

METHOD OF DESIGN EVALUATION FOCUSED ON RELATIONS OF MEANINGS FOR A SUCCESSFUL DESIGN

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1. Introduction

In order to create a successful design or for supporting design creation, an understanding of the characteristics of successful design is required. This understanding extends to knowledge of the design features which are evaluated as excellent by users. Therefore, much of the research was performed to determine the factors which lead to a successful and positively evaluated design. Design outcomes were analysed using many methods, and various important factors were extracted. However, understanding these kinds of factors is not sufficient to create design, because it does not relate directly to the design methodology. To drive the process in order to obtain a successful design, we need a more precise procedure to operate factors enabling creative design. Understanding the mechanism of underlying factors, which is related to high evaluation results, is important feature. Hence, this research proposes a methodology of the analysis of successful design and one of its factors giving a good impression, which is connected with a methodology of design.

1.1 Background of Design Evaluation

Knowledge of design method needs connection with successful results of design. Understanding of the design characteristics requires applicability in order to contribute to design methodology. Inheriting the viewpoint of design as meaning-producing [Kazmierczak 2003] and furthermore, meaning-centred, we focus on the obtaining of practical knowledge of the connection of the meaning factors with evaluation of design. The most explicit meanings-centred design, thus the most analyzable, is the communication design.

Previous studies on the evaluation of design describe a number of factors [Henderson et. al. 1998, 2003]. A method of evaluation of design characteristics through user ratings, questionnaires and factors was employed, and the ratings were analysed to identify the underlying connections. In the case of graphic design, factors such as familiarity, harmony, naturalness and elaborateness, together with many different evaluations are well explored and connected to design evaluation. Another example is the study of logo design and word combinations [Haase and Theios 1996] by categorizing them. These studies contribute to extend the understanding of design characteristics by an analysis of design results. For example, they report that 'balanced', 'symmetrical', 'natural' and 'harmonious' are the important factors to relate to the characteristics of highly evaluated communication designs, e.g. logo design.

However, from the viewpoint of creativity, previous methods of evaluation [Henderson et. al. 2003] which are not yet sufficient to create design involve the analysis of the result of design (e.g. Semantic Differential Method) for understanding evaluation factors. In order to create successful design,

designers need procedures which they can operate on to draw these factors. An analysis of the method of evaluation of design, which leads to the design process, is required.

1.2 Focusing on the Meanings

From the perspective of creativity in design, the structure of meaning has been explored, because, from both viewpoints of design process intentions and of functional application, it is desirable that designs enable meanings. In design research, meaning has been addressed as the factors [Henderson et. al. 1998], and its important role in influencing people's impression has been pointed out. Structure of meaning has been researched as the semantics of product design, and it is extended to the view that similarity of language bridges the designer's knowledge [Dong 2005]. Also, to create impressive graphic design, the meanings are regarded as the main tool for the design process [Mollerup 1997]. Although meanings are reported as they connect with design characteristics [Henderson et. al. 2003], the connection is thought to be a weak one, and generally to be a predictor of factors such as familiarity.

On the other hand, recently, research on meanings in natural language processing is advancing outside of its original domain. The structures of meanings can be considered as those which are operated by informatics processing technology based on human knowledge, e.g., a concept dictionary such as WordNet [Pedersen et. al. 2004]. There are different measures of meanings using the WordNet database as ontology of concepts. Such estimations of relations and similarity of concepts [Pedersen et. al. 2004] are applicable to other domains [Pedersen et. al. 2007, Georgiev et. al. 2007]. This is a reflection of a general idea, which is that meanings represent the missing factors of design [Kazmierczak 2003]. These concepts provide a prospect for a methodology for design support [Georgiev et. al. 2006]. Since design practices have been observed to be more intuitive than analytical [Mollerup 1997], they have not yet been theoretically explained. By evaluating and structuring the meanings, the use of WordNet is expandable into a practical support for design. Connecting evaluation analysis and humans' understanding in the form of meanings creates such a possibility. For example, in graphic designs, logos and symbols are functioning not only as visual effects, but also as meaning emerging in the mind.

2. Aim of research

The aim of this research is to propose a methodology of analysis of design factors, based on meanings and, furthermore, to propose and extract factors of meanings which relate to a design highly evaluated by users, focusing on the relations of meaning. This process consists in identifying practical factors of meanings, which possibly contribute to the evaluation of design. This understanding of the role of meanings in design assessment factors is a step towards the development of a meaning-based support method of design.

In order to verify the methodology, our aim focuses on graphic design factors. This paper analyses the results of a survey through structural equation modelling and path analysis, using factors of meanings obtained from WordNet measures.

3. Method

3.1 Factors of meanings

For the needs of meanings, the analysis in this research proposes three original factors of meanings. The first is based on an idea for a factor which summarizes meanings. The following two factors are based on an idea for factors which represents relations between meanings.

For the actual calculations of the last two factors, the WordNet database and the similarity and relatedness measuring software WordNet::Similarity were used [Pedersen et. al. 2004]. The simplest measure among those defined in this database, relatedness concepts by path length [Pedersen et. al. 2004], was used in our research.

Sum of Meanings, Relatedness by Path and *Relatedness by Path – Standard Deviation* are discussed as factors of meanings. They are defined as follows:

- *Sum of Meanings* counts the number of all meanings per example (Equation 1):

$$Sum_{meanings} = \sum_{i=1}^n Meaning_i \quad (1)$$

Where n is the number of meanings in a design example;

- *Relatedness by Path* is defined as the average value (Equation 2) of all meanings similarities by shortest path in the WordNet database (Equation 3) [Pedersen et. al. 2004]:

$$Relatedness_{path} = \frac{\sum_{i=1}^N Sim_{path_i}}{Sum_{Meanings}^2} \quad (2)$$

Where the similarities (Sim_{path}) are defined as:

$$Sim_{path}(Meaning_1, Meaning_2) = \frac{1}{Path} \quad (3)$$

Sim_{path} is a real number between 0 and 1.

The path is measured in steps in the WordNet database. Equation 3 is a standard measure in WordNet::Similarity [Pedersen et. al. 2007]. Generally, the Relatedness by Path factor is a measure of the average distance between meanings of design.

- *Relatedness by Path – Standard Deviation* is defined as the unbiased standard deviation of the *Relatedness by Path*:

$$RelatednessPath_{SD} = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2} \quad (4)$$

The Relatedness by Path – SD factor is a measure of how widely values of Relatedness by Path are dispersed from its average value. This factor is an addition to the Relatedness by Path factor.

3.2 WordNet similarity measures

The actual procedure of the meanings analysis of one design example is illustrated in Figure 1, and is also listed below:

- The design is characterized by the number of meanings (Stage 1). e.g. the list of meanings – Balance, Border, Circle, Completeness, Connectivity, Cube and so on.
- The interpretation of meaning relatedness between the example pair of words Balance and Connectivity is visualized in the WordNet path (Stage 2). The shortest path is calculated with WordNet::Similarity as Balance – Spatiality – Property – Connectivity, which consists of 4 steps. According to Equation 3, the Relatedness by Path is 0.25.
- For every example design, a matrix of path relatedness of all meanings is calculated (Stage 3). This matrix is summarized by Equation 2.

The real value (between 0 and 1) of the factor *Relatedness by Path* is obtained with this method.

In summary, the method incorporates calculations of factors of meanings, accounting of the number of meanings and evaluating relations among all the meanings.

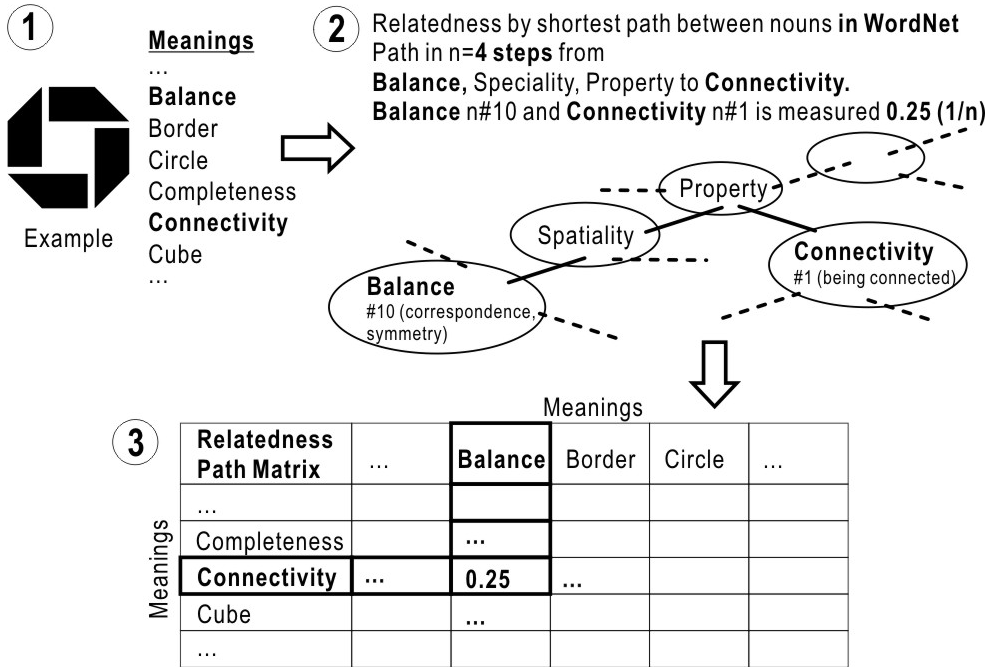


Figure 1. Procedure of meanings analysis of a design example

4. Survey

In order to verify the effectiveness of the proposed factors of meanings, we completed the following procedure:

- A questionnaire for the evaluation of factors and meanings. It investigates assessment factors, including the evaluation and interpreted meanings for the design examples of logo symbols.
- An extensive analysis of gathered meanings, using the WordNet database and the relatedness measures. The factors of meanings are extracted. The procedure of meaning analysis and factors of meanings take into account the differences between the indicated meanings. Furthermore, factors of meanings are compared with the evaluation and common factors for the assessment of symbols.
- An interpretation of findings using Structural equation modelling (SEM). The purpose is to build a model which predicts the influence of meanings factors on the evaluation of design.

Our assumption is that, together with common factors, represented in this study by familiarity and harmony, factors of meanings have a strong influence on the global evaluation of the design of symbols.

4.1 Participants

Eighty-six students in the second year of the engineering design major completed a questionnaire for this study. The selection of participants is based on the assumption that all of them already have a fundamental knowledge of the design process, but that they are not practising professionals. This follows our opinion that results will be better applicable in design support. Moreover, this selection is relevant to the general goal of developing a new support method for design through this analysis. All the participants are volunteers, who received no additional course credits for their participation.

4.2 Structure and procedure

The questionnaire that was conducted included 60 design examples of symbols in colour, and was divided into two parts (Figure 2). The first part included assessment factors on a 7-point scale, as shown in Table 1. The second part focused on the interpretation of meanings of examples. Every participant assessed 20 examples and pointed out the meanings of 20 other examples. For every participant, the first and second group included different examples in a different order. Parts of the questionnaire included an explanation of the factors under assessment and meanings respectively. The examples chosen were from different origins and have different design characteristics. They cover a broad range of successful examples of design of logos in use, highlighting different design characteristics.



<p>Part 1. Evaluation of symbol responses Subjective parameter of assessments, evaluated by a 7-point scale</p>  <p>Poor <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Excellent</p> <p>Unclear <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Clear</p> <p>Meaningless <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Meaningful</p> <p>Unfamiliar <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Familiar</p> <p>Inharmonious <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Harmonious</p>	<p>Part 2. Meanings interpretation Subjective parameter of meanings found in an example. Non-scale verbal description – one or more verbal meanings</p>  <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p>
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Figure 2. Example of questionnaire structure

Table 1. Characteristics of assessment factors as dependent variables

Assessment Factors	Judgement of:	Characteristic	7-point Scale
Evaluation	Value of total quality of design - Refers to evaluative reaction to the impression created by design in terms of goodness, quality and likeness	Modified/ Generalized from previous studies	Poor/Excellent
Clearness	Easiness to perceive and appearance of design elements - Refers to perception clarity and uninterrupted transfer of design intentions	New	Unclear/Clear
Meaningfulness	Creation of meaning and understanding design - Refers to the degree and success of meaning creation, understanding meanings	New	Meaningless/ Meaningful
Familiarity	Being familiar and with common design - Degree of remembering or impression of that design is seen or with common features	Common/ Generalized from previous studies	Unfamiliar/Familiar
Harmony	Combination of pleasing elements in design - Involves balance and symmetry of design from a Gestalt perspective of arrangement of elements	Common from previous studies	Inharmonious/ Harmonious

4.3 Factors

The chosen assessment factors are *evaluation*, *clearness*, *meaningfulness*, *familiarity* and *harmony*. The last two factors are common factors for the assessment of the design of symbols [Henderson et. al. 2003, 1998]. An analysis of these common factors like shows that only a few of them are relevant to meanings. The choice of familiarity is connected to the creation of meaning, while harmony is common generalizing factor of e.g. balance, symmetry, Gestalt [Henderson et. al. 1998]. The factors known as to be influenced by cross-cultural differences are excluded. The factors used in this research, their judgements (as it was denoted to the participants prior to questionnaire) and characteristics are shown in Table 1. The newly added factors are “clearness” and “meaningfulness”. The choice of *clearness* and *meaningfulness* was derived from the assumption that both these factors are connected with the interpretation of meaning. These factors are also relevant to the general graphic

design tasks. Furthermore, among aesthetic assessment factors, harmony is chosen as the most general one, incorporating balance and symmetry.

5. Results

5.1 Assessment factors

For every example, the average value of every assessment factor is calculated. This means that all 60 examples received scores for the factors *evaluation*, *clearness*, *meaningfulness*, *familiarity* and *harmony*. The initial descriptive statistics of the assessment factors is shown in Table 2.

The familiarity assessment of the examples was relatively low. Compared to all other assessment factors, the evaluation factor has the smallest standard deviation. This means that participants made a relatively narrower judgement on evaluation than on other factors.


5.2 Interpretation of meanings

In the second part of the interpretation of meanings, participants indicated as many meanings as they discovered in the examples that were presented (Figure 1, Part 2). There were no limitations in the meanings to be indicated. Predominantly, the words used by subjects are nouns. For every example, the meanings, including those repeated more than once, are grouped together for further analysis. The meanings that were discovered vary from 31 to 84 nouns. Table 3 presents one example, indicated meanings and factors of meanings. The total of 60 groups of indicated nouns are used in the WordNet analysis.

Table 2. Descriptive statistics summary of average assessment factors

Assessment Factors	Mean	SD	N
Evaluation	4.45	0.79	60
Clearness	4.16	1.05	60
Meaningfulness	4.15	0.91	60
Familiarity	2.99	1.00	60
Harmony	4.78	0.87	60

Table 3. Example, indicated meanings and factors of meanings calculations

Example	Meanings	Sum of Meanings	Relatedness by Path	Relatedness by Path - SD
	alliance (5), band, blend, collection, communication, connection (4), crescent, dove, dynamics (2), freedom, fun, gaiety, game, hand, harmony (3), hieroglyph, hug (2), human, letter (5), line, man, mobility, movement (3), net, orbit (2), plus (2), receiver, ribbon, road, seal, sign, sound, symbol (2), telephone, twist, unity, water, wave, wholeness	59	0.198	0.182

5.3 Summary of factors of meanings

From the calculations in the previous step, for every example, three factors of meanings were computed: first, the simple sum of discovered meanings per example; second, the relatedness by path, which is the average relatedness between all the meanings of the considered example; and finally, the standard deviation (SD) of the relatedness by path. The summary of descriptive statistics for all examples is shown in Table 4. The average number of meanings per example is 55.7, and the average relatedness by path is .2378. After the obtaining meanings (Figure 1, Step 1), for every pair of words the relatedness by path was calculated (Step 2). These measures were grouped into a relatedness-by-path matrix (Step 3), constructed from every example. This resulted in 961 to 7056 calculated relatedness measures between meanings of words. Then, the average relatedness by path and its standard deviation were calculated.

5.4 Factors correlations

The first step of this analysis was the evaluation of the correlations between the assessment factors and the factors of meanings. The analysis of correlations showed no strong correlations between factors of meanings and assessment factors (Table 5). The common factors of familiarity and harmony were not significantly correlated to any of the observed factors of meanings.

Table 4. Descriptive statistics summary of factors of meanings

Factors of Meanings	Mean	SD	N
Sum of Meanings	55.7	14.2	60
Relatedness by Path	.238	.050	60
Relatedness by Path - SD	.246	.050	60

Table 5. Factor correlations between factors of meanings and assessment factors

Factor correlations		Assessment Factors				
		Evaluation	Clearness	Meaningfulness	Familiarity	Harmony
Factors of Meanings	Sum of Meanings	.257 *	.201 ns	.266 *	-.041 ns	.174 ns
	Relatedness by Path	.273 *	.424 ***	.363 **	.138 ns	.174 ns
	Relatedness by Path - SD	.243 *	.468 ***	.398 **	.132 ns	.128 ns

ns – not significant; * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$

If we consider the factors of meanings, the correlations and significance are higher with “clearness” and “meaningfulness”, and lower with “evaluation”. This suggests the presence of more complex connections between all the factors. A model of predictions of factors will possibly provide a better explanation for these results. The commonly approved factors “familiarity” and “harmony” are excluded from the final model because their correlations are not significant.

Furthermore, in this study, the dependent variable is considered for the evaluation of design, and the independent variables are the factors of meanings and other assessment factors – clearness, meaningfulness, familiarity and harmony. The regression analysis conducted in the next step shows significant correlations also within assessment factors. The regression analysis correlations used for the model are shown in Table 6.

The correlation matrix shows the Pearsonian r 's and the significance of each r – the effect of factors of meanings on the evaluation and assessment factors. The levels of significance are shown below. The only correlations that are not significant are those of the sum of meanings with the relatedness factors and with clearness.

5.5 Structural Equation Modelling (SEM)

In the next step of the analysis, Structural Equation Modelling (SEM) was used to evaluate the influence of factors of meanings on the design evaluation. As a statistical technique for estimating relationships, it is a suitable theory testing [Structural Equation Modelling using AMOS, 2001]. This modelling is an extension of the general linear model and represents relationships among variables using path diagrams.

N=60; ns – not significant; * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$

After regression analysis was performed, a path analysis using the SEM of these factors was conducted. This is a search for direct and indirect effects of the variables on the evaluation. It shows the causality of factors in the final evaluation. The factor of evaluation is considered as a dependent variable in the path analysis result, as shown in Figure 3.

Table 6. Regression analysis between factors used in the model

Correlations		Evaluation	Clearness	Meaningful-ness	Sum of Meanings	Relatedness by Path	Relatedness by Path- SD
Pearson Correlation	Evaluation		.722 ***	.759 ***	.257 *	.273 *	.243 *
	Clearness	.722 ***		.932 ***	.201 ns	.424 ***	.468 ***
	Meaningfulness	.759 ***	.932 ***		.266 *	.363 *	.398 **
	Sum of Meanings	.257 *	.201 ns	.266 *		-.056 ns	-.083 ns
	Relatedness by Path	.273 *	.424 ***	.363 **	-.056 ns		.875 ***
	Relatedness by Path- SD	.243 *	.468 ***	.398 **	-.083 ns	.875 ***	
Sig. (1-tailed)	Evaluation		.000 ***	.000 ***	.024 *	.017 *	.031 *
	Clearness	.000 ***		.000 ***	.062 ns	.000 ***	.000 ***
	Meaningfulness	.000 ***	.000 ***		.020 *	.002 *	.001 **
	Sum of Meanings	.024 *	.062 ns	.020 *		.335 ns	.265 ns
	Relatedness by Path	.017 *	.000 ***	.002 **	.335 ns		.000 ***
	Relatedness by Path- SD	.031 *	.000 ***	.001 **	.265 ns	.000 ***	

5.6 Interpretation of the output of SEM

We now explain the validity of the output model. The resulting model has good evaluations according to “global model fit” criteria. The measured goodness-of-fit index (GFI) of the model reaches 0.973 (Figure 3), and the adjusted goodness-of-fit index (AGFI), 0.929.

The model reaches a minimum at a chi-square of 4.86 with 8 degrees of freedom and a probability level of .772 [Structural Equation Modelling using AMOS, 2001]. The model contains both unobserved (error variances) and observed variables (WordNet factors, factors of meanings and assessment factors). Common assessment factors of familiarity and harmony do not improve the goodness of the model. They are to a larger extent caused by outside factors, not by factors connected to meaning characteristics.

The practical interpretation of the model is based on the direction of the arrows and standardized regression weights besides them (Figure 3). For example, when the relatedness by path increases by 1 standard deviation, the relatedness by path SD increases by 0.87 units. Also, when the relatedness by path SD increases by 1 standard deviation, the meaningfulness rises by 0.42 standard deviation. Through this mechanism, the influence of factors of meanings as predictors of dependent variable evaluation is made clear.

6. Discussion

The result of structural equation modelling clearly shows the influence of the WordNet-based factors of meanings on the final evaluation of design. The *Sum of meanings* factor, the factor of *Relatedness by Path* and connected to it, the *Relatedness by Path - standard deviation (SD)*, are introduced as factors, describing meanings in designs. As such, and as a base in a complex ontology such as WordNet, they can be applicable in design support.

These three factors of meanings (*Sum of meanings*, *Relatedness by Path*, *Relatedness by Path – SD*) are strongly connected to the Clearness and Meaningfulness of symbol designs, e.g. logo design. The Sum of meanings has a smaller, but notable impact in the model on the meaningfulness factor.

The influence of relatedness by path and SD of relatedness by path in the model shows the importance of the meaning relations (Figure 3). These relations have both an indirect and a direct influence on the evaluation of design. Moreover, the discovered factors suggest the presence of a more complex factor to describe meanings. Relatedness by path and SD are relatively simple descriptors of the relations

between meanings. The model, as a relevant result, confirms the analysis and the factors of meanings proposed in the methodology.

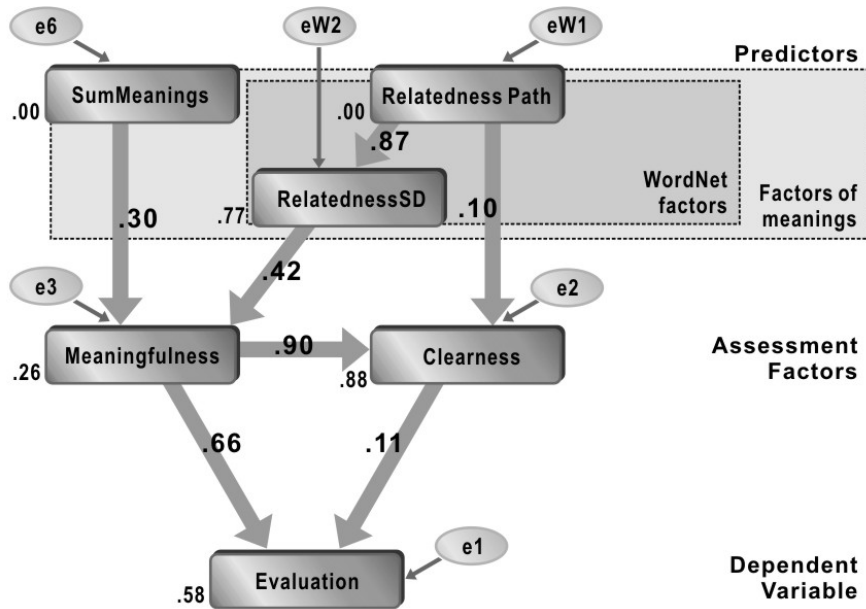


Figure 3. Path analysis of effects of factors on evaluation. Standardized estimates are shown beside arrows. The unobserved variables from e1 to e3, e6, eW1 and eW2 are error variances.

7. Conclusion

This paper introduces factors of meanings, which are describable, and connects them in a model for the prediction of evaluations of design. This model is verified by structural equation modelling. Compared to the common assessment approach to symbols, it introduces the additional assessment factors of clearness and meaningfulness. The model describes the causality between factors of meanings and assessment factors. Elaborating these factors and factors of meanings completes a preliminary model involving meanings in a successful design of symbols.

The influence of the characteristics of meanings measured directly on the general evaluation of design is rather indirect (Figure 3). It is stronger on the factors of meaningfulness and more important on clarity. Thereby, the relatedness is connected to the evaluation by the factors of clarity and meaningfulness. Both of these factors are strongly connected to the evaluation. Conversely, the common assessment factors from previous studies have a smaller contribution to the judgement of quality of symbol, with the exception that only harmony directly influences evaluation.

Understanding the role of meanings in design assessment factors is a step in the development of a support method of the overall process of designing. This possibility is related to the design method and to the operation of meanings relations in the design process. The factors of meanings which we introduced, and particularly the relatedness by path, can be involved in an approach to support design process.

8. Implications

Such supporting approach can elaborate a real-time evaluation of meaning relatedness of concepts in the process of design. With such means the designer would have the opportunity to structure the concepts along with structuring the form of the design product, integrating them into the whole design

meaning. This structuring of the design concepts is particularly applicable to the areas with impression meaning creation, such as product design or product graphics. This methodology of analysis bridges the gap to supportable process of synthesis of meanings in design methodology. Future work will focus on a further investigation of relations between meanings of design, and on developing a design methodology from the viewpoint of meaning relations.

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