SOFIA UNIVERSITY "ST. KLIMENT OHRIDSKI"
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COMPARATIVE SCANNING METHOD (cSM) CAPABILITIES IN ANALYSIS, VISUALIZATION, AND PSYCHOLOGICAL INTERPRETATION OF EXPERIMENTAL 'PREFERENTIAL CHOICE' DATA

DISSERTATION ABSTRACT

of PhD thesis for acquiring the educational and science degree "Doctor"

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- Introduction;
- Chapter 1. (Part 1 / Part 2);
- Chapter 2. (Part 3);
- Chapter 3. (Part 4 / Part 5 / Part 6 / Part 7);
- Conclusion;
- Bibliography;
- Appendices.

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ABRIDGED CONTENTS OF THE DISSERTATION

INTRODUCTION

First of all: *What is* cSM?

The ***comparative Scanning Method*** (**cSM**) is an innovative technology for processing, analyzing, visualizing and interpreting of psychological experimental data.

The cSM was first introduced in the paper: *Comparative Scanning Method (cSM). Aspects of psychological experimental data of the 'preferential choice' type processing and interpretation*, published by the author of this dissertation in issue (3-4), pp. 118–142 (Panov, 2000). Initially, cSM was viewed as a psychometric technology for analyzing data related to perception of visual stimuli. In recent years, however, the concept of the method has undergone significant expansion both in terms of application domains and theoretical complementarity in the areas of Statistics and Psychometrics.

- **Topic rationale and relevance**

Because the general normative features of research imply a sequence of activities that, in their totality, lead to comprehensive answers to a set of key questions, namely:

- What is the scientific focus of the study?
- Is the research area up to date?
- What is the scope of the study?
  /or what are the *object* and the *subject*, from a philosophical point of view/
- What is the purpose of the study?
- What are the tasks through the solution of which the goal is reached?
- What is the hypothesis for the overall solution / expected results /?
- What are the results of solving the problems?
- What is the significance of the results for science?
- What are the implications of the results for practice?

the motivation for the choice of the topic stems from the opportunity to make a scientific contribution, by presenting the capabilities of the comparative Scanning Method (cSM) in the analysis, visualization and psychological interpretation of experimental data of the '*preferential choice*' type.

Scientific focus of the research

The comparative Scanning Method (cSM) is directly related to two of the main components in *A Theory of Data*[1] published in 1964 by its author, Clyde Coombs. Collecting, processing, visualizing, and analyzing psychological experimental data of the *Preferential Choice* type, conceptually—within the cSM framework—transformed into data of the *Similarities* type, is the basis for interpreting, explaining, and predicting the complex behavior of subjects. In particular, the results obtained by cSM in different application domains contribute to the extension of the psychometrics paradigm, as well as to theoretical complementarity in statistics (through the specific mathematical algorithm of comparative scanning). Since cSM is to a large extent an autonomous method with its own theoretical basis, it should be noted that there is no opposition to fundamental concepts in psychometrics, but only a complementation of the knowledge system of this scientific field. The main practical application of the comparative Scanning Method is in the field of Psychology of Personality, regardless of the chosen research approach: *nomothetic* (oriented towards regularities that are valid for the sample under study as a whole); or *idiographic* (oriented towards establishing the characteristics inherent in the individual person under study).

[1] Coombs, C. H. (1964). *A Theory of Data*. New York: Wiley.

Relevance of the research area

Since the comparative Scanning Method is an innovative technology, the historiography of the dissertation research topic is relatively brief. After the formulation of the theoretical foundations of the method and the creation of a software tool for the computational algorithms (Panov, 2000) cSM was initially used for psychophysical analysis of data related to perception of visual and acoustic stimuli. The results of the pilot experiments conducted provide a basis for assuming that the concept of comparative scanning is an adequate approach for data analysis and interpretation. In recent years, the ideology of the method has expanded in two directions, determining the relevance of the topic for science and practice: in terms of theoretical complementarity in the fields of psychometrics; and in terms of areas of application.

The relevance of the research in the field of psychometrics is justified by the introduction of two new concepts leading to the expansion of the possibilities of interpretation of *preferential choice* data, namely:

- Uniform (diffuse) idiographic distribution
  [*type I distribution*]
- Idiographic distribution "clustering/grouping"
  [*type II distribution*]

In essence, the introduced concepts express the two boundary "scenarios" or possibilities for idiographic distribution of individual *ideal points* (or *reference stimuli*) in some attributive space: (1) Uniform distribution across the entire volume or (2) Clustering in a small area of the space. The uniform distribution (*type I*) may be associated with the absence of a common premise or pattern underlying the demonstrated preferences in the population under study. A 'clustering' or 'clumping' type distribution (*type II*) is an indicator of an objective cause of similar preferences, which may be *real* or *"apparent"* (due to multiple factors, some of them random). The form of the ranked (in ascending order) distribution of individual (idiographic) minimum values of the so-called *Matching Factor*, which is a basic construct in cSM, can be used to differentiate the type of the now overall "nomothetic" picture. The two limiting options for this distribution are (1) an *S*-shaped curve with an inflection point around the mean value of F_{min} /the minimum value of the *Matching Factor*/, which "suggests" that the distribution is *normal* /*Gaussian*/, and (2) a *linear* distribution conditioning on a real objective cause for the subjects' similar preferences.

Moving out of the realm of psychophysics, the relevance of the research in terms of areas of application is justified by the possibilities for scientific contribution also in the Psychology of Personality. In the last three years, research has been conducted through cSM, some of which focused on: Integrating the nomothetic and idiographic approach into a single experimental model through the comparative Scanning Method (Bardov & Panov, 2022) (Panov, 2022b); Social stereotypes and individual aesthetic standards. Psychological measurement of "preference choice" (Panov, 2021a); Comparative Scanning Method (cSM) in controlled dreaming technology (Panov, 2021c); Application of the comparative Scanning Method (cSM) for investigation of subjective preferences concerning the golden ratio in visual perception of geometric shapes (Panov & Bardov, 2021) (Panov & Bardov, 2022) (Panov, 2022a); Textbook page structure elements, examined by comparative scanning (cSM) with additional eye-tracking (Panov, Zlatev, & Vasileva, 2022). The relevance of the research in terms of personality psychology (in particular: *value systems*) is also increased by the possibility of the comparative Scanning Method (cSM) to serve as an additional tool for integrating into a unified research model tasks, both nomothetic and idiographic type when dealing with *preferential choice data* (Bardov & Panov, 2022). Study limitations of cSM are ranged to psychophysical research and psychological (*personality*) research, but applicability in the field of *artificial intelligence* is also possible.

Since the relevance of the research should be considered not only in a scientific but also in a practical aspect, the aspiration for the widest possible application of cSM is primarily directed towards the preparation of elements of *individual psychological profiles* that would be useful in a range of activities of counseling psychology, family therapy, criminal investigations, forensic psychological examinations, personnel selection, case follow-up (longitudinal or developmental analyses), etc.

- **Scope of the dissertation**

The expression of preference (when comparing a set of stimuli) is likely the result of a series of *internal* conscious and/or unconscious informational phenomena. In this sense, "choice by preference" can be viewed as a multi-component simultaneous cognitive process, inherent both (or mainly) in natural information processing systems (individual or social) and in some engineered ones such as neural networks or other systems with embedded artificial intelligence, which (so far) lack an emotional element influencing the decision.

Cognitive phenomenon on which the research is focused

Choice by preference (or *why* and *how* we like, prefer, or even are attracted to certain objects and not to others) broadly comprises the following relatively independent components: (1) Situational or concrete perception; (2) Comparison with a current "internal criterion" /benchmark/; (3) Decision-making. Since the second of the described components is the basis of preference and is the focus of the comparative Scanning Method, it is the particular case of an ***alternative forced choice between two stimuli***, in which a "preferential choice" is realized, that is the main cognitive manifestation investigated in this dissertation.

Approach to the cognitive phenomenon under study

The comparative Scanning Method (cSM) for processing, analyzing, visualizing and interpreting of psychological experimental data of the type *Preferential Choice Data*, transformed (within its own theoretical conception) into data of the type *Similarities Data*, defines the aspect, perspective, and research direction towards the psychological phenomenon under study. Since cSM is a kind of subjective model of choice by preference—explicating its most essential characteristics—it also answers the question: *How will the cognitive phenomenon be viewed?*, namely, through geometric representations (as in the Theory of Data) and measurement of the model's own concepts related to the specific psychological phenomena accompanying preference.

- **Research objectives and tasks**

In general, the present dissertation aims to validate the comparative Scanning Method (cSM) as a theoretical concept and technological tool for analysis, visualization, and psychological interpretation of "preferential choice" type experimental data produced by *an alternative forced choice* between two objects (stimuli). Such data can be obtained from a wide range of specific empirical studies. Regardless of the field of application (e.g., Psychophysics, Personality Psychology, etc.), cSM offers a universal algorithm for planning and conducting experimental procedures so that specific software processing can be applied to the data to produce a convincing interpretation of the results, based on the theoretical concept of the method.

Main objective of the study

Presentation of the capabilities of the comparative Scanning Method (cSM) in analysis, visualization, and psychological interpretation of experimental ‘preferential choice’ data

Research tasks

The tasks arising from the aim of the thesis follow their own logical sequence which leads to the revelation of the essence of the method of comparative scanning, and thus to a deeper understanding of the potential of cSM for the psychological interpretation of empirical research results.

(1) First of all—in order to position cSM within the general framework of methods for analyzing psychological research data—it is necessary to review established data collection and processing technologies, the main ones being: laboratory/controlled experiment; field experiment; quasi-experiment; correlational research; case study. To these it is appropriate to add the methods of: interview (structured or unstructured); prospective study; retrospective study; longitudinal study; cross group study; meta-analysis; content analysis. The smooth transition to cSM also requires special attention to *the Black Box method* popularized by N. Wiener for considering an unknown system to be investigated with the methods of system identification. The fundamental

Theory of Data (by Clyde Coombs), however, is playing a role as *a starting point*, which implies a more detailed presentation of its nature, scope and significance for psychological measurement. Because of some similarity between constructs from cSM and MDS (*Multidimensional Scaling*), it is useful to make a comparison between the method of comparative scanning and multidimensional psychological scaling. Finally, in order to complete the framework of the first research task, it is necessary to present both basic approaches to the analysis of psychological experimental data: *nomothetic* and *idiographic*.

(2) The second research task is entirely focused on the full presentation of the method of comparative scanning in all its aspects, revealing its nature, possibilities and limitations. The focus is on: the premises of comparative scanning; the theoretical framework (underlying assumption); the rationale and relevance of the method; the computational algorithms; the implications complementary to psychometric theory (in terms of specific distributions of reference stimuli); additional contributions and other aspects of the choice by preference.

(3) The third research task is to update and complete the computational toolkit implementing the comparative scanning. The evolution of the software—associated with the cSM—implies the improvement of its capabilities, in line with the extended concept of the method (in theoretical and applied terms). The new software which inherits *the IRRA beta* computer program should contain a sequence of clear instructions to users regarding: the installation and start-up of the application; the preparation of the data for processing; the specific characteristics (definition of the *theoretical probability* which is a basic construct in cSM); the vectors of *empirical probabilities* (another basic constructs in cSM); the results of the computational procedures. It is also appropriate to create a web-platform to provide free access to the computational tools of cSM to all researchers in the field of psychological measurement.

(4) The fourth research task is a key to providing empirical evidence on the adequacy of cSM, both theoretically and interpretively. The practical application of the comparative Scanning Method in a series of more or less interrelated empirical studies and experiments is the "touchstone" for the validity and reliability of cSM. A priori pilot experiments (*psychophysical*, *hybrid*, and *acoustic*) based on cSM (Panov, 2000, 2022b, 2022c) provide a rationale for accepting the concept of *comparative scanning* as an adequate and productive approach for analyzing data (of the *Preferential Choice* type, transformed into data of the *Similarities* type) as well as for interpreting them reliably. To more fully reveal the range of cSM application possibilities, the following focus areas have been selected: Psychophysics, in particular *aesthetics* (investigation of subjective preferences regarding the *golden ratio* in the visual perception of geometric ratios); Applied Cognitive Psychology, in particular *architectonics* (investigation of subjective preferences regarding the construction and content of a textbook page); Personality Psychology, in particular *value systems* (indirect assessment of persistent tendencies in the process of making sense of the semantic content of value concepts).

(5) An additional research task revealing the potential of the comparative Scanning Method is to annotate the logical connectivity between cSM and the authors' *Theoretical Model of Associative Interactions* (TMAI), presented in Appendix 1, whose implications indirectly link *comparative scanning* to the theory of *multidimensional psychological scaling*.

- **Expected results**

The main idea of the dissertation, representing the author's vision of how to achieve the stated goal, is to build confidence in the scientific community about the qualities and possibilities of the comparative Scanning Method through empirical research in the focal areas of psychology described above, implemented on the basis of cSM. An additional idea (or goal) is to provoke the expansion of the psychometrics paradigm not only by introducing the two new concepts (the uniform "diffuse" idiographic distribution [*type I*] and the "clustering/grouping" idiographic distribution [*type II*]), increasing the possibilities for interpretation of the *preferential choice* data, but also by providing an upgrading alternative to *direct* psychological scoring on Likert Scales—by *indirect* scoring using results from the application of cSM (computed coordinates of reference points considered as scale values)—leading in most cases to higher measurement accuracy as well as to additional information amenable to analysis and extended psychological interpretation.

Verification of cSM

Although the *comparative Scanning Method* is itself constructed with maximum internal consistency and logical coherence—in terms of its own theoretical framework and the technology for data analysis and interpretation—the full unveiling of cSM capabilities (in the analysis, visualization and psychological interpretation of experimental *preferential choice* data) is invariably linked to empirical evidence of the validity and reliability of the method. In this sense, the expectation is that the planned experiments and empirical studies will provide sufficient grounds for establishing the method as a psychometric tool as well as for a new direction in the development of psychological measurement in general. This also provides the conditions for: *verifiability* (the principled possibility of independent replication of cSM results); *comprehensiveness*; *predictability*; *scientific novelty*; *conservatism* (reference to already accumulated scientific experience).

Results of the problem solving

Following the positioning of cSM within the general framework of methods for analyzing psychological research data and the updating of the computational toolkit implementing comparative scanning, the practical application (or approbation) of the method through the series of interrelated empirical studies and experiments described above is the main tool for verifying the claimed characteristics and reliability of cSM. In order to achieve all the objectives of the thesis research—besides by the method of comparative scanning—the data analysis in some of the experiments and empirical studies is carried out by the validated ones:

- Two-sample *t-test* with unequal variances (*One-way* ANOVA);
- *Exploratory Factor Analysis* [Varimax];
- *Two-factor analysis of variance* (ANOVA);
- *Psychometric curves* by the method of constant stimuli.

In this way—when comparing the results—further reassurance is also provided that the cSM does not contradict but extends the possibilities for analysis and psychological interpretation.

The second chapter of the thesis presents the software toolkit for the multiple computational procedures in the cSM algorithm, called Gen21cSM or *Generator for Comparative Scanning Method outcomes*. Evolutionarily, it builds on the originally created multi-purpose software called IRRA beta or *Imprinting Reliable Rate Analysis* (presented in Appendix 2). The third research task compares Gen21cSM and IRRA beta, matching parameters specific to the two programs such as: dimensionality of the attributive space explored; visualization of results; eigenvalues of cSM (F_{min}, F_{min}/norm/, coordinates of F_{min}, F_{max}, F_{max}/norm/, range, sampling points /on each axis/, 5% /min volume relative/); and the ability to process data simultaneously. Detailed instructions are also presented for the installation of the application, the preparation of the data for processing, the interpretation of the specific characteristics and the results of the computational procedures. Free access to Gen21cSM on the Internet is provided via a QR code and a link, as well as via the *cSMinventory.online* platform which is a result of the implementation of a scientific project entitled "Internet-based toolkit for computational procedures...", funded by the Scientific Research Fund (2022): Projects in support of PhD students / operated by the Sofia University "St. Kliment Ohridski".

As a key to providing empirical evidence on the capabilities of cSM, the fourth research task brings together analyses of the results of 12 empirical studies and experiments conducted in three focal areas: Psychophysics, Cognitive (Applied) Psychology and Personality Psychology. The main features of the studies conducted for the purpose of this dissertation—demonstrating the potential of the comparative Scanning Method in the analysis, visualization, and psychological interpretation of choice-by-preference experimental data—are as follows:

- *Experiment* 01 is a pilot laboratory experiment from the focal area of Psychophysics (*visual perception*) conducted with 30 subjects.
- *Experiment* 02 is a pilot laboratory experiment from the focal area of Psychophysics (*auditory perception*) conducted with 21 subjects.
- *Experiment* 03 is a pilot hybrid experiment from the focal areas of Psychophysics and Personality Psychology conducted with 438 subjects.

- *Experiment* 04 is an empirical study from the focal area of Psychophysics (in particular *aesthetics*) conducted with 96 subjects.
- *Experiment* 05 is an empirical study from the focal area of Psychophysics (in particular *aesthetics*) conducted with 152 subjects.
- *Experiment* 06 is an empirical study from the focal area of Psychophysics (in particular *aesthetics*) conducted with 30 subjects.
- *Experiment* 07 combines laboratory and field experiments from the focal area of Psychophysics (*visual perception*) conducted with 30 + 100 subjects.
- *Experiment* 08 is a laboratory experiment from the focal area of Psychophysics (in particular *aesthetics*) conducted with 34 subjects.
- *Experiment* 09 is a laboratory experiment from the focal area of Cognitive Psychology (in particular *architectonics*) conducted with 30 subjects.
- *Experiment* 10 is a laboratory experiment from the focal area of Personality Psychology (in particular *value systems*) conducted with 15 subjects.
- *Experiment* 11 is an empirical study from the focal area of Personality Psychology (in particular *value systems*) conducted with 209 subjects.
- *Experiment* 12 is a laboratory experiment from the focal area of Personality Psychology (in particular *value systems*) conducted with 26 subjects.

The very first pilot experiment (planned and conducted using the IRRA beta multipurpose software implementing full-scale *comparative scanning*) revealed the structure and specific features of the three-dimensional attributive space of independent characteristics of particular visual stimuli chosen for the study. The individualization of results predicted in the theoretical framework of cSM is confirmed with respect to all eigenparameters[2] of the method, which are presented in detail and exhaustively in the first chapter (part 2.) of this dissertation. More importantly, however, the affirmative answer to the fundamental question concerning the existence of the underlying construct in the comparative Scanning Method in the first place, namely the *reference stimulus*, gives the green light to a related series of new questions surrounding it, specifying not only its measurable parameters as well as those of the space in which it is located, but also questions of a gnoseological nature (e.g. *Why does a reference stimulus arise*?; *When and how is it formed*?; *What is the significance of the reference stimulus for the perception*?).

The second pilot experiment (also planned and conducted using the computer program IRRA, as well as using another acoustic sample /sound fragments/ software), in addition to revealing the structure and specific features of the attributive space of specific auditory stimuli selected for study, also answers the question about the *dynamics of the reference stimulus* through an individual developmental outcome. Namely, in the process of personal development and growth the "internal criterion" underlying *preferential choice* is stabilizing. This refers both to the degree of expressiveness (or "strength" of the criterion in decision making) and to localization (the coordinates in space that quantify the internal criterion, on each individual attribute examined). This result corresponds to the expectation that, as individual personality is shaped over time, the benchmarks for different personal preferences follow their own evolution and, as they "mature" become increasingly conservative.

The third pilot experiment which is "hybrid" by nature, in terms of domains of application, was planned and conducted using the IRRA computer program, as well as using the *State-Trait Anxiety Inventory* (STAI/Form Y), designed by Charles Spielberger and collaborators (Spielberger et al). The main research task was to find possible relationships between the data obtained from the successive application of the IRRA and STAI in the same sample of respondents. For this purpose, on one hand, correlations were calculated between the values of the *matching factor* (F_{min}) and the *range* obtained by cSM, and, on other hand, the values of situational and persistent anxiety /standardized z-scores/ obtained by STAI (as a momentary state and personality trait measured

[2] (F_{min}, F_{min}/norm/, *coordinates* of F_{min}, F_{max}, F_{max}/norm/, *range*, 5% /min volume relative/)

right after the psychophysical examination). The frequency distribution of the minimum value of the *matching factor* (F_{min}) obtained from the experiment is approximately normal (Gaussian), which is a basis to assume that the reason for the demonstrated similar preferences of the individuals is due to multiple factors, some of which, however, are random. In other words, the particular "idiographic" distribution is unreal (*type II*). Regarding the results of the personality component, there is a moderate positive linear relationship between anxiety as a state and as a personality trait, but more significantly, when comparing the results of the perceptual and personality components of the hybrid experiment, there is no (linear) relationship between the stability of preference and the anxiety of the subjects. However, in confirmation of the result of the second pilot experiment, it is found that the intensity of the reference stimulus increases with age! (The criteria of harmony, aesthetics and impact are being validated).

The conceptually related experiments—the fourth, the fifth, and the sixth—lead to the application of the comparative Scanning Method to investigate subjective preferences regarding the *Golden Ratio* in the visual perception of geometric proportions. The integrated research task includes: (1) construction of a *preference curve* after matching pairs of two-dimensional geometric figures (inscribed circles of type *outline*) by the subjects; (2) registering the possible effects of the inclusion of a third dimension of the visual stimuli /a differing contrast in the gray scale between the two constituent elements of type 'inscribed circles' was used as such/; (3) demonstration of the capabilities of the comparative Scanning Method in the analysis, visualization and psychological interpretation of experimental data of the *preferential choice* type. Consistently, the results demonstrate that: (1) the actual preference is for a visual stimulus whose constituent *diameters* are in the "golden ratio" proportion compared to a stimulus whose constituent *areas* are in the same proportion; (2) the inclusion of a third dimension /contrast between the two elements, in the gray scale/ degrades or removes the preference for the stimulus whose *diameters* are in the "golden ratio" proportion; (3) in contrast to the many cases in which the averaged parameters of individual preferences /uniformly distributed over some attributive space/ lead to the impossibility of identifying a real collective *ideal point,* in the last of the series of experiments it is found that not only does one exist but the strength of the "internal criterion" is greater than any of the individual *ideal points*. This is probably related to the high degree of general validity of the sense of visual harmony due to the "golden ratio" proportion.

As the seventh experiment which is inherently a combination of a laboratory component and a field empirical study—but is outside the scope of the dissertation topic—its full description (Material and Method; Results and Discussion) is presented in Appendix 5. Based on the psychophysical *method of constant stimuli* (Mateeff, 1981) a *Similarities Data* collection procedure is implemented under a *forced-choice*. Technologically, the experiment is realized by the tachistoscopic method. The aim of the study is to compare data from different experimental conditions, which are related to the peculiarities of the left and right brain hemispheres (*laboratory study*), as well as the work of the intact brain in non-laboratory conditions (*field study*). The research task is to illustrate some aspects of visual perception related to subjective preferences concerning the "golden ratio" embedded in the stimuli of the sixth experiment.

The eighth experiment is also in the field of Psychophysics, in particular *aesthetics* (investigation of subjective preferences regarding the *Golden Ratio* in the visual perception of geometric proportions). The experiment was carried out by laboratory application of gaze-tracking technology on screen to investigate subjective preferences about the "golden ratio". *Eye Tracking* was used to establish a relationship between preferential choice and how visual stimuli (number of saccades[3] and gaze dwell time on objects) were subjectively attended. *The hypothesis is that subjects' gaze will linger longer on more preferred objects* (visual stimuli similar to those in the fifth and sixth experiments). The obtained results demonstrate the relationship between choice by preference and the way of subjective viewing of visual stimuli (on a computer screen), namely, subjects' gaze lingers significantly longer on preferred objects. This corresponds with the intuitive hypothesis that objects of preference have a greater "power" of attracting and holding attention.

[3] A saccade is a quick, simultaneous movement of both eyes between two or more phases of fixation in the same direction.

The ninth experiment is in the field of Applied Cognitive Psychology, in particular *architectonics* (the study of subjective preferences regarding the construction and content of a textbook page). Again, this experiment was carried out through a laboratory application of *Eye Tracking* (gaze-tracking technology on a screen). The main objective is to investigate the visual perception of the quantity and placement of the main elements in an arbitrary textbook page, and using the comparative Scanning Method (cSM), the specific research task is to determine the most harmonious combination of the main text in the architectonic[4] of the page with the complementary images and diagrams. A derived additional goal is to identify the eye retention zones on the page by tracking the saccades. In this regard, it is found that there is no difference in gaze movement with respect to left and right visual fields, and the highest degree of gaze retention is on the middle of the page if that is where the images or figures are positioned. The strong position of the gaze in the middle of the page is a reason to believe that the essential learning information should be placed there and other parts of the page should be filled by additional information, pointing and guiding headings or other data. In applied terms, a hybrid learning situation—combining forms of digitally used resources and those presented on paper—suggests the construction of tools (methodological instruments) that use both modes.

The results of this experiment (in terms of cSM) are comparable to the results of the third experiment presented, regardless of the different focal areas in which they were conducted. When the planes of the attributive spaces in which the reference points (*ideal points*) are found were visualized (scanned using the computer program IRRA), it was found that in both cases their corresponding points were not localized in the center of the spaces under investigation. This is grounds for rejecting an assumption concerning the absence of a common assumption or regularity underlying the preferences demonstrated for the sample under study (something characteristic of uniform *type I* distributions, where only exceptionally may the reference point be in the center of the examined space). In the two experiments presented here (the third and the ninth), their respective distributions are of the "grouping/clustering" type (*type II*) which is an indicator of an objective reason for the similar preferences of the individual subjects. The focus of the research task for this particular comparison is whether this cause is *real*: due to population-wide assumptions; or whether it is "*apparent*": due to multiple factors, some of which are random. Comparison of the distributions of F_{min} values in the third and the ninth experiments (arranged in ascending order) reveals a difference, the basis of which is the expectation of a real or "apparent" objective reason for demonstrating similar preferences. On the one hand, the specific *S*-shaped curve (with an inflection point in the center of the distribution) "suggests" that in the third experiment the distribution is *normal* (Gaussian). This is a basis to suppose that the reason for the similar preferences of the different subjects in this experiment is due to multiple factors, including random ones. In other words, there is an unreal "idiographic" *type II* distribution. On the other hand, the *linear* distribution of the minimum values of the matching factor found in the ninth experiment suggests that the cause of the similar preferences of the individual subjects is due to prerequisites, conditions, or predictors common to the population under study. In this case, there is a genuine "idiographic" *type II* distribution.

The last group of conceptually related experiments are in the field of Personality Psychology, in particular *value systems* (for indirect assessment of persistent tendencies in the process of making sense of the semantic contents of value concepts). The main goal of the tenth experiment is to demonstrate the performance of the comparative Scanning Method (cSM) in processing, analyzing, visualizing, and interpreting *preferential choice data* related to the ***indirect*** assessment of *terminal values*, as defined by Milton Rokeach (Rokeach, 1973), through complex verbal (textual) stimuli in a three-dimensional semantic (attribute) space. The research task is to apply cSM in a three-dimensional space defined not by features (attributes) of a single value concept (e.g., *attainability*, *social* or *subjective relevance*, etc.) but by three different relatively independent values from Rokeach's list. Since the analysis of the results revealed the presence of *reference zones* of different shape, size, salience, and localization of the individual subjects, it can

[4] *Architectonics* refers to the specific layout of elements on pages, usually separated by headings with specific content specified in a legend. Such headings are: with information containing a conceptual presentation of a new concept; for independent work; for control and evaluation; for extending the body of knowledge.

be assumed that (1) the comparative Scanning Method is suitable for individual studies (*case study*); (2) the parameters of the reference zones (or the quantitative combination of the three selected value concepts) from the given attributive space of complex verbal stimuli are strictly individual for each subject; (3) there is no universal reference zone in terms of defined feature space. In this case, the established "nomothetic" distribution is of *type I*. The research task of the eleventh experiment is twofold: (1) to determine /by *Exploratory Factor Analysis*/ the importance and attainability of a set of values including some of those originally defined by Rokeach as *terminal*, but some of them modified and supplemented. The aim is to examine their social image into individual consciousness by ***direct assessment*** on Likert Scales; (2) to prepare the material for the research design of the last (twelfth) experiment, which examines the social image of values into individual consciousness by means of ***indirect assessments*** using the comparative Scanning Method (cSM). The results obtained at this "nomothetic" stage of the study demonstrate that direct evaluations (on seven-point Likert Scales) correspond to the subjective meanings that emerge from the set of value-stimuli in individual minds. The final research task in this group of experiments is to determine both the respondents' collective and individual reference zones/areas/points (*ideal points*), in terms of three latent factors identified by the ***direct*** evaluations (on Likert Scales in the preparatory eleventh experiment): (1) *attainability*, (2) *social meaning*, and (3) *subjective meaning*. The twelfth experiment applied the comparative scanning algorithm to a set of selected values, those with the highest factor loadings after the first stage of the study (*Happiness*, *Self-Esteem*, and *Health*), whose reference areas were expected to be characterized by location in feature/attributive space (*coordinates*), salience (minimum value of the *matching factor*), size (*range*), and shape (*gradient*). The results demonstrate that cSM can effectively describe and visualize the emergent "Meaning Gestalts" both in group and individual consciousness. A characteristic feature of all three selected (target) value concepts is that the "nomothetic" *minimum* value of the matching factor (F_{min}) is smaller than any "idiographic" one. Also, no individual i*deal point* is located into the corresponding nomothetic reference zone, and the distributions are clustered, of the "grouping/clustering" type (*type II*). This is a basis to suppose that the reason for the similar preferences of the individual subjects (in the different clusters) is due to common preconditions, states or predictors. In other words, there are several genuine *type II* "idiographic" distributions. The results also demonstrate that if the sample is split into two parts—based on the coefficients of the overall linear correlation between the ***indirect*** (via Likert Scales) and ***direct*** (via cSM) assessment of value concepts—only for one third of the respondents the "declarative" values coincide with the "real" ones. All of the above gives reason to assume that the comparative Scanning Method (cSM) is a valuable additional tool for integrating into a unified research model tasks—both of nomothetic and idiographic type—with applicability in the field of Personality Psychology when dealing with *preferential choice data*.

- **Significance to science and applicability**

As a technology for processing, analyzing, visualizing, and interpreting experimental data from a wide range of psychological studies, the comparative Scanning Method (cSM) is not only a tool but also an opportunity to extend the psychometric paradigm. The ways for doing so are several: from introducing new *measurable*, *comparable*, and *interpretable* concepts into its own theoretical base, through defining idiographic distributions of individual ideal point (or reference stimuli) *types* in some attributive space (developing the concept of real/genuine or "apparent" reasons for similar personal preferences), to provoking interrelations with the *Theoretical Model of Associative Interactions* (TMAI).

Significance of the results for science

Following the conceptual coherence of the *comparative Scanning Method* with the *Theory of Data*, it can be assumed that the positioning of cSM in the "hierarchy" of other methods for analyzing psychological research data is somewhere between *Multidimensional Psychological Scaling* (MDS) and *Factor Analysis*. The scientific novelty that cSM contributes is in several directions:

(1) By introducing the method's own concepts, as well as extending the meaning of other common methodological constructs (*Attributive /stimulus/ space*; *Semantic/attributive /feature/*

space; *Internal criterion*; *Reference stimulus*; *Reference area*; *Theoretical probability*; *Empirical probability*; *Matching Factor* /F/; *Localization of the reference area*; *Range*; *Gradient*; *Idiographic cSM analysis*; *Nomothetic cSM analysis*; *Uniform /diffuse/ idiographic distribution: type I*; *"Clustering" idiographic distribution: type II*), an additional opportunity is created to model and study ***preferential choice*** as a multi-component cognitive process. A key construct for this is the experimentally established *reference stimulus* which directly corresponds to the *ideal point*, the perfect quantitative balance between the attributes or characteristics of a perceived object. A conceptual nuance in the distinction between the "reference stimulus" and the "ideal point" is noticeable in the definition of the two almost overlapping concepts, namely: the *reference stimulus* is a "subset" of the *ideal point*, since only a portion (albeit the most significant one) of the attributes of the object-stimuli under study defines the space in which its localization and "strength" are sought. Since comparative scanning is applicable to the study of choice by preference both idiographically (for a single specific case or *case study*), and nomothetically (in samples or populations), in the latter case the prerequisites for future research towards the genesis and characteristics of the "collective" referent stimulus are established. For now, it suffices to note that the results presented in this dissertation from heterogeneous experiments conducted with cSM and explicating different types of ideal point distributions "suggest" a further direction of search in terms of collective preferences, in particular, new cases with common preconditions, states or predictors for the population under study leading to similarity in preferences, or conversely, cases where *ideal point distributions* are "diffuse" and not due to common objective causes. All of this will lead to a further collection of facts that may provoke a revision of current theoretical concepts even in the field of Social Psychology, where the main object of scientific interest is human behavior as a function of the social environment. A possible aspect of such future research (with the technological involvement of cSM) is the ***distinction*** between *individual* and *social* "ideal", in any life domain. Thus, it may also extend in the future the synergy between Statistics and Theoretical Psychology.

(2) Despite the experimental establishment of the *reference stimulus*, there is still room for discussion of a critique of the model, in terms of *constructivism* which offers an alternative to the described geometric representations, in which feature/attributive spaces are not necessary. Since constructive cognitive processes are seen as processing relational structures, the assumption of "generating" a semantic/attributive space as the result of a multi-component cognitive process involving both perception and memory is somewhat acceptable, but only for the specific moment and context, not in general. However, it is also an opportunity for cSM to provide arguments in support of the geometric representations that underlie both the *Theory of Data* and the method "*Comparative Scanning*".

(3) The study of the *choice by preference* in multicomponent stimuli is severely hampered by the complexity and varying degrees of importance (or "weight") of the individual attributes of the objects being evaluated, as well as the context (real or artificial) in which they are located. Since modeling complex attributes using multidimensional feature spaces is a non-intuitive and complex mathematical procedure (especially if the dimensionality of the space is greater than 3), a question of model optimization arises. One possibility for this is the use of ***schematic*** stimuli if they evoke a clear and unambiguous picture in the minds of the subjects. Such artificial visual stimuli, for example, were used in the first pilot experiment planned and conducted using the computer program IRRA. The design of these stimuli involved only three meaning-distinctive and context-independent (invariant) parameters that elicited an overall picture of the objects subjected to alternative choices by preference. And even though real stimuli possess numerous features, their reduced number in artificial substitutes turns out to be sufficient for imagination especially if they are selected with a high degree of salience/"weight" for perception. In this way, the basic premise of *comparative scanning* is also realized, namely: defining a subset of independent physical or abstract/verbal characteristics (measurable features/parameters) of the stimuli within which the "internal criterion"[5] will be investigated—depending on the goals of a given research, resulting in a study focused only on the experimentally relevant subset of properties of the objects under investigation.

[5] (Mateeff, 1981)

(4) By presenting the capabilities of the comparative Scanning Method (cSM) in the analysis, visualization, and psychological interpretation of "choice-by-preference" experimental data, a foundation for subsequent research in psychometrics is established, greatly facilitated by the available open-access computer applications developed for the purposes of this dissertation. The software implementation of *comparative scanning* is the only possibility to overcome the time overspend resulting from the complexity and energy intensity of computational procedures in cSM. Implementing the computational algorithm of the comparative Scanning Method, specialized programs (IRRA, Gen21cSM, cSMinventory.online) identify and quantify the eigenvalues of the method (F_{min}, F_{min}/norm/, coordinates of F_{min}, F_{max}, F_{max}/norm/, range, 5% /min volume relative/) that follow their psychological interpretation according to the theoretical foundations of cSM. It is important to note that the visualization of the results by means of scanning (with the IRRA software) also detects possible unreliable (accidental or intentional) behavior during the survey of the respondents, indicated by the appearance of specific axes of symmetries in the scanning planes.

(5) The most concrete current contribution of the comparative Scanning Method, adding scientific novelty to the study, is the identification of two of the border variations of the shape of the ranked distribution of individual (idiographic) minimum *matching factor* values, namely: The *S*-shaped curve with an inflection point around the mean value of F_{min} (in the third experiment), which is an indicator of a *normal* (Gaussian) distribution, and the *linear* distribution (in the ninth experiment), conditioning on a real objective reason for the similar preferences of the individuals under study. Of particular note is the finding (in the twelfth experiment) that it is possible to have a picture in which no individual *ideal point* falls within the sample's characterizing reference (nomothetic) zone, challenging the scientific conventions of norm setting based on statistical estimation of central tendencies in a particular data type. In addition, the second experiment (within a longitudinal study) also establishes dynamics in the localization and "maturation" of a particular reference stimulus.

Significance of the results for practice

In addition to the described contributions of cSM to extend the psychometric paradigm through its innovative computational algorithm and its own theoretical basis and constructs, the study goes beyond abstract scientific knowledge, providing a toolkit for the work of psychologists from different fields of application. This is facilitated by the free/open access provided to the software implementing the comparative scanning.

Practical applicability of cSM—giving a wide range of possibilities for individual diagnostics (*case study*) in the field of Counseling Psychology—is the determination of the degree of personal "distancing" from the actual for a particular time and place *social norms* which sometimes have a destructive impact on the mental functioning of a person. No matter how exactly the social patterns that prompt dependent behavior arise, some of their manifestations can be linked to stereotypes and prejudices. In such a case, *self-knowledge* is a key to overcoming the possible negative consequences of the emerging cognitive dissonance or "contradiction" between the socially imposed *'external' norms* of what to like (or how to behave) and the *'internal' benchmarks* for behavior, in terms of thoughts, feelings and actions. This is why non-quantitative *indirect* self-assessment through cSM is an opportunity for deeper self-knowledge, and hence for reasoned opposition to destructive social messages.

Another aspect of the applicability of cSM stands out in studies where the respondents are younger children or people with certain cognitive deficits (moreover, it is sometimes the only option for people with a particular type of disability). The comparative Scanning Method is a possible alternative to quantitative *Likert Scales*, both in terms of the way of assessment (***direct*** in Likert Scales and ***indirect*** in cSM) and the accuracy of the results, which (as will be clarified later in this dissertation) is greater in the non-quantitative assessment by comparing dyads of stimuli by preference, since in the indirect qualitative (or intuitive) assessment analyzed by cSM, the respondent is only required to make an alternative choice in a series of stimulus pairs /a lengthier procedure, but with minimal risk of subjective errors/. The indirect *qualitative* ratings thus obtained are "transformed" into *quantitative* ones by the coordinates of the reference stimulus in the space under study, and each of the axes of this space can be interpreted as an independent *Likert Scale-continuum* with very high "resolution".

Longitudinal studies (in nomothetic or idiographic aspect) are also feasible by diagnostic application of cSM. The set of eigen-quantitative parameters of the comparative Scanning Method (F_{min}, F_{min}/norm/, coordinates of F_{min}, F_{max}, F_{max}/norm/, range, 5% /min volume relative/) is traceable over time, which is an opportunity to compare individual moments of the development or "maturation" of personality (e.g. as in the second experiment presented). The practical value of this type of study lies in the possibility of assessing the "speed" of personality development—if norms of functional age are established in advance by cSM, to be compared with biological age.

Finally, although the comparative Scanning Method has been successfully applied in a number of empirical studies from different focal areas of scientific or practical research, the main application of cSM is directed towards the construction and implementation of laboratory (or clinical-diagnostic) experiments in the fields of: Psychophysics, Personality Psychology, Counseling Psychology, Social Psychology, Clinical Psychology and even Psychotherapy. Moreover, cSM is also applicable in the field of Artificial Intelligence, for example, in the analysis of *preferential-choice-data* from simulation through artificial neural networks.

Summarizing what has been presented in this introduction, it should be noted that the study as a whole meets five of the generally accepted attributes of scientific novelty, which relate to:

• *posing a new scientific problem;*

• *introducing new scientific categories and concepts;*

• *discovery of new regularities of phenomena or processes;*

• *application of new methods, technologies, equipment and software for research;*

• *developing new scientific ideas about the world, man, and society.*

comparative Scanning Method, cSM

If a set of physical (or abstract/verbal) stimuli in experimental conditions is sequentially presented in a series of pairs (pairs of all possible combinations between the stimuli) and for each pair a subject (a participant in the experiment) chooses one of the both stimuli depending on: *The condition Who is more X?* (predefined for the purposes of the experiment an ***external criterion***; X is some quality of the stimuli) and his/her *Preference* (an ***internal criterion***, according which the subject makes a decision), than the obtained data are of the so-called preferential choice type. Such data are subject to processing and analysis through classic techniques proposed by Joy P. Guilford (Guilford, 1954), Warren S. Torgerson (Torgerson, 1958) and Clyde Coombs (Coombs, 1964). Currently, this is also possible through the algorithmic-statistical procedure named *comparative Scanning Method* (cSM).

Nature, capabilities and limitations of cSM

The comparative Scanning Method is a technology for processing, analyzing, visualizing and interpreting of psychological experimental data of type *Preferential Choice Data* transformed into *Similarities Data*.

A prerequisite for cSM is a prior definition of some subset of independent physical or abstract/verbal features (measurable characteristics/ parameters) of the stimuli, within which the ***internal criterion*** will be examined (Mateeff, 1981). The main assumption is that the stimuli causing the strongest psychological effect form the so-called ***Reference Zone*** into the selected attributive space (Panov, 2000). It is the presence of a *reference stimulus* that transforms the classification of the data: the subject rates the preferred stimulus as more similar to one's own reference.

The reference stimulus is a point (or *zone*) of the semantic space, the coordinates of which determine numerically the most harmonious quantitative combination of characteristics. It is expected that a stimulus with these characteristics will be preferred over any other in this space. If two random stimuli from the set space are offered for preference rating, the one that is closer to the reference stimulus will be selected.

Comparison of the comparative Scanning Method and the Multidimensional Psychological Scaling

In general, the task of *Multidimensional psychological scaling* (MDS) can be formulated as follows: A given set of objects is characterized by an unknown number of independent quantitative properties which can be considered as axes of a multidimensional space. Using subjects' assessments of the similarity between objects, the space axes and scale values of the objects for each property should be found.

The main postulates in the theory of multidimensional psychological scaling are: 1. Psychological space is a subjective reflection of objectively existing independent properties of objects; 2. The distance between two points in space is a function of the similarity between the corresponding objects. The greater the similarity between two objects is, the smaller the distance between their corresponding points in psychological space is (Gerganov & Alexieva, 1988).

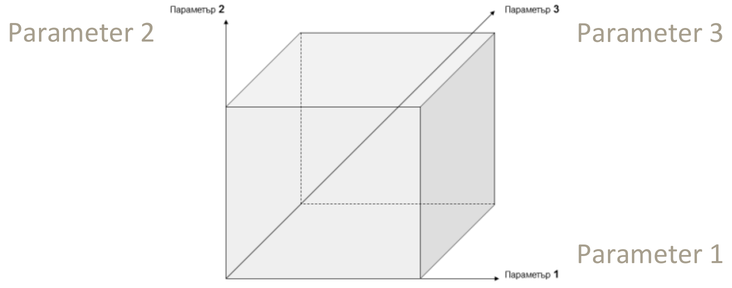
Unlike multidimensional psychological scaling of the comparative Scanning Method (cSM), the dimension of the feature space and the characteristics of the axes are set in advance, depending on the goals and objectives of the given study. Thus, the study focused only on an experimentally relevant subset of stimulus properties.

Ground and significance of cSM

One of the most significant tasks (that is realized by applying the comparative Scanning Method) is detection of the exact localization of the ***reference stimulus*** in the generated (or available) attributive space—despite the possibility of logical collapse of the geometric model, which could be illustrated by the following way:

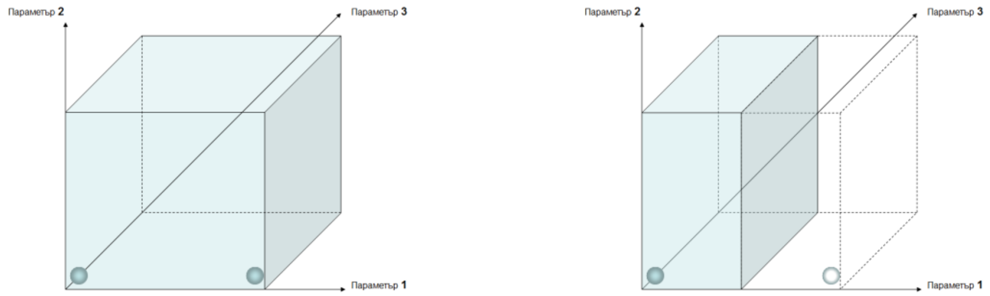
If the possible pairs of stimuli from the set space are offered for preference evaluation (selected to have only marginal levels of each physical or abstract parameter) a *logical paradox* arises related to the geometric approach to localization of the reference stimulus (zone) consisting in the following: *Since the localization of the reference stimulus in the feature space of physical characteristics is based on the answers of the researched person, and these answers are probabilistic in nature (that applies to most natural systems of perception and information processing), the direct application of geometric considerations (in case of conflicting answers) leads to the impossibility of locating the searched reference area in space.*

The series of figures presented below illustrate the described situation in the 3-dimensional particular case. Let a subspace be defined in the given feature space (bordering on the perception of stimulus parameters):



The geometric model of cSM defines the ***reference stimulus*** as a point (or zone) in the *generated* semantic space. Its coordinates within determine numerically the most harmonic quantitative combination of the features (parameters/properties).

If the pair of boundary stimuli from Parameter 1 (shown on the left figure below) is offered as a *preference rating* and the respondent chooses, for example, the left stimulus (with the low value of the parameter), than…

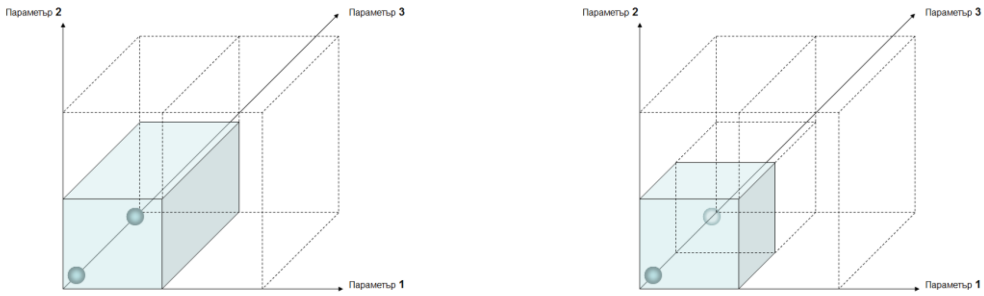


according to the geometric model, the ***reference stimulus*** is located within the preference half-space (shown on the right figure above), since each point in this half-space is closer to the left stimulus than to the right one, and ***preference selection is determined by similarity to the reference stimulus***—*the one of the boundary pair of stimuli that is closer to the reference stimulus is chosen*.

If the pair of boundary stimuli from Parameter 2 (shown on the left figure below) is offered as a *preference rating* and the respondent chooses, for example, the lower stimulus (with the low value of the parameter), than…

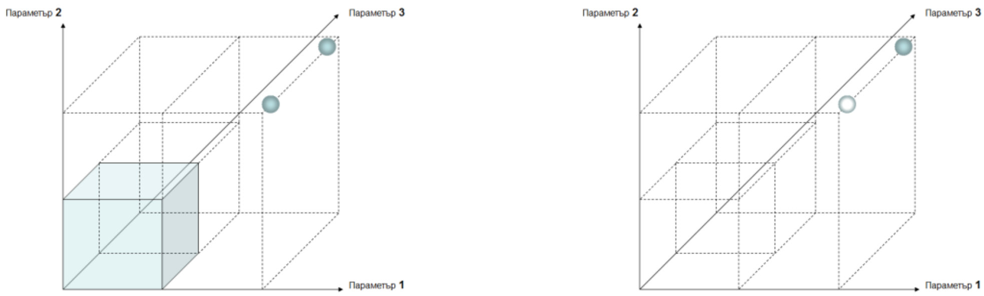
according to the geometric model, the ***reference stimulus*** is located within the preference quarter-space, since each point in this quarter-space is closer to the lower stimulus than to the upper one. And in this hypothetical situation, as well as in the previously presented case, the one of the pair of boundary stimuli that is selected is geometrically closer to the sought reference one.

If the pair of boundary stimuli from Parameter 3 (shown on the left figure below) is offered as a *preference rating* and the respondent chooses, for example, the front stimulus (with the low value of the parameter), than…



according to the geometric model, the ***reference stimulus*** is located within the preference space, since each point of this ⅛-space is closer to the anterior stimulus than to the posterior one. As in the previous two presented cases, from the pair of (boundary) stimuli, the one that is geometrically closer to the sought reference one is selected.

If the pair of boundary stimuli from Parameter 3 (shown on the left figure below) is offered as a *preference rating* and the respondent chooses, for example, the rear stimulus (with the high value of the parameter), than…



according to the geometric model, for the ***reference stimulus*** <u>no possible subspace remains</u> (shown on the right figure above). This is precisely the logical paradox of the model. Moreover, although the presented sequence of related "choices of preference" is hypothetical, it (as practice demonstrates) often happens to be realized in real experimental designs.

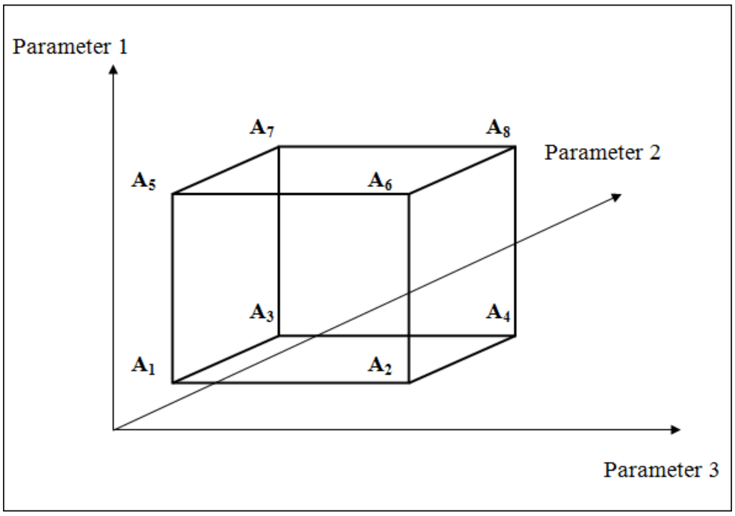
The comparative Scanning Method (cSM) offers a solution to so described logical or computational case: *A localization of the reference stimulus in the attributive space of the physical characteristics is possible by modification of the described geometric model into a statistical (probabilistic) analysis*.

Theoretical framework of cSM

The comparative Scanning Method is implemented by an innovative algorithm analyzing each point of the attributive space ("generated" semantic space). At the base of this analysis is the calculation of a ***Matching Factor*** (**F**) by matching theoretical expectations with empirical data. This matching factor is the measure of the degree of overlapping between an arbitrary stimulus (with coordinates at point ***i***) from the defined space and the putative reference stimulus—the smaller the value of **F**, the more likely point ***i*** is to match with the ***internal criterion*** according to which the respondent makes a decision.

Variant in three-dimensional space (with physical stimuli)

Let there be given a 3-dimensional attributive space of physical characteristics and the stimuli $\mathbf{A_1}$, $\mathbf{A_2}$, $\mathbf{A_3}$, $\mathbf{A_4}$, $\mathbf{A_5}$, $\mathbf{A_6}$, $\mathbf{A_7}$, and $\mathbf{A_8}$ located in this space at a distance significantly greater than one *just noticeable difference* (JND) as shown in the figure below:



The parameters from the three-dimensional physical (attributive) space are a subset of all possible physical parameters of the stimuli and are chosen to be independent. The eight stimuli have only two levels of each parameter. Selected in this way, they are arranged in the feature space at the vertices of a parallelepiped (or topologically similar object). Since all possible combinations of n number of stimuli are $n(n\text{-}1)/2$, in this case the dyads (pairs of stimuli) to be rated by preference are 28, as follows:

[A_1, A_2], [A_1, A_3], [A_1, A_4], [A_1, A_5], [A_1, A_6], [A_1, A_7], [A_1, A_8],
[A_2, A_3], [A_2, A_4], [A_2, A_5], [A_2, A_6], [A_2, A_7], [A_2, A_8],
[A_3, A_4], [A_3, A_5], [A_3, A_6], [A_3, A_7], [A_3, A_8],
[A_4, A_5], [A_4, A_6], [A_4, A_7], [A_4, A_8],
[A_5, A_6], [A_5, A_7], [A_5, A_8],
[A_6, A_7], [A_6, A_8],
[A_7, A_8].

The coordinates-levels of the stimuli are as follows:

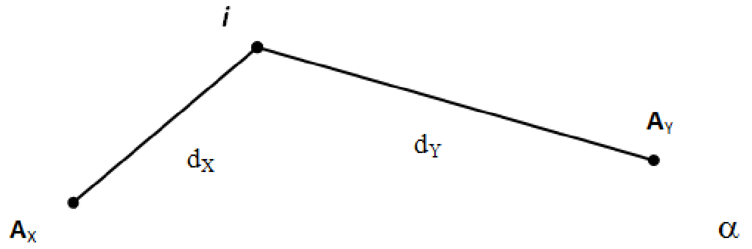
Stimulus	*Parameter 1*	*Parameter 2*	*Parameter 3*
A_1	low	low	low
A_2	low	low	high
A_3	low	high	low
A_4	low	high	high
A_5	high	low	low
A_6	high	low	high
A_7	high	high	low
A_8	high	high	high

At the core of cSM is the idea of comparing the theoretical and empirical probability that a given stimulus is "more X" than another (where X is some macroscopic property) ***for each point*** *in the feature/attributive space of physical stimuli.*

On the one hand, calculating the theoretical probability that a given stimulus is *more X* than another is based on geometric and logical considerations. On the other hand, the preference ratings of the 28 pairs of stimuli correspond to the empirical probability that one stimulus is "more X" than another one at any point of the attributive space. The main task of cSM is to demonstrate to what extent the point ***i***—randomly selected from the attributive space of the physical (or the complex) stimuli—matches the supposed (searched) reference stimulus.

The theoretical probability that a given stimulus is preferred over another stimulus can be defined differently. For the operation of cSM, it does not matter exactly how this probability is determined, as long as it is analytically and unambiguously defined.

There is a relatively simple and almost "natural" way to determine the theoretical probability $\boldsymbol{p}(A_X\ i \mid A_Y)$ – putative reference stimulus with coordinates at point ***i*** to be more similar to $\mathbf{A}_X$ than to $\mathbf{A}_Y$. The theoretical probability that the stimulus $\mathbf{A}_X$ is preferred over $\mathbf{A}_Y$ should have the following characteristic (boundary) values: $\boldsymbol{p}(A_X\ i \mid A_Y) =$ **0,0** (when stimuli ***i*** and A_Y coincide); $\boldsymbol{p}(A_X\ i \mid A_Y) =$ **0,5** (when stimulus ***i*** is equidistant from $\mathbf{A}_X$ and $\mathbf{A}_Y$); $\boldsymbol{p}(A_X\ i \mid A_Y) =$ **1,0** (when stimuli ***i*** and $\mathbf{A}_X$ match). Regardless of the dimension of the space in which they are located, the stimuli are on one only plane α /alpha/:



If the distance between $\mathbf{A}_X$ and ***i*** is equal to d_X, and the distance between $\mathbf{A}_Y$ and ***i*** is equal to d_Y—the theoretical probability can be defined by the distances between the stimuli as follows [fulfilling the required boundary characteristic values]: $\boldsymbol{p}(A_X\ i \mid A_Y) = d_Y / (d_X + d_Y)$. The theoretical probability could also be defined by the distances between stimuli in this alternative way: $\boldsymbol{p}(A_X\ \boldsymbol{i} \mid A_Y) = 1 / [\ 1 + (d_X / d_Y)^{\boldsymbol{n}}\ ]$[6].

The empirical (experimental, statistical) probability that a given stimulus is preferred over another can be determined in various ways. The main factors determining this probability are: *Percentage of choosing a given stimulus over another* (equal to the ratio: number of preferences for a given stimulus / number of submissions of the stimulus pair for evaluation) and *Reaction Time* (proportional to the amount of "indecision" in making a decision—the larger it is, the closer the probability is to the value ½).

Calculation algorithm of the *Matching Factor*

Assuming that $(p^{\#}_1, p^{\#}_2, \ldots, p^{\#}_{28})$ is a *vector* obtained after an experimental study of a given subject [the elements of which are the *empirical probabilities* that the left stimulus was preferred in each of the 28 dyads]:

$p^{\#}_1 = \boldsymbol{p}(A_1\ \#\mid A_2) =$ *empirical probability* that $\mathbf{A_1}$ is *more X* than $\mathbf{A_2}$
$p^{\#}_2 = \boldsymbol{p}(A_1\ \#\mid A_3) =$ *empirical probability* that $\mathbf{A_1}$ is *more X* than $\mathbf{A_3}$
...
$p^{\#}_{28} = \boldsymbol{p}(A_7\ \#\mid A_8) =$ *empirical probability* that $\mathbf{A_7}$ is *more X* than $\mathbf{A_8}$

and assuming that $(p^i_1, p^i_2, \ldots, p^i_{28})$ is a *vector* [the elements of which are the *theoretical probabilities* at point ***i*** that the left stimulus was preferred in each of the 28 dyads]:

$p^i_1 = \boldsymbol{p}(A_1\ i \mid A_2) =$ *theoretical probability* that $\mathbf{A_1}$ is *more X* than $\mathbf{A_2}$
$p^i_2 = \boldsymbol{p}(A_1\ i \mid A_3) =$ *theoretical probability* that $\mathbf{A_1}$ is *more X* than $\mathbf{A_3}$
...
$p^i_{28} = \boldsymbol{p}(A_7\ i \mid A_8) =$ *theoretical probability* that $\mathbf{A_7}$ is *more X* than $\mathbf{A_8}$

If the elements of the vectors $(p^i_1, p^i_2, \ldots, p^i_{28})$ and $(p^{\#}_1, p^{\#}_2, \ldots, p^{\#}_{28})$ form modules of the differences: $\Delta_1 = |\ p^i_1 - p^{\#}_1\ |$, $\Delta_2 = |\ p^i_2 - p^{\#}_2\ |$, **…**, $\Delta_{28} = |\ p^i_{28} - p^{\#}_{28}\ |$, the analytical definition of the *MATCHING FACTOR* for the point ***i*** is:

$$\mathbf{F}^{\,i} = \sum_{k=1}^{28} \Delta_k$$

[6] ***n*** is the *dimension* of the attributive space—this definition is based on the author's concept presented in Appendix 1, named *Theoretical Model of Associative Interactions* (Panov, 2000).

The matching factor **F** $\subset$ [0 ; 28] is the measure of the degree of bijection (or overlapping) between a stimulus (with coordinates at point ***i***) and the putative reference stimulus—the smaller the value of **F** is, the more likely point ***i*** is to define the ***internal criterion*** according to which the subject makes a decision (*preferential choice*).

If the described procedure is performed for all points in the attributive space of the physical (or complex abstract/verbal) stimuli, and for each point the calculated match factor is mapped and plotted with a "temperature color", the cSM will visualize (scan) the space with colors, the warmest of which will depict the reference zone that defines or matches the ***internal criterion****.*

The minimum value of the *matching factor*, the *localization* of the reference zone, the *gradient*, and the *range* (the difference between the maximum and minimum value of **F** for the given attributive space of the physical stimuli) are parameters that characterize the specific cognitive system (the subject).

Basic software

For the implementation of the comparative Scanning Method (cSM), a computer program **IRRA beta** or *Imprinting Reliable Rate Analysis* was created (presented in Appendix 2), which is a stand-alone multipurpose software product. The multiple calculation procedures of the cSM algorithm are implemented instrumentally through updated software named **Gen21cSM** or *Generator for comparative Scanning Method outcomes*, version 2021.

Reference stimuli (*ideal point*) distributions

In nomothetism, the investigated phenomenon is considered from normative positions—it is assessed for the degree of manifestation and the assessment thus obtained is compared with a pre-made standard usually formed on the basis of the average assessments of the sample of individuals examined according to the given psychological indicator… The idiographic approach expresses the opposite orientation—the respondent/subject is a completely independent object of study; that he/she analyzes himself/herself and in relation to his/her previous states, and not by direct comparisons with the peculiarities of other individuals… In the nomothetic approach, there is an explicit requirement for standardization, as the only way to obtain reliable scientific information. It is this requirement that has strengthened over the years as the main argument in the claim for a monopoly on the reliability of the results (their full reproducibility when repeating the empirical study) and, accordingly, on their credibility (Bardov, 2014)[7].

Hermans (Dutch psychologist) analyzes the possibilities of integration between the approaches. The central question is not whether there is a need to combine the approaches, but how exactly to combine them into a workable model. He proposed that empirical data should be subjected to two different forms of analysis: *nomo-analysis* and *idio-analysis* (Hermans, 1988).

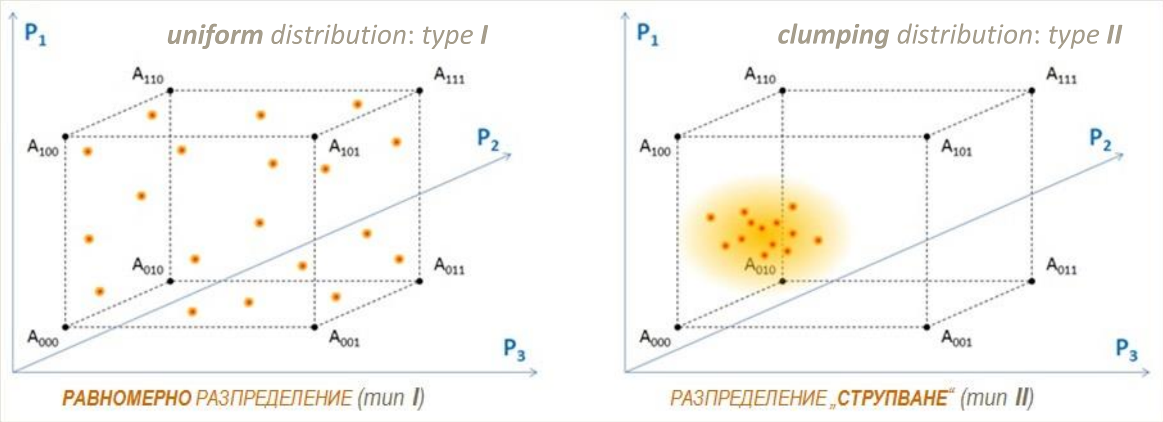
One of the manifestations of this tendency is also related to the comparative Scanning Method, in the application of which a nomothetic feature is established, consisting in the following:

When processing averaged experimental data [nomo-analysis] obtained from participants in planned and conducted cSM experiments, results are DIFFERENT from those obtained from statistical analysis of central tendencies (arithmetic means) in the distributions of individual results [idio-analyses] from the same source data.

The main reason for the described difference is the nonlinearity in the theoretical probability defined by TMAI: $\boldsymbol{p}(A_X\ \boldsymbol{i}\ |\ A_Y) = 1\ /\ [\ 1 + (d_X\ /\ d_Y)^{\boldsymbol{n}}\ ]$, where the dimension of the attributive space ***n*** is a power exponent in the formula.

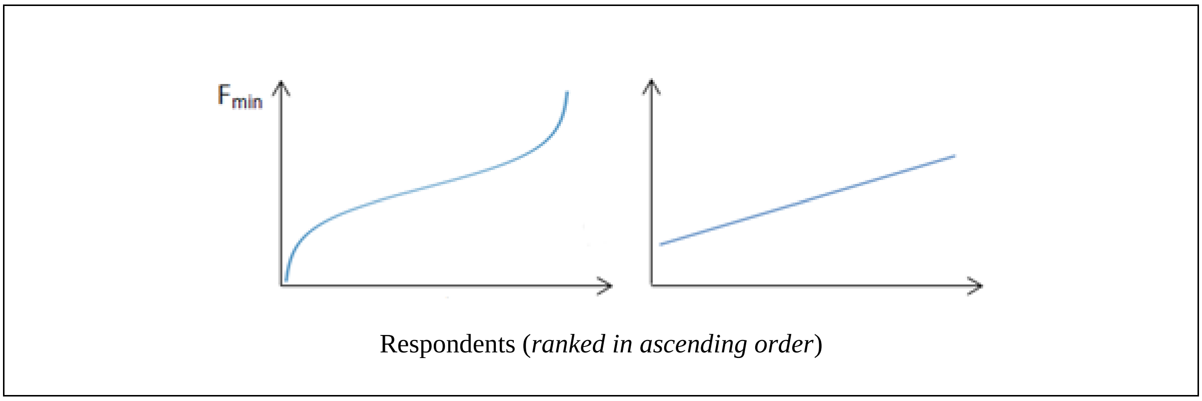
[7] Bardov, I. (2014). Nomothetic and idiographic approaches in the psychological cognition of personality: a possible model for integration. *Proceedings of the VII National Congress of Psychology in Sofia*, 184–195. (in Bulgarian)

The figure below presents two of the possible "scenarios" for the idiographic distribution of individual *ideal points* (individual *reference stimuli*) in a given attributive 3D space: (1) *Uniform distribution throughout the volume* or (2) *Clustering in a small area of space*:



The *uniform distribution*: *type I* (on the left side of the figure) can be connected to the lack of a general premise or regularity underlying the demonstrated preferences for the studied population. A *clustering* or *clumping distribution*: *type II* (on the right side of the figure) is an indicator of the presence of an objective reason for similar preferences, which may be *real* or "*apparent*" (due to multiple factors, some of which random).

In this dissertation, an example of an *actual/real* and an "*apparent*" nomothetic picture is demonstrated—for the differentiation of which the type (or rather the shape) of the ranked (in ascending order) distribution of the idiographic minimum values of the ***Matching Factor*** (**F_{min}**) can be used. The following figure illustrates the two boundary variants: an *S-curve* with an inflection point around the mean value of **F_{min}**, which "suggests" that the distribution is normal/Gaussian (on the left side of the figure) and a *linear distribution* (on the right side of the figure below):



More aspects of the choice by preference

Objects of perception

The stimuli offered to respondents for evaluation and preference selection can be broadly classified as: physical (psychophysical) and abstract (verbal). Physical stimuli can be real or artificial, unimodal (visual, auditory, olfactory, gustatory, tactile, etc.) or complex, static or dynamic, constant or variable. Abstract stimuli are most often combinations of verbal (textual) descriptions, evoking different representations within the feature spaces selected for research purposes. According to the technological requirements for cSM, the elements of complex verbal stimuli must always express boundary (minimum or maximum) statements or attributive descriptions.

Time and information deficit perception

With tachistoscopic[8] activation of the sensory input of the visual modality through non-inert stimuli, the subject is in a mode of limitation both in terms of the time for direct (situational) perception and in terms of the information about the assessed object stored in the iconic memory—due to the buffering effect of the visual sensory register. In such a situation, it can be assumed that preference ("liking") considered as a complex cognitive process (involving *perception*, *comparison* with a current ***internal criterion*** or standard, and *decision-making*) is realized by "generating" a context-dependent semantic space. In the paradigm of the two approaches to the human cognitive system: *bottom-up* and *top-down* processes, this would mean that the indicated deficits "force" the respondent to quickly "filter" the available information and highlight the meaningful features of the assessed object, which become the *main axes* (*parameters*) of the semantic space. This leads to the idea of a *variable feature space,* in which the priority of the axes/parameters can depend not only on the external context, but also on "internal factors".

Independence of the space axes

One of the *prerequisites* for cSM is to define in advance some subset of independent physical or abstract characteristics (measurable features or parameters) of the stimuli, within which the ***internal criterion*** will be examined (Mateeff, 1981). However, the requirement of independence of stimulus characteristics is not always feasible. It is recommended that the investigated feature space have orthogonal (independent) axes whenever possible in an experimental design, as the interpretation of the results in these cases is facilitated. Technologically ensuring the independence of the parameters (axes) of the researched space is possible by preliminary conducting an *Exploratory Factor Analysis*—the statistical technique designed to transform the set of truly correlated data into a new set with uncorrelated artificial variables (factors) explaining as much of the total variation of the source data as possible. Since psychological research as a rule deals with a large number of constructs such as perceptions, personality characteristics, attitudes, etc., which are usually measured by means of specific standardized test scales, the results of the measurements are considered in interval metric scales, which allows the calculation of means, variances, and correlation coefficients. Linear transformations of such quantities do not change the correlations between them, and the main goal of *Factor Analysis* is to reduce the dimensionality of the space of observations without significant loss of information—in order to identify the dimensions of the latent space that determines the results of observations or research.

More aspects of the comparative Scanning Method

Now that the theoretical framework of cSM and the computational algorithm for the matching factor have been laid out, a direct comparison can be made between the *Multidimensional Psychological Scaling* (MDS) and the *comparative Scanning Method* (cSM), where the following is found:

The starting point of the MDS method is the so-called quadrant Q4 (*Similarity Data*) and of cSM is quadrant Q1 (*Preferential Choice Data* transformed to *Similarity Data*)[9]. The data format in the MDS method is a similarity matrix (proximity, distance) while in cSM it is a vector of empirical estimates (probabilities). The tasks of the MDS are: for a given (most often Euclidean) metric of a space in which the objects (stimuli) are located, to discover the axes (dimension), and to determine the scale values of the objects for each axis. However, the tasks in cSM are: to find the coordinates of the reference stimulus/area along each of the axes of the given (sub)space; to calculate the minimum value of the matching factor; to visualize the change (gradient) of the space around the reference zone; to determine (to calculate) the difference

[8] *Tachistoscope* (from Greek ‘ταχύς‘ meaning ‘*rapid*‘) is a general name for technical systems aimed to short-term exposure to visual stimuli—for a specific amount of time. The device is used in experiments concerned with visual perception, recognition speed, and memory. It is also widely used in market research concerned with advertising, logos, branding, and so forth.

[9] Quadrants Q1, Q2, Q3, and Q4 are constructs from Clyde Coombs' theory described in the book: Coombs, C. H. (1964). *A Theory of Data*. New York: Wiley. In general, the experimental data in the theory are considered as *Preferential choice* (Q1); *Single stimulus* (Q2); *Stimulus comparison* (Q3); *Similarities* (Q4).

between the maximum and the minimum value (*range*) of the *Matching Factor* (**F**) for the given attributive space of the stimuli—for a given metric and for a predetermined dimension (a subset of independent features viewed as axes). While the MDS method is universal, the *applicability* and *study limitations* are limited to psychophysical research and psychological (personality) research. In contrast to *Multidimensional Psychological Scaling*, the *comparative Scanning Method* requires the dimension of the attributive space and the characteristics of the axes to be set depending on the goals and objectives of the given study. Thus, the study focused only on an experimentally relevant subset of stimulus properties, which is an important contribution of the method.

Summary

The comparative Scanning Method (cSM) is a psychometric technology for processing, analysis, visualization and interpretation of psychological experimental data originally created to study the perception of visual stimuli. The concept of cSM is undergoing expansion both in terms of fields of application and in the direction of theoretical complementarity in statistics and psychometrics. In addition to psychophysical and psychological (personality) research, cSM is also applicable in the field of artificial intelligence, e.g. in analyzing data from artificial neural networks simulating *preferential choice*.

Definitions of the specific concepts in cSM

- *Attributive (stimulus) space*
  It is a geometric space defined by the basic (physical or abstract/verbal) features of the stimuli.
- *Semantic/attributive (feature) space*
  It is strictly individual for each respondent "generated projection" of the stimulus space within which the ***internal criterion*** is examined.
- *Internal criterion*
  It is the stimulus with parameters qualitatively identical to those of the stimuli presented for evaluation but with an optimal quantitative combination (with an ideal quantitative harmony of the constituent elements).
- *Reference stimulus*
  It is the point/zone (*ideal point*) of the semantic space, the coordinates of which determine numerically the most harmonious quantitative combination of the stimulus' attributes.
- *Reference area*
  It is a set of stimuli producing the strongest psychological effect.
- *Theoretical probability*
  It is an analytically defined probability that a given stimulus is preferred over another stimulus—depending on the distance to the reference stimulus and/or other parameters.
- *Empirical probability*
  It is the experimental (statistical) probability that a given stimulus is preferred over another stimulus—in the dyad presented for evaluation.
- *Matching Factor* (**F**)
  It is a measure of the degree of bijectivity (*overlapping*) between an arbitrary stimulus with coordinates at a given point ***i*** within defined space and the sought reference stimulus—the smaller the value of **F**, the more likely the point ***i*** is to define the ***internal criterion*** according to which a subject makes a decision.
- *Localization of the reference area*
  It is the subspace coordinates of the stimuli with the minimum **F** value.
- *Range*
  It is the difference ($\mathbf{F_{max}} - \mathbf{F_{min}}$) between the maximum and minimum value of **F** for the given attributive/feature space.
- *Gradient*
  It is the visualized (*scanned*) "temperature color" space by the ***Matching Factor*** distribution—the warmest colors /bright red, yellow, and white/ represent the reference area that defines the ***internal criterion***.

- *Idiographic cSM analysis*

  It is (*case study*) research of a specific respondent or of a group of people whose results are analyzed individually.

- *Nomothetic cSM analysis*

  It is a study analyzing (1) pooled sample *data* or (2) pooled sample cSM *results*.

- *Uniform (diffuse) idiographic distribution: type I*

  It is a distribution in which the individual reference stimuli (*ideal points*) are located evenly throughout the entire volume of the studied space—a situation that can be connected to the lack of a general premise or regularity underlying the demonstrated preferences for the studied population.

- *"Clustering" idiographic distribution: type II*

  It is a distribution in which the individual reference stimuli (*ideal points*) are clustered into a small area of the studied space (or are grouped in clusters)—an indicator for presence of an objective reason for the similar preferences, that may be *real* or "*apparent*" /due to depending on multiple factors, some of them occasional/.

Additional cSM contribution

(a) The comparative Scanning Method can also be used as an additional tool for integrating into a single research model tasks—both of nomothetic and idiographic type—with applicability in the field of Personality Psychology when dealing with *Preferential Choice Data*.

(b) The normalized values of $\mathbf{F_{min}}$ and $\mathbf{F_{max}}$ (calculated by the *Gen21cSM* software) are always in the interval from 0.00 to 1.00 and do not depend on the dimensionality of the space, since they are obtained from the ratio: *a specific value* divided by *the maximum theoretical value* (in the given space). Consequently, this allows for clearer mathematical interpretation as well as direct comparison of individual values. *Gen21cSM* also calculates a minimum volume of the scanned space with a 5% deviation from the $\mathbf{F_{min}}$ value (*5% min volume relative*), which allows statistical interpretation—one of the type of confidence (spatial) interval.

(c) The comparative Scanning Method is a possible alternative to quantitative Likert Scales—both in terms of the way of assessment (***direct*** assessment through Likert Scales and ***indirect*** assessment through cSM) and in terms of the accuracy of the results, which is greater in non-quantitative assessment by comparing stimulus dyads.*

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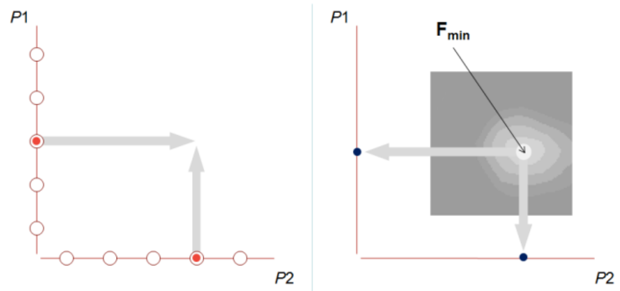
* [1] The respondent's preferred value on Likert Scales "summarizes" the direct quantitative assessment actually located in the sector defined by the selected scale value ± ½ of the scale value. [2] In terms of indirect qualitative /intuitive/ assessment (analyzed by the comparative Scanning Method) the respondent is only required to make an alternative choice in a series of pairs of stimuli—a longer procedure, but with a minimal risk of subjective errors. The indirect ***qualitative*** estimates obtained in this way are "transformed" into ***quantitative*** ones through *the coordinates* of the reference stimulus in the studied space. Each of the axes of this space can be interpreted as a self-contained *Likert-scale* continuum with a very high "resolution"—as opposed to the standard 3-, 5-, 7- or 10-level scales.

The figure below depicts a particular case of comparing ***direct*** and ***indirect*** estimation with respect to the parameters *P*1 and *P*2 defining a two-dimensional attributive space:



At the left part of the figure, two 5-level orthogonally arranged Likert Scales are presented. Thus, the chosen scale values on *P*1 and on *P*2 uniquely determine the possible location of the "combined" ideal point—with the accuracy (or error) described above in [1]. At the right part of the figure, a two-dimensional semantic/attributive space is depicted, in which the *reference stimulus* was detected by cSM—coordinates on *P*1 and *P*2 are exactly the exact scale values. Moreover (in addition to the exact location of the ideal point for a particular respondent) the value of $\mathbf{F_{min}}$ also demonstrates how strongly the reference zone is fixed. In other words, what is the "conservatism" of the researched person in relation to his/her own choice of preference: the greater the $\mathbf{F_{min}}$ value, the more immature or labile the ***internal criterion*** is.

Empirical studies and Experiments

Key features of the research (*empirical studies* and *experiments*) conducted for this dissertation demonstrating the capabilities of the comparative Scanning Method (cSM) in the analysis, visualization, and psychological interpretation of "choice-by-preference" experimental data:

Experiment 01	
Type of research	Pilot Laboratory Experiment
Focal area	Psychophysics (visual perception)
Participants / respondents	30 (thirty)
Technological implementation	IRRA*
Experiment 02	
Type of research	Pilot Laboratory Experiment
Focal area	Psychophysics (auditory perception)
Participants / respondents	21 (twenty-one)
Technological implementation	Music Sculptor** / IRRA*
Experiment 03	
Type of research	Pilot Hybrid Experiment
Focal area	Psychophysics; Personality Psychology
Participants / respondents	438 (four hundred and thirty-eight)
Technological implementation	IRRA* / Gen21cSM***** / STAI-Y***
Experiment 04	
Type of research	Empirical Study
Focal area	Psychophysics; Aesthetics (the golden ratio)
Participants / respondents	96 (ninety-six)
Technological implementation	Google Forms****
Experiment 05	
Type of research	Empirical Study
Focal area	Psychophysics; Aesthetics (the golden ratio)
Participants / respondents	152 (one hundred and fifty-two)
Technological implementation	Google Forms****
Experiment 06	
Type of research	Empirical Study
Focal area	Psychophysics; Aesthetics (the golden ratio)
Participants / respondents	30 (thirty)
Technological implementation	Google Forms**** / Gen21cSM*****
Experiment 07 [Appendix 5.]	
Type of research	Laboratory / Field Experiment
Focal area	Psychophysics (visual perception)
Participants / respondents	30 (thirty) / 100 (one hundred)
Technological implementation	Tachistoscopic method ******
Experiment 08	
Type of research	Laboratory Experiment
Focal area	Psychophysics; Aesthetics (the golden ratio)
Participants / respondents	34 (thirty-four)
Technological implementation	Eye Tracking*******

Experiment 09	
Type of research	Laboratory Experiment
Focal area	Architectonics (textbook page structure)
Participants / respondents	30 (thirty)
Technological implementation	Gen21cSM***** / Eye Tracking*******
Experiment 10	
Type of research	Laboratory Experiment
Focal area	Personality Psychology (values)
Participants / respondents	15 (fifteen)
Technological implementation	Microsoft PowerPoint / IRRA*
Experiment 11	
Type of research	Empirical Study
Focal area	Personality Psychology (values)
Participants / respondents	209 (two hundred and nine)
Technological implementation	Google Forms****
Experiment 12	
Type of research	Laboratory Experiment
Focal area	Personality Psychology (values)
Participants / respondents	26 (twenty-six)
Technological implementation	IRRA* / Gen21cSM*****

Note 1: In the text of the thesis, all studies conducted are labeled as experiments (Experiment 01, Experiment 02, ... , Experiment 12), although some of them are empirical studies conducted outside the laboratory, in the "field" or online. This is for ease of reading and comparison of results.

Note 2: At the time of the full-time PhD study (January, 2020 - January, 2023), Experiment 04, Experiment 05, Experiment 06, Experiment 08, Experiment 09, Experiment 10, Experiment 11, and Experiment 12 were planned and conducted.

*____________ *software* – IRRA beta (*Imprinting Reliable Rate Analysis*)
**___________ *software* – MIDI Sequencer (*Music Instrument Digital Interface*)
***__________ *questionnaire* – STAI-Y (*State-Trait Anxiety Inventory, Form Y*)
****_________ *software* – Google Forms (*online software for surveys and questionnaires*)
*****________ *software* – Gen21cSM (Generator for cSM outcomes)
******_______ *hardware* – Gerbrands G1136 4-field Tachistoscope
*******______ *hardware & software* – Tobii PCEye Mini / Dynavox GazeViewer

Brief description of the dissertation chapters

The first chapter (***Theoretical Overview***) reviews the main methods for analyzing quantitative or qualitative data from psychological research. Only some of the possible research approaches in which *comparative scanning* is applicable are briefly described:

- *Laboratory Experiment*;
- *Field Experiment*;
- *Quasi-Experiment*;
- *Correlational Research*;
- *Case Study*.

Since *Black Box method*, *Theory of Data*, *Multidimensional Scaling*, and *Nomothetic* and *Idiographic approaches* are of particular importance for the aims and research objectives of this dissertation, they are presented in detail in the first part of the theoretical overview. In the second part, the comparative Scanning Method (cSM) is also presented in detail: Introduction to the comparative Scanning Method; Nature, capabilities, and limitations of cSM; Basic assumption; Rationale and significance of cSM; Theoretical framework of cSM /variant in three-dimensional space/; Computational algorithm of the Matching Factor (F); Distributions of reference stimuli (*ideal points*); More aspects of the choice by preference; Comparison of cSM and MDS; Additional contributions of cSM; Definitions of the specific concepts in cSM.

The second chapter (***Computational Toolkit***) provides an overview of the software implementing the *comparative scanning*. The multiple computational procedures in the cSM algorithm are implemented instrumentally by an updated software product called Gen21cSM or *Generator/Calculator for comparative Scanning Method outcomes*, version 2021.

The third part presents in detail: the evolution of the software related to the cSM method; installing and running Gen21cSM; preparing the data for processing; the *empirical probability* vector; free access to Gen21cSM on the Internet; specific features of: Gen21cSM; IRRA computer program; cSMinventory.online web platform.

The third chapter (***Empirical Studies and Experiments***) covers the research conducted for the purpose of this thesis, demonstrating the capabilities of the comparative Scanning Method (cSM) in the analysis, visualization and psychological interpretation of experimental *preferential choice data*.

In the fourth part (*Pilot experiments based on cSM*) the previously conducted "psychophysical" Experiment 01, "acoustic" Experiment 02, and "hybrid" Experiment 03 are described. The general (cSM-confirmed) hypothesis is: *If a set of physical (visual/acoustic) stimuli is selected from a predefined feature/attributive space, according to the requirements of cSM, then a subspace—the subject's REFERENCE ZONE—**exists** in this space*. The stimuli, that are most likely to be preferred over all others if subjected to evaluation through alternative (forced) choice by preference, are located into this zone.

The presence of reference zones of ***different*** shape, size, salience, and localization of the individual examined persons demonstrates that:

- The comparative Scanning Method (cSM), designed for processing, analysis, visualization and interpretation of *preferential choice data*, is suitable for individual studies (*case studies*);
- The parameters of the *reference zone* of a given feature/attributive space of physical stimuli are strictly individual for each person studied;
- There is no universal *reference zone* with respect to the feature/attributive spaces defined in the experiments.

An additional assurance that the comparative Scanning Method adequately performs the task at hand is based on the fact that after the experiment procedure, each subject is presented with a stimulus from his or her reference zone for evaluation—this stimulus (in combination with all others) proves to be the most preferred.

In the fifth part (*Application of the comparative Scanning Method (cSM) to investigate subjective preferences for the Golden Ratio in the visual perception of proportions in geometric figures*), the related Experiment 04, Experiment 05, and Experiment 06, as well as the complementary technological Experiment 07 and Experiment 08, are described. The task of the first one is to construct a *preference curve* when matching pairs of two-dimensional geometric figures. The task of the second one is to register the possible effects of including a third dimension of the visual stimuli. The task of the third one is to demonstrate the capabilities of the comparative Scanning Method (cSM).

The sixth part (*Application of the comparative Scanning Method (cSM) for the study of subjective preferences regarding the architectonics of a textbook page*) describes Experiment 09. The main research hypothesis is analogous to that of the pilot experiments. An additional goal of the study is to use *Eye Tracking* technology to identify the areas of gaze fixation on the page by tracking saccades (simultaneous eye movements between two or more fixation points).

In the seventh section (*Application of the comparative Scanning Method (cSM) for indirect assessment of elements of value systems*), the related Experiment 10, Experiment 11, and Experiment 12 are described. Again, the overall aim is to demonstrate the comparative Scanning Method (cSM). The resulting first research objective is to apply cSM in a three-dimensional space defined not by the characteristics of a single value concept (e.g., *attainability, social* or *subjective relevance*, etc.) but by three different relatively independent values from Rokeach's list. The task of the second of the group of experiments is twofold: (1) to determine /by *Exploratory Factor Analysis*/ the importance and attainability of a set of values including some of those originally defined by Milton Rokeach as *terminal*, but some of them modified and supplemented. The aim is to examine their social image into individual consciousness by ***direct assessment*** on Likert Scales; (2) to prepare the material for the research design of the last (twelfth) experiment, which will examine the social image of values into individual consciousness by means of ***indirect assessments*** using the comparative Scanning Method (cSM). The final research task in this group of experiments is to determine both the collective and individual reference zones/points (*ideal points*) of respondents—in relation to the three latent factors identified by direct assessments (on Likert Scales in the preparatory Experiment 11)—those with the highest factor loadings, whose reference zones visualize the "Meaning Gestalts" emerging in group and individual consciousness.

Explanation: For each part of the thesis (parts 5, 6, and 7), presenting a specific practical application of the comparative Scanning Method, a short independent theoretical overview is done, on the basis of which the corresponding empirical studies and experiments are planned, conducted, and analyzed (Experiments 04 ÷ 12).

CONCLUSION

The *comparative Scanning Method* (cSM) is an innovative technology for processing, analyzing, visualizing, and interpreting psychological experimental *preferential choice data* type, conceptually transformed into *similarity data* type. The results obtained by cSM in different application domains are the basis for interpreting, explaining, and predicting the complex behavior of the subjects and contribute to the extension of the Psychometrics paradigm as well as theoretical complementarity in the field of Statistics.

Scientific novelty

The presented dissertation meets most of the generally accepted requirements of scientific novelty, as follows:

<u>*Posing a new scientific problem*</u>

The comparative Scanning Method is an autonomous technology with its own theoretical basis, which does not oppose the fundamental concepts of Psychometrics, but complements the system of knowledge in this scientific field. Initially, cSM was used for psychophysical analysis of data related to perception of visual and acoustic stimuli. The results of the pilot experiments conducted provide grounds to assume that the concept of *comparative scanning* is an adequate approach for data analysis and interpretation. The directions in which cSM can provoke scientific inquiry are threefold: (1) by introducing its own *measurable*, *comparable*, and *interpretable* concepts—to ***model*** in a novel (alternative or complementary) way "choice-by-preference", especially in the second of the components of the complex cognitive process considered as: Situational or concrete perception; Comparison with a current "internal criterion" /benchmark/; Decision-making; (2) by defining the *types* of idiographic distributions of individual ideal points (or reference stimuli) in some attributive space to ***develop*** the concept of real/genuine or "apparent" reasons for similar personal preferences; (3) a challenge to scientific conventions of norm setting (based on statistical estimation of central tendencies in a particular data type) is posed by the fact discovered in the twelfth experiment—it is possible to have a "picture" in which no individual *ideal point* falls within the boundaries of the reference "nomothetic" zone characterizing the sample. In such a situation, the direction of scientific inquiry should focus on ***refining*** the technology for determining "normality", and cSM should be used as a toolkit for discovering new examples containing such a "contradiction".

<u>*Introduction of new scientific categories and concepts*</u>

Part of the defined fifteen specific concepts in cSM: *Attributive (stimulus) space*; *Semantic/attributive (feature) space*; *Internal criterion*; ***Reference stimulus***; ***Reference area/zone***; *Theoretical probability*; *Empirical probability;* ***Matching Factor*** (**F**); *Localization of the reference area/zone*; *Range*; ***Gradient***; *Idiographic cSM analysis*; *Nomothetic cSM analysis*; *Uniform (diffuse) idiographic distribution:* ***type I***; *"Clustering" idiographic distribution:* ***type II***; are inherently new scientific categories. To these may be added the idea of schematic stimuli, which have certain technological advantages in the study of "choice-by-preference".

<u>*Revealing new regularities of phenomena or processes*</u>

All the experiments and empirical studies presented in the thesis lead to results related to new regularities or scientific facts, most of them unknown until now. The first pilot experiment reveals the structure and specific features of the three-dimensional attributive space of independent visual stimuli chosen for investigation and provides a confirmatory answer to the fundamental question concerning the existence of the underlying construct (the *reference stimulus*) in the comparative Scanning Method at all. The second pilot experiment also reveals the structure and features of a attributive space of specific stimuli (in this case, auditory stimuli) chosen for investigation, but in addition, by means of an individual ontogenetic result, it also answers a question concerning the dynamics of the *reference stimulus*. It is clarified that in the process of personality development and growth, the "internal criterion" that underlies the *preferential choice* stabilizes, which corresponds to the expectation that in the individual shaping of personality over time, benchmarks for different personal preferences follow their own evolution and, "maturing", become increasingly conservative. The third hybrid experiment confirms the longitudinal result obtained in the second pilot experiment, finding that the intensity of the referent stimulus increases with age. In other words, the criteria of harmony, aesthetics and impact become more and more validated, but in addition, no direct relationship is found between the *choice-by-preference* and measured *personality* and *momentary anxiety* in respondents. The frequency distribution of the minimum value of the matching factor (F_{min}) obtained from the experiment is approximately normal (Gaussian/"apparent" of *type II*), which is a reason to assume that the reason for the demonstrated similar preferences of the individual respondents is due to multiple factors, some of which, however, are random. The conceptually related (fourth, fifth, and sixth) experiments, examining subjective preferences regarding the "golden ratio" in the visual perception of geometric proportions, sequentially reached results indicating that the actual preference was for a visual stimulus, whose compound *diameters* are in the "golden ratio" relative to a stimulus whose constituent *areas* are in the same proportion, and the inclusion of a third dimension impairs or completely eliminates the preference for the stimulus whose *diameters* are in the "golden ratio". And something else, the "strength" of the *internal criterion* is greater than any of the individual *ideal points*, which is probably related to the high degree of generality of the sense of visual harmony due to the proportion "golden ratio". The results obtained in the eighth experiment demonstrate the relationship between choice-by-preference and the way visual stimuli are subjectively attended to on a computer screen, namely, the subjects' gaze registered by the *Eye Tracking* technology lingered significantly longer on the preferred objects, which corresponds to the intuitive hypothesis that objects of preference have greater "power" of attracting and holding attention. The results obtained by cSM in the ninth experiment are comparable to those of the third experiment—regardless of the different focal areas in which they were conducted. Their respective distributions are of the "grouping" or "clustering" type (*type II*), which is an indicator of an objective reason for the similar preferences of the individual subjects. When comparing the distributions of the F_{min} values (ranked in ascending order), a difference emerges, the basis on which is also the hypothesis of the presence of a real/genuine or "apparent" objective reason for demonstrating similar preferences. On the one hand, the specific *S*-shaped curve "suggests" that in the third experiment the distribution is *normal* (Gaussian), which is a reason to suppose that the similar preferences of the individual subjects in this experiment are due to multiple factors, including random ones. On the other hand, the *linear* distribution of the minimum values of the matching factor found in the ninth experiment gives reason to suppose that the cause of the similar preferences of the individual subjects is due to preconditions, states or predictors that are common to the population under study—there is genuine a *type II* "idiographic" distribution. The last group of conceptually related experiments in the field of Personality Psychology demonstrates the performance of the comparative Scanning Method (cSM) in processing, analyzing, visualizing, and interpreting *preferential choice data* related to the ***indirect*** assessment of persistent tendencies in the process of making sense of the semantic contents of value concepts. Since the analysis of the results of the tenth experiment revealed *reference zones* of *different* shape, size, expression/"strength" and localization of the individual subjects, it can be assumed that: (1) the comparative Scanning Method is suitable for individual studies (*case study*); (2) the parameters of the reference zones (or the quantitative combination of the selected value concepts) are strictly individual for each subject; (3) there is no universal reference zone with respect to the attributive space defined in the experiment, and in this case the established "nomothetic" distribution is of *type I*. The goal achieved in the eleventh experiment—to examine the social image in individual consciousness of a set of values (including some of those originally defined by Milton Rokeach as *terminal*) by ***direct*** Likert Scale assessment—prepares for the final research task determining both the respondents' collective and individual reference zones/points (*ideal points*), in terms of three latent factors: (1) *attainability*, (2) *social salience*, and (3) *subjective salience*. Applying the *comparative scanning algorithm* to a set of selected values—with the highest factor loading from the preparatory stage of the study (*Happiness*, *Self-Esteem*, and *Health*), whose reference zones are expected to be characterized by localization in the feature/attributive space (*coordinates*), expressivity (*minimum value of matching factor*), size (*range*), and shape (*gradient*)—the twelfth experiment demonstrated that cSM can effectively describe and visualize emergent "Meaning

Gestalts" in group and individual consciousness. A particular feature of all three target value concepts is that the "nomothetic" *minimum value* of the matching factor (F_{min}) is smaller than any "idiographic" one. Also, no individual *ideal point* is located within the corresponding nomothetic reference zone, and the distributions are clustered (*type II*). This is a reason to suppose that the reason for the similar preferences of the individual subjects (in the different clusters) is due to common preconditions, states or predictors. In other words, there are several genuine *type II* "idiographic" distributions. The results also demonstrate that if the sample is divided into two parts—based on the coefficients of the overall linear correlation between the ***indirect*** (using Likert Scales) and ***direct*** (using cSM) assessment of values—only for one third of the respondents the "declarative" value concepts coincide with the "real" ones.

Application of new research methods, technologies, equipment and software

The full presentation of the comparative Scanning Method in all the aspects, revealing its nature, capacity, and limitations, is realized by the second research task in the dissertation. The highlights of this process are on: prerequisites of comparative scanning; theoretical framework (the basic assumption); justification and relevance of the method; computational algorithms; implications complementary to psychometric theory (in terms of specific distributions of reference stimuli); additional contributions; and other aspects of the preferential choice. The technological underpinning of the method (the third dissertation task) is realized by updating and complementing the computational toolkit implementing comparative scanning. The evolution of the software related to cSM implies the improvement of its capabilities, in line with the extended concept of the method (in theoretical and applied terms). The new software—inherited the *IRRA beta* computer program, and developed for the purposes of this thesis—contains a sequence of clear instructions to users regarding: installation and start-up of the application; preparation of the data for processing; specific characteristics (definition of the *theoretical probability* which is a basic construct in cSM); the vectors of the *empirical probability* (other basic constructs in cSM); results of the computational procedures. This is also supported by the web-platform, providing free access to the computational tools of cSM to all researchers in the field of psychological measurement.

Developing new scientific ideas about the world, man, and society

The transformation of psychological experimental ***Preferential Choice Data*** into ***Similarities Data***, embedded in the theoretical underpinnings of cSM, leads to a new scientific notion of *the-choice-by-preference*, viewed as a complex cognitive process (encompassing *perception*, *comparison* with a current "internal criterion", and *decision making*) in which a context-dependent semantic space is "generated". Namely, preferential choice is determined by a "hidden /and sometimes unconscious/ factor"—this is the *reference stimulus* positioned somewhere in the semantic space. Considering that the main practical application of the comparative Scanning Method is in Personality Psychology, regardless of the chosen research approach, *nomothetic* (oriented towards regularities that are valid for the studied sample as a whole) or *idiographic* (oriented towards establishing the characteristics inherent in the individual person under study), the relevance of cSM research is also justified by the introduction of the two new concepts, leading to the expansion of the possibilities of interpretation of choice-by-preference type data: the uniform (diffuse) idiographic distribution (*type I*), and the "clustering" idiographic distribution (*type II*). Since the introduced concepts inherently express the two boundary "scenarios" or possibilities of positioning individual ideal points in some feature/attributive space, the form of the ranked (in ascending order) distribution of individual (idiographic) minimum values of the *matching factor* is used to differentiate the type of the now overall "nomothetic" picture. As it becomes clear, the two options for this distribution are: an *S*-shaped curve with an inflection point around the mean value of F_{min}, "suggesting" that the distribution is *normal* /Gaussian/ and a *linear* distribution conditioning on a real/genuine objective reason for the similar preferences of the subjects. By providing these opportunities for analysis and interpretation, the comparative Scanning Method (cSM) becomes a valuable additional tool for integrating into a unified research model tasks (of both nomothetic and idiographic types) with applicability in the field of Personality Psychology when dealing with *preferential choice data*. Last but not least, despite the experimental establishment of the existence of the ***referent stimulus***, it is still possible to criticize the model—from the point of view of *constructivism*, which offers an alternative to the described geometric representations in which feature spaces are not necessary.

Since constructive cognitive processes are seen as processing *relational structures*, the assumption of "generating" a semantic space as a result of a multi-component cognitive process involving both perception and memory is somewhat acceptable, but only for the specific moment and context. However, it is also an opportunity for cSM to contribute arguments in support of the geometric representations that underlie both the Theory of Data and the comparative Scanning Method.

Strengths and study limitations

This dissertation validates the comparative Scanning Method (cSM) as a theoretical concept and technological tool for the analysis, visualization, and psychological interpretation of *choice-by-preference* experimental data produced by an *alternative forced choice* between two objects (stimuli). Such data can be obtained from a wide range of specific empirical studies. Regardless of the application domain (e.g. Psychophysics, Personality Psychology, etc.), cSM offers a universal algorithm for planning and conducting experimental procedures so that specific software processing can be applied over the data to produce a convincing interpretation of the results. The comparative Scanning Method is built with maximum internal consistency and logical coherence—in terms of its own theoretical framework and technology for data analysis and interpretation. Full disclosure of its capabilities is invariably linked to empirical evidence of the validity and reliability of cSM, which is achieved through the results of the experiments and empirical studies presented. This also provides the requirements for: *verifiability* (the principle possibility of independent replication of cSM results); *comprehensiveness*; *predictability*; *scientific novelty*; and *conservatism* (reference to existing scientific experience). Since the significance of the research should be considered not only in scientific but also in practical terms, the aspiration for the widest possible application of cSM can be directed towards the preparation of elements of *individual psychological profiles* that would be useful in a range of activities of counseling psychology, family therapy, criminal investigations, forensic psychological examinations, personnel selection, case tracking (longitudinal analysis), etc.

The limitations of cSM (*study limitations*) restrict the applicability of the method to psychophysical research and psychological (personality) research. Additional applicability is also possible in the field of artificial intelligence—in the analysis of data from artificial neural networks which simulate *choice-by-preference*.

Contributions to science

The contributions presented in this dissertation are in three categories, which are relatively independent: (1) scientific contributions to the theory of Psychometrics and Statistics; (2) technological contributions related to computational algorithms for data processing, as well as their software support; (3) acquisition of new knowledge about the manifestations of the multi-component simultaneous cognitive process "choice-by-preference", which are prerequisites for alternative or complementary modeling of its mechanism.

<u>*Scientific contributions in theory*</u>

The comparative Scanning Method (cSM) itself, as an innovative technology for processing, analyzing, visualizing and interpreting psychological experimental data, is the *main scientific contribution* of this thesis. However, looking at cSM in detail, some of the new concepts embedded in the theoretical foundations of the method and subject to psychological interpretation can also be nominated as contributions:

• The functionally related concepts of "Internal Criterion"[10], "Reference Stimulus"[11], and "Reference Zone/Area"[12] lead to transforming psychological experimental data of the *preferential choice* type into data of the *similarities* type—the theoretical argumentation of the comparative Scanning Method, which is also the basis for interpreting, explaining, and predicting the complex behavior of subjects. The proven affirmative answer to the fundamental question concerning the

[10] The stimulus with parameters qualitatively identical to those of the stimuli presented for evaluation but with optimal quantitative combination (with perfect quantitative harmony of the constituent elements).
[11] The point/zone (*ideal point*) of the semantic space, the coordinates of which determine numerically the most harmonious quantitative combination of the features.
[12] The set of stimuli producing the strongest psychological effect.

existence of the underlying construct in the comparative Scanning Method (the *reference stimulus*), gives "green light" to series of related questions about it, specifying not only its measurable parameters (as well as those of the space in which it is located), but also those of a gnoseological nature (e.g.: *Why does a reference stimulus arise*?; *When and how is it formed*?; *What is the significance of the reference stimulus for perception*?). The experimentally established ***reference stimulus*** directly corresponds to the ***ideal point***—the perfect quantitative balance between the features or characteristics of a perceived object. A conceptual nuance in the distinction between the "reference stimulus" and the "ideal point" is noticeable in the definition of the two almost overlapping concepts, namely: the *reference stimulus* is a "subset" of the *ideal point*, since only a portion (albeit the most significant one) of the attributes of the object-stimuli under study defines the space in which its localization and "strength" are sought.

• The concept of a ***structured*** semantic/attributive space, which reveals the "inside picture" of a person's momentary psychological attitudes with respect to preference (or liking) of certain objects, leads to *scan planes* depicting both areas of highly salient reference stimulus and areas of minimally harmonious quantitative combination of the features comprising the space. This is unified by the related concepts of "Attributive (stimulus) space"[13], "Semantic/attributive (feature) space"[14], "Matching Factor (F)"[15], "Localization of the reference area/zone"[16], "Range"[17], and "Gradient"[18].

• Overcoming the logical paradox[19], associated with the geometric approach to reference stimulus (area) localization, leads to vector juxtaposing of "Theoretical Probability" (the analytically defined probability of given stimulus to be preferred over another one, depending on the distance to the reference stimulus and/or other parameters) and "Empirical Probability" (the experimental /statistical/ probability that a stimulus is preferred over another stimulus in a dyad presented for evaluation). Thus, the algorithm for searching the minimum value of the *matching factor,* and hence the feature/attributive space scanning, is implemented. Moreover, the notion of "Theoretical Probability" in cSM links the method to the *Theoretical Model of Associative Interactions* (TMAI) presented in Appendix 1 of the dissertation.

• The latter concepts, related to the comparative Scanning Method, are essentially contributions to Statistics. A *diffuse*/*uniform* "idiographic" distribution (*type I*), where individual reference stimuli (*ideal points*) are located throughout the studied space, is associated with the absence of a common premise or pattern underlying the demonstrated preferences of the population under study. The "idiographic" *clustering*/*grouping* distribution (*type II*), where individual reference stimuli (*ideal points*) are located in a small area of the studied volume (or are grouped in clusters) is an indicator of an objective cause of the similar preferences, which may be real/genuine or "apparent" (due to multiple factors, some of them random). An additional contribution is the criterion for this itself, namely—the discriminant shape of the ranked ascending distribution of individual "idiographic" minimum values of the *matching factor* (*S-shaped curve* or *linear* distribution).

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[13] The geometric space defined by the basic/underlying (physical or abstract/verbal) features/characteristics of the stimuli.

[14] Strictly individual for each respondent "generated projection" of the stimulus space within which the *internal criterion* is examined.

[15] The measure of the degree of bijectivity (*overlapping*) between an arbitrary stimulus with coordinates at a given point ***i*** within defined space and the sought reference stimulus—the smaller the value of F, the more likely the point ***i*** is to define the *internal criterion* according to which a subject makes a decision.

[16] The subspace coordinates of the stimuli with the minimum value of F.

[17] The difference ($F_{max} – F_{min}$) between the maximum and minimum value of F for the given attributive/feature space.

[18] The visualized (scanned) "temperature color" space by the Matching Factor distribution—the warmest colors /bright red, yellow, and white/ represent/depict the reference area/zone that defines the internal criterion.

[19] *Since the localization of the reference stimulus in the feature space of physical characteristics is based on the answers of the researched person, and these answers are probabilistic in nature (that applies to most natural systems of perception and information processing), the direct application of geometric considerations (in case of conflicting answers) leads to the impossibility of locating the searched reference area in space.*

By introducing the method's own concepts, as well as expanding the meaning of other common methodological constructs, an additional opportunity is created to model and study the ***choice-by-preference*** as a multi-component cognitive process. Longitudinal (nomothetic or idiographic) studies are also feasible through the diagnostic application of cSM. The set of eigen-quantitative parameters of the comparative Scanning Method (F_{min}, F_{min}/norm/, coordinates of F_{min}, F_{max}, F_{max}/norm/, 5% /min volume relative/) is traceable over time, making it possible to compare individual moments of personality development or "maturation" (e.g. as in the second experiment presented). The practical value of this type of study lies in the possibility of assessing the "speed" of personality development if norms of *functional* age are established in advance by cSM to be compared with *biological* age.

Technological contributions in data processing algorithms

• The capabilities of the comparative Scanning Method in the analysis, visualization, and psychological interpretation of *choice-by-preference* experimental data provide a foundation for subsequent research in Psychometrics, greatly facilitated by the available open-access software applications developed for the purposes of this dissertation. The software toolkit presented for the multiple computational procedures in the cSM algorithm, called Gen21cSM or *Generator for comparative Scanning Method outcomes*, builds evolutionarily on the original multi-purpose software product, IRRA beta or *Imprinting Reliable Rate Analysis* (Appendix 2). Computer implementation of *comparative scanning* is the only option to overcome the time overrun resulting from the complexity and energy intensity of computational procedures in cSM. Implementing the computational algorithm of the comparative Scanning Method, specialized programs (IRRA, Gen21cSM, cSMinventory.online) identify and quantify eigenvalues that are psychologically interpretable, according to the theoretical underpinnings of cSM.

• A specific contribution of the visualization of the results by *scanning* with the IRRA beta software product is the detection of possible unscrupulous (accidental or intentional) behavior during the survey by the respondents, indicated by the appearance of particular axes of symmetries in the scanning planes.

• An additional contribution stands out in studies where respondents are people with certain cognitive deficits. The comparative Scanning Method is a possible alternative to quantitative *Likert Scales*, both in terms of the way/method of assessment (***direct*** assessment by Likert Scales and ***indirect*** assessment by cSM) and in terms of the accuracy of the results, which is greater in non-quantitative assessment through *choice-by-preference* in dyads of stimuli, since in indirect qualitative (or intuitive) assessment the respondent is only required to make an alternative choice in a series of pairs of stimuli—a longer procedure but with minimal risk of subjective errors. The indirect qualitative ratings thus obtained are "transformed" into quantitative ones by the *coordinates* of the reference stimulus in the space under study, and each of the axes of this space can be interpreted as an independent *Likert-Scale-continuum* with very high "resolution". Ultimately, despite the more energy-intensive (longer) procedure of cSM, indirect qualitative assessment is sometimes the only option for the study of young children or people with a certain type of disability.

New knowledge about "choice-by-preference" as a cognitive process

The results of the presented empirical studies and experiments conducted in the selected focal areas of Psychophysics, Cognitive (applied) Psychology, and Personality Psychology are essentially contributions in two directions: (1) new knowledge through *idiographic cSM analysis*: a study of a specific respondent (*case study*) or a group of respondents whose results are analyzed individually, and (2) new knowledge through the application of conventional research methods in psychology as well as through *nomothetic cSM analysis*: a study in which pooled sample ***data*** or pooled sample cSM ***results*** are analyzed.

To the first group belong: The affirmative answer to the fundamental question about existence of the underlying construct (the *reference stimulus*) in the comparative Scanning Method /Exp.01/; The revealed structure and specifics of the three-dimensional feature/attributive space of visual stimuli /Exp.01/ and of acoustic stimuli /Exp.02/ chosen for the study; The stabilization of the "internal criterion" (which is the basis of the *preferential selection/choice*) in the process of personal development and growth /Exp.02 and Exp.03/.

To the second group belong: the established *normal* (Gaussian) distribution of the *minimum value of the matching factor* (or an non-genuine "idiographic" distribution of *type II*, which is the basis for the assumption that the reason for the demonstrated similar preferences of the individual subjects is due to multiple factors, some of which, however, random) /Exp.03/; The weak correlation between the stability of the preference and the anxiety of the subjects /Exp.03/; The actual preference for a complex visual stimulus whose constituent *diameters* are in the "golden ratio" proportion relative to a stimulus whose constituent *areas* are in this proportion /Exp.04/; The impaired or completely eliminated preference for a visual stimulus whose *diameters* are in the "golden ratio " proportion—after inclusion of a third dimension (*contrast* between the components, in the gray scale) /Exp.05/; The experimentally established collective "ideal point" whose strength of the "internal criterion" is greater than any of the individual "ideal points" (in contrast to the many cases in which the averaged parameters of individual preferences, uniformly distributed over some feature/attributive space, lead to the impossibility of defining a real collective "ideal point"—in this case the sense of visual harmony due to the "golden ratio" proportion is common to a large part of the population) /Ep.06/; Demonstrated correlation between the "choice-by-preference" and the manner of subjective viewing of visual stimuli (on a computer screen), namely, the gaze of the subjects lingers significantly longer on the preferred objects, which corresponds with the intuitive hypothesis that the objects of preference have greater "power" of attracting and holding attention /Exp. 08/; The established "nomothetic" distribution of *type I*, arguing for the non-existence of a universal reference zone with respect to a defined feature space /Exp.10/; The effective description and visualization of the emerging in group and individual consciousness "Meaning Gestalts" in which the "nomothetic" *minimum value of the matching factor* is smaller than any "idiographic" one /Exp.12/; The availability of several actual "idiographic" *type II* distributions, but also the finding that no individual *ideal point* is within the corresponding nomothetic reference zone[20] (the distributions are of type "clustering/grouping" (*type II*), which is a reason to assume that the origin of the similar preferences of the individual subjects in the different clusters is due to common-valid preconditions, states or predictors) /Exp.12/.

To the facts presented, it may be added that a comparison of the distributions of F_{min} values (ranked in ascending order) between the third and ninth experiments reveals a difference, on the basis of which is the expectation/notion of a real or "apparent" objective reason for similar preferences. On the one hand, the specific *S*-shaped curve "suggests" that in the third experiment the distribution is *normal* (Gaussian). This is a basis to suppose that the reason for the similar preferences of the individual subjects in this experiment is due to multiple factors, including random ones. In other words, there is an unreal/ non-genuine "idiographic" *type II* distribution. On the other hand, the *linear* distribution of the minimum values of the matching factor found in the ninth experiment suggests that the cause of the similar preferences of the individual subjects is due to preconditions, states or predictors common to the population under study. In this case, there is a genuine *type II* "idiographic" distribution.

One more thing—implementing the second research task of Experiment 03, it is verified that processing the ***averaged experimental data*** [nomothetic analysis] (obtained from the participants in a planned and conducted by cSM experiment) produces results that are DIFFERENT from those obtained from statistical analysis of central tendencies (arithmetic means) in the distributions of ***individual results*** [idiographic analyses] from the same initial data[21].

[20] This leads to the question—to what extent the *ideal point* (reference zone) found in the nomothetic analysis can be considered as a *central tendency* of the idiographic results?

[21] The probable reason for the existence of the described difference is the nonlinearity in the theoretical probability defined by the TMAI: $\boldsymbol{p}\,(A_X\, i \mid A_Y) = 1 / [\, 1 + (d_X / d_Y)^{\boldsymbol{n}}\,]$, where the dimensionality of the feature/attributive space ***n*** is a *power exponent* in the formula.

SUMMARY OF THE CONTRIBUTIONS IN THE DISSERTATION

Scientific contributions in theory:

- Innovative technology for experimental design, and for processing, analysis, visualization and interpretation of psychological experimental data—the comparative Scanning Method (cSM).
- Concept of experimental research under time and information deficit.
- Peculiar for cSM theoretical basis.
- Connectivity between cSM and TMAI (*Theoretical Model of Associative Interactions*).
- New *measurable*, *comparable*, and *interpretable* concepts in the own theoretical base: Internal criterion; Reference stimulus/area; Structured semantic/attributive (feature) space; Matching Factor (F); Localization of the reference area/zone; Range; Gradient; Uniform/diffuse "idiographic" distribution (*type I*); Clustering/grouping "idiographic" distribution (*type II*).
- A criterion for validity or seemingly (due to multiple factors, some of which are random) of common prerequisites, conditions, or predictors in the population under study that lead to similarity in preferences.

Technological contributions in data processing algorithms:

- Software toolkit for the multiple computational procedures in the cSM algorithm (*IRRA*, *Gen21cSM*, *cSMinventory.online*), computing the eigenvalues of the comparative Scanning Method: F_{min}, F_{min}/norm/, coordinates of F_{min}, F_{max}, F_{max}/norm/, 5% /min volume relative/ (a time-traceable set of quantities allowing for moment-to-moment comparisons in longitudinal studies).
- Technological recognition of unscrupulous (accidental or intentional) behavior by respondents during the survey, indicated by specific *axes of symmetries* in the IRRA beta scanning planes.
- Alternative to quantitative *Likert Scales*, both in terms of the way/method of assessment (***direct*** assessment by Likert Scales and ***indirect*** assessment by cSM) and in terms of the accuracy of the results, which is *greater* in non-quantitative assessment through *choice-by-preference* in dyads of stimuli.
- Possibility/option of alternative research on respondents with certain cognitive deficits or young children for whom quantitative self-assessment in an experimental procedure is difficult (or practically impossible).

New knowledge about "choice-by-preference" as a cognitive process

- Verification of the fundamental construct in the comparative Scanning Method: the *reference stimulus*.
- Revealing the structure and specifics of three-dimensional feature/attributive spaces of visual and acoustic stimuli selected for investigation.
- Ascertaining the stabilization of the "internal criterion" in the process of personal development and growth.
- Finding out an example of a *normal* (Gaussian) distribution of the *minimum value of the matching factor* (an unreal/ non-genuine "idiographic" *type II* distribution).
- Discovering a weak correlation between *preference stability* and *anxiety of the subjects*.
- Drawing a psychometric curve explicating the actual preference for a complex visual stimulus whose constituent *diameters* are in the "golden ratio" proportion relative to a stimulus whose constituent *areas* are in the same proportion.
- Demonstration of an impaired or abolished preference for a visual stimulus whose *diameters* are in the "golden ratio" proportion—following the inclusion of a third dimension in the stimulus (*contrast* between constituent elements).
- Demonstration of the relationship between the "choice-by-preference" and the manner of subjective viewing of visual stimuli—the subjects' gaze lingered significantly longer on preferred objects.
- Finding out an example of "nomothetic" *type I* distribution.
- Efficient application of the criterion-indicator for the existence of an objective reason (real or "apparent") for similar preferences in the few genuine *type II* "idiographic" distributions found.

Publications

The cSM was first introduced in the paper: *Comparative Scanning Method (cSM). Aspects of psychological experimental data of the 'preferential choice' type processing and interpretation*, published by the author of this dissertation in issue 3-4 of the *Bulgarian Journal of Psychology* (Panov, 2000). A total of 12 papers were prepared and published during the full-time PhD program, 11 of which were related to the comparative Scanning Method. Only the article: *Education 3.0 and psychological aspects of its manifestations as an activity-motivational process*, published in the *Balkan Scientific Review*, Vol. 4, No. 1(7), 2020, Impact Factor: 2.656 RSCI, DOI:10.34671/SCH.BSR.2020.0401.0015 has no direct relation to the method which is however listed in the bibliography. One studious (Panov & Bardov, 2021), one book (Panov & Bardov, 2022), and one article (Bardov & Panov, 2022) have been published in co-authorship with the thesis supervisor, Assoc. Prof. Ivan Bardov, PhD. One article (Panov, Zlatev, & Vasileva, 2022) has been published in cooperation with other authors. The remaining materials /one book, one studious and five articles/ are individual publications (Panov, 2021a, 2021b, 2021c, 2022a, 2022b, 2022c, 2022d). The comparative Scanning Method (cSM) has also been cited by authors working in other scientific fields.

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Bardov, I., **Panov**, I. (2022). Integrating the nomothetic and idiographic approach into a single experimental model through the comparative Scanning Method (cSM). *Collected papers of the National school for doctoral students and young researchers in social sciences, 3*. Sofia: Institute for Population and Human Studies, Bulgarian Academy of Science, 171–180. ISSN: 2683-0868 (online) [in Bulgarian]

Research project

The project *Internet-based toolkit for the computational procedures in the algorithm of the innovative comparative Scanning Method (cSM) for processing, analysis, visualization and psychological interpretation of experimental data of preferential-choice type* is funded by the Scientific Research Fund (2022): Projects in support of PhD students / operated by the Sofia University "St. Kliment Ohridski". The project focuses on the creation of a web-platform to provide free access to the computational tools of the comparative Scanning Method (cSM) to all researchers in the field of psychological measurement. The main project activities are in the following directions: Creation of a web-platform (open access portal) for the analysis of psychological research data using cSM; Testing the platform with data from different experimental designs (from fields such as: Psychophysics; Psycholinguistics; Personality Psychology, *values*, *aesthetics*, etc.); Creation of a *Handbook* for operating with the cSM; Information and publicity (activities for dissemination of the technology and know-how). The results and scientific contributions of the project are in the direction of refinement, finalization and validation of a technological toolkit based on the new theoretical approach for data analysis. The project also contributes to the *dissemination*[22] of the innovative method presented.

As a result of the implementation of the project it is expected to build additional academic authority of the Department of General, Experimental, Developmental and Health Psychology, Faculty of Philosophy, Sofia University "St. Kliment Ohridski"[23].

Future directions

As a technology for processing, analyzing, visualizing, and interpreting experimental data from a wide range of psychological studies, the comparative Scanning Method (cSM) is not only a tool but also an opportunity to extend the psychometric paradigm. Because the *comparative scanning* is applicable to the study of the *choice-by-preference* both ideographically /for a single specific research (*case study*) / and nomothetically /for samples or populations/, in the latter case prerequisites for future research towards the ***genesis*** and ***characteristics*** of the "collective" reference stimulus are established. The results presented in this dissertation from heterogeneous experiments conducted using cSM (and explicating different types of *ideal point distributions*) "suggest" a direction of search in terms of collective preferences, and more specifically, new cases with common preconditions, states or predictors for the population under study leading to similarity in preferences, or conversely, cases where ideal point distributions are "diffuse" and not due to common objective causes. In this way—in addition to improving the synergy between Statistics and Theoretical Psychology—the collection of facts will be enriched, which may provoke a revision of current theoretical concepts even in the field of Social Psychology, where the main object of scientific interest is the behavior of humans functioning in the social environment.

Using cSM, it is possible to register a situation in which the same stimuli perceived through different sensory modalities, however, "generate" semantic spaces in which the established reference areas do not correspond to each other. In other words, that "independent" *visual* ideal points, *tactile* ideal points, etc. exist, which is an interesting research direction.

A possible aspect of future research (with the technological involvement of cSM) is the ***distinction*** between *individual* and *social* "ideal", in any life domain. Whatever the reason for a possible personal "drift" away from the *social norms* relevant to a particular time and place (which

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[22] Through the platform created for the project: www.cSMinventory.online

[23] In the longer term, it is also possible to integrate cSM into the data processing and statistical analysis tool in a graphical environment: IBM *SPSS* (originally titled as *Statistical Package for the Social Sciences* and later renamed, keeping the same abbreviation, to *Statistical Product and Service Solutions*).

sometimes have a destructive impact on the mental functioning of a particular person), *self-knowledge* is key to overcoming the negative consequences of the emerging cognitive dissonance or "contradiction" between socially imposed "external" norms of what to like (or how to behave) and "internal" standards of behavior—in terms of thoughts, feelings and actions. This is why non-quantitative *indirect* self-assessment through cSM is an opportunity for deeper self-knowledge, and hence for reasoned/motivated confrontation of destructive social messages.

An additional direction for research inquiry is the announced relationship between cSM and the *Theoretical Model of Associative Interactions* (TMAI). The TMAI provides an alternative way of defining the *theoretical probability* in the cSM algorithm. Some of the model's features indirectly link the concept of comparative scanning to the *Theory of Multidimensional Psychological Scaling*. The key constructs in TMAI—*Cognitive Loading* ($\mathbf{C}_i$) *of concept* $\boldsymbol{i}$ and *Association Force* $\mathbf{F}_{\mathbf{A}ij}$ *between concepts* $\boldsymbol{i}$ *and* $\boldsymbol{j}$—lead to the constant ψ, which explicates the dependence of associative strength on the distance between objects in the cognitive concept space and their information load[24]. In this sense, a mandatory future research direction is the "quantification" of the value of the constant ψ, which may turn out to be universal!

[24] For details see Appendix 1 of the dissertation.

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Appendices of the dissertation:

Appendix 1. *Theoretical Model of Associative Interactions* (TMAI);
Appendix 2. IRRA *computer program*;
Appendix 3. STAI (*State-Trait Anxiety Inventory*) Form Y Questionnaire;
Appendix 4. Results of processed data from surveys and experiments;
Appendix 5. Experiment 07 /Material and Method; Results and Discussion/;
Appendix 6. Experiment 12 /Non-randomized Questionnaire/;
Appendix 7. Basic definitions (*in English*) of concepts in cSM and TMAI.

Additional appendix (*An intuitive introduction to the comparative Scanning Method*)

ACCESS TO THE FULL TEXT OF THE DISSERTATION (*QR code* and *link*) [in Bulgarian]

https://drive.google.com/file/d/1lNoCKYJIUqQDenwFTXdM1b6j3XzleOvV/view?usp=share_link

Additional Appendix

An intuitive introduction to the comparative Scanning Method

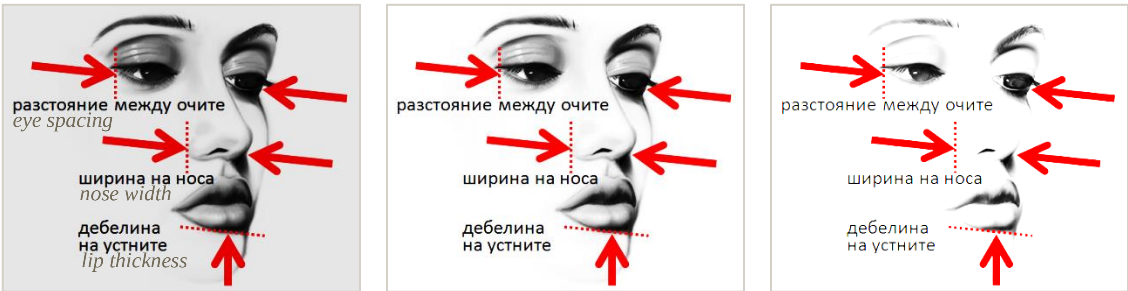
(*quick introduction to* cSM)

Choice by preference (or *why* and *how* we like, prefer, or even are attracted to certain objects and not to others) broadly comprises the following relatively independent components: (1) Situational or concrete perception; (2) Comparison with a current "internal criterion" /benchmark/; (3) Decision-making.

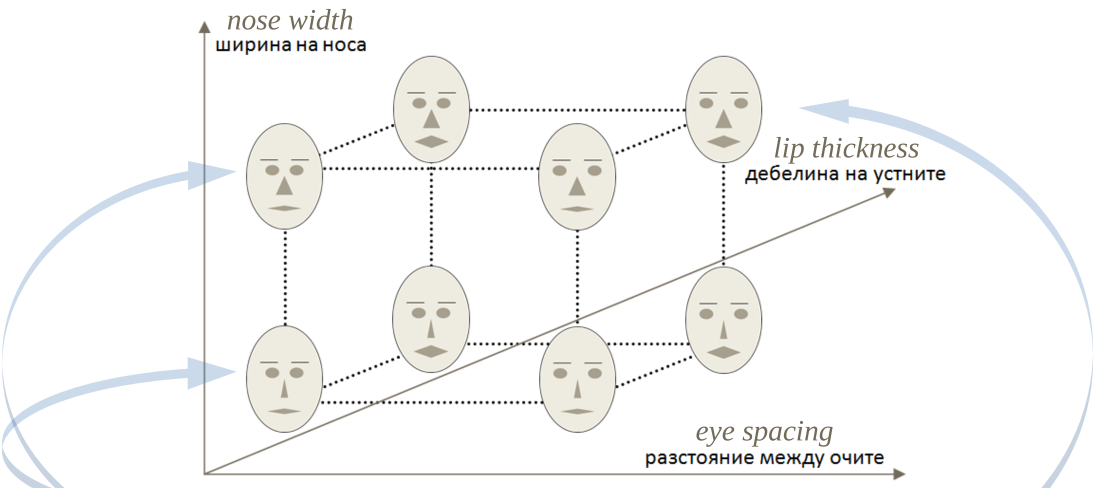
The special case of an ***alternative forced choice between two stimuli***, where a *preferential choice* is realized, is the focus of the comparative Scanning Method.

To illustrate this innovative technology, so-called "meaning-distinguishing" features of the human face can be used. It has been empirically established that certain invariant measures (such as *eye spacing*, *nose width*, and *lip thickness*) play a significant role in face perception and recognition, a process referred to in neuropsychology as *prosopgnosis* (Pencheva & Panov, 1994)*, (Pencheva, Gerganov, & Panov, 1997)**.

The three proposed measures (or measurable quantities) are invariant because they retain their quantitative values, regardless of changes in the perceptual context:



If these ***three*** independent quantities are considered as feature space parameters, ***eight*** schematic visual stimuli with boundary combinations of the three "meaning-distinctive" features of a human face can be constructed, located in this feature/attributive space at the vertices of a parallelepiped (or topologically similar object):



(1) close-set eyes + narrow nose + thin lips;
(2) close-set eyes + broad nose + thin lips; **…**

(8) distant-set eyes + broad nose + full lips.

Is it possible to detect in this space a stimulus with "ideal" quantitative characteristics (on all three parameters of the space), based only on information experimentally obtained by *pairwise comparison* (of all possible combinations between boundary stimuli) and *selection by preference* in each pair of schematic faces?

The answer to this question is affirmative—yes, it is possible!

The comparative Scanning Method (cSM) not only detects the stimulus in question (its localization in the defined space, as well as its "strength" influencing the choice by preference), but also explores the structure of the whole feature/attributive space.

Although the subjective sense of aesthetics (or attractiveness of the human face) is a result of multiple processes occurring in parallel, the degree of attractiveness depends mostly on the momentary visual perception. And regardless of the numerous perceptual characteristics of the human face (individual elements or ratios between them), it is sufficient to examine only the "meaning-distinctive" features, since the second of the components of the *choice-by-preference* process—the comparison with an ongoing "internal criterion"—presupposes the existence of a ***reference*** (with maximum quantitative harmony of the constituent elements: *eye spacing*, *nose width*, and *lip thickness*).

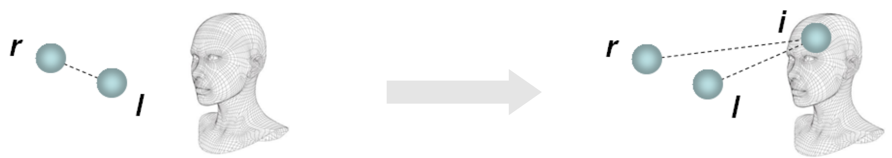
The current "internal criterion" in cSM terminology is the key ***reference stimulus*** in the model, which directly corresponds to the *ideal point* (the perfect quantitative balance between the attributes or characteristics of a perceived object). A conceptual nuance in the distinction between the "reference stimulus" and the "ideal point" is obvious in the definition of the two almost overlapping concepts, namely: the *reference stimulus* is a "subset" of the *ideal point*, since only a portion (albeit the most significant one) of the attributes of the object-stimuli defines the space in which its localization and "strength" are sought. The comparative Scanning Method (cSM), however, has no bearing on the origin of this standard (*when*, *how*, and *why* it is formed), but can track it quantitatively over time, as well as the space around it.

Geometric representation, in turn, leads to a logical paradox, which is the following: *Since the localization of the reference stimulus in the attributive space of physical features is based on the subject's responses, which are probabilistic in nature (common to most natural information perception and processing systems), the direct application of geometric considerations (in the case of inconsistent responses) leads to an inability to localize in the space of the sought reference area* [see pp. 57–61].

The comparative Scanning Method (cSM) offers a solution to the logical paradox: *Localizing the reference stimulus in the attributive space of physical or abstract features is possible by modifying the geometric model in a statistical (probabilistic) analysis, based on comparing the theoretical and empirical probability of a stimulus being "more attractive" than another for each point in the feature/attributive space*.

How does this happen? The information obtained experimentally by *pairwise comparison* (of all possible combinations between the boundary stimuli) and *choice-by-preference* within each pair of schematic faces is organized into a number raw, each element of which is the observed proportion/percentage of preference for the first of the pair of stimuli. In this way a so-called ***empirical vector*** is formed, which in this case contains 28 elements [see page 65]. All elements of the empirical vector are compared with their corresponding elements of a ***theoretical vector*** [see page 64]. The elements of the theoretical vector are the probabilities that the first in the pair of stimuli is preferred—in terms of their similarity to the reference standard, if it is located in the investigated area of the feature/attributive space.

Preferential Choice Data | *Similarities Data*



empirical vector: {element $\mathbf{1}^E$, element $\mathbf{2}^E$, … , element $\mathbf{28}^E$}

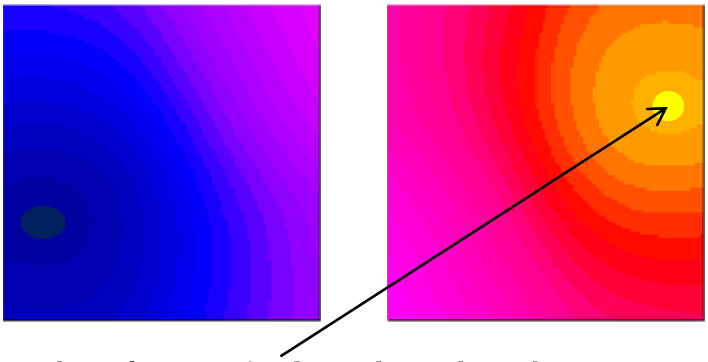
theoretical vector: {element $\mathbf{1}^T$, element $\mathbf{2}^T$, … , element $\mathbf{28}^T$}

For each compared pair of elements of the empirical and theoretical vectors, the absolute value of the difference is determined, and then all the resulting differences are summed. This yields a summary measure of the degree to which the feature/attributive space zone (or point) under investigation matches the reference stimulus under investigation, called ***Matching Factor***—*the smaller the sum of the differences, the more certain it is that the point under investigation matches the reference stimulus*.

The matching factor "colors" the examined area of space with a so-called "temperature" color (from dark blue to bright yellow, even white)—the smaller its numerical value for a given point, the warmer the denoting color:

In the given three-dimensional feature/attributive space, this computational algorithm is executed 1 000 000 (one million) times, for each point in the space that receives its own "temperature" color.

The colored dots ("pixels") are visualized by moving scanning planes, controlled by specialized software:



This localizes the ***reference stimulus*** and visualizes the structure of the entire feature space. The individual color "bands" in the scan planes depict the areas with similar "intensity" of the matching factor and construct the *gradient* of the attributive space. This also enables the detection of "cold" zones, where the stimuli with the most inharmonious quantitative feature combinations are located. In other words, those stimuli (opposite to the referent) that are not indifferent with respect to the effect of their perception, but even induce a negative (repulsive) sense of disharmony. This is important to note because when the reference stimulus (or unformed criterion of preference) is weakly expressed in the particular space under study, the scanning planes are predominantly colored with the intermediate "temperature" colors, which is associated with "indifference" to the perceived objects.

Implementing the computational algorithm of the comparative Scanning Method, specialized software tools (IRRA beta, Gen21cSM, cSMinventory.online) identify and quantify method eigenvalues that are psychologically interpretable, according to the theoretical underpinnings of cSM [see pp. 62-69].

Further confidence that the comparative Scanning Method adequately performs the task at hand is based on the following fact: *If a subject is presented with a stimulus (from his or her established personal reference zone) for evaluation, this stimulus (in combination with all others) proves to be the most preferred*.

An important distinguishing feature of cSM (compared to most methods of collecting and analyzing data from psychological research) is the mode of restriction both in terms of time for direct (situational) perception and in terms of information about the objects being assessed—only their basic "meaning-distinguishing" features that form the attributive space under study. Thus, perception under time and information deficit (in this case concerning the multi-component human face reduced to an artificial schematic face with three basic parameters) optimally "activates" the complex cognitive process of ***preference*** (attraction or liking).

The main applicability of the method is *idiographic* cSM-*analysis*: the study of a particular respondent (*case study*) or of a group of study subjects whose results are analyzed individually. However, interesting findings are also obtained by *nomothetic* cSM-*analysis*: the study in which (1) pooled sample data or (2) pooled sample cSM-scores are analyzed [see page 136]. Analyzing the different distributions (of individual ideal points in the study space or of ranked minimum values of the matching factor) also leads to the concept of a *criterion of validity* or "seemingness" (due to multiple factors, some of them random) of preconditions, states or predictors common to the study population that lead to similarity in preferences.

Another possible applicability of cSM stands out in studies where respondents are younger children or people with certain cognitive deficits. The comparative Scanning Method is a possible alternative to quantitative Likert Scales, both in terms of the way of assessment (***direct*** in Likert Scales and ***indirect*** in cSM) and in terms of the accuracy of the results, which is *greater* in non-quantitative assessment by comparing dyads of stimuli—indirect qualitative assessments are "transformed" into quantitative ones by the *coordinates* of the reference stimulus in the space under study, and each of the axes of this space can be interpreted as an independent *Likert Scale-continuum* with very high "resolution".

A possible aspect of future research (with the technological involvement of cSM) is the ***distinction*** between *individual* and *social* "ideal", in any life domain. Whatever the reason for a possible personal "drift" away from the *social norms* relevant to a particular time and place (which sometimes have a destructive impact on the mental functioning of a particular person), *self-knowledge* is key to overcoming the negative consequences of the emerging cognitive dissonance or "contradiction" between socially imposed "external" norms of what to like (or how to behave) and "internal" standards of behavior—in terms of thoughts, feelings and actions. This is why non-quantitative *indirect* self-assessment through cSM is an opportunity for deeper self-knowledge, and hence for reasoned/motivated confrontation of destructive social messages (or stereotyped behavior).

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