Linear		Contrast by size	
		Circular				Rhythm by repetition	
		Warm colors				Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	X
						Sphere	
						Cylinder	2
						Cube	2
						Cone	
						Torus	
						Mono-curve	
		Black colors	X			Bi –curve & compound curve	
		Grey colors	X			Composite form	2
		White colors	X			Integrated form	2
		Analog colors				Linear matter	
		Triadic				Flat matter	
		Complementary				Massive matter	2
		Quadtratic					

Years	Product categories	Abstraction level one (1)		Abstraction level two (2)		Abstraction level three (3)	
2009-2014	Turntables, sound bars, compact systems, smartphone speakers, boomboxes, mp3-players, smartphones, travel gramophones	Vertical		Central	X	Contrast by shape	X
		Horizontal	X	Orthogonal	X	Contrast by form	
		Triangular		Radial		Contrast by orientation	
		Square	X	Linear	X	Contrast by size	
		Circular	X			Rhythm by repetition	
		Warm colors	X			Rhythm by rotation	
		Cold colors	X			Rhythm by reflection	X
						Sphere	
						Cylinder	2
						Cube	2
						Cone	2
						Torus	
						Mono-curve	
		Black colors	X			Bi –curve & compound curve	
		Grey colors	X			Composite form	1
		White colors	X			Integrated form	2
		Analog colors	X			Linear matter	
		Triadic				Flat matter	1
		Complementary	X			Massive matter	2
		Quadtratic					

C. List of manufacturers

Manufacturers	Years	Product categories
Edison speaking phonograph	1878-1920	Phonographs Graphophones Gramophones (All with external horns)
Berliner gramophone		
Deutche grammophon		
Bell graphophone		
Kämmer & reinharts		
Pathe & Farre		
Sonora	1913-1970	Travel gramophones
HMV		
Cremona		
Philips		
Jobo		
Sonett		
Luxor		
DUX		
Excelda		
Perpetuum ebner		
AGA		
Victor Talking Machine Co	1911-1930	Internal horn gramophones (used at home)
Columbia Disc Gaphophone		
Sonett		
Pathe & Farre		
Bang & olfusen		
HMV		
DUX	1920-1960	Radio gramophones
Luxor		
AGA		
Blaupunkt		
Bang & olufsen		
Centrum Radio		
Telefunken		
Philips		
SRA		
Braun		

Bang & olfusen	1950-2014	Turn tables
DUX		
Philips		
Thorens		
Technics		
Sony		
Pioneer		
Michelle engineering		
Sondek		
Garrad		
Grundig	1960-2000	Portable cassette players personal cassette players
JVC		
Sony		
Philips		
SHARP		
Panasonic		
Pioneer		
Clairtone		
Lasonic		
Hitachi		
Grundig	1981-2005	Portable CD players Stationary CD players
JVC		
Sony		
Philips		
SHARP		
Panasonic		
Pioneer		
Clairtone		
Lasonic		
Hitachi		
Technics		
Jens of Sweden	1997-2014	Portable MP3
Apple		
Sony		
JVC		
Creative		
Grundig		
Panasonic		
Digital		

Grundig	1950-2014	Multisystems Hi-fi systems Hi fi systems
JVC		
Sony		
Philips		
SHARP		
Panasonic		
Pioneer		
Clairtone		
Lasonic		
Hitachi		
Technics		
Vision		
Vega		
Commander		
Clairtone		
Bang & olufsen		

CHALMERS UNIVERSITY OF TECHNOLOGY
SE 412 96 Gothenburg, Sweden

Phone: + 46 (0)31 772 10 00
Web: www.tekniskdesign.se