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Effects of the Environmental Factors on Decision Consistency

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Abstract Responsible decisions are taken both in our everyday lives and in business processes of big enterprises. Decisions have an effect on our future, the efficiency of our work, our successes. There are decisions which need an especially substantial and persuasive decision process because taking them is complex problem or their consequences are important to us. In these cases the decision process is particularly important to be well-established and clear from the point of initialization to the point of defining the final solution. The most sensitive part of a decision process is the human factor, the inconsistency of the Decision Maker(s) (DMs). Hence we should pay due attention not only to developing the most appropriate algorithm but also to improving the intuitive efficiency of the DMs. The impact of internal factors on inconsistency like the type of the problem (subjective or objective), the size of the pairwise comparison matrix or the order of filling have been studied in several papers (i.e. [2,9]). However, the authors of these papers usually ignore the human factor of the decision process. We investigated what by what means and how we can enable the DMs to make the most consistent decision inspired by design.

Keywords: *Analytic Hierarchy Process, interior design, inconsistency, Software Design and Development*

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1. Introduction

In our paper we studied how the external factors, like the interior design of the room provided for the decision process, the quality of the Graphical User Interface (GUI) or the different types of modules provided for comparisons can influence the consistency of the DMs.

We created a survey with both objective and subjective questions which offers different modes for comparisons as well. We developed this survey in two different qualities from the point of view of software design. Two rooms were also prepared for the completion of the survey. These rooms were very different in aspect of interior design.

Investigating the effects of the surroundings on people's work quality is not a new topic in architecture, psychology or social sciences. Several researchers studied this topic earlier (e.g.: [3,4,10,14]), but they usually did not use such kind of analytical measures like the consistency ratio for revealing the impact of the design of the surroundings. Comparisons were conducted typically in terms of speed of working, accuracy of outputs or psychological measures, like brain rhythms.

What really differentiates our research from the others is the analyzation of the inconsistency level of the answers obtained by conducting this experiment in two different circumstances. This measure is a numerically established way to describe the quality of work or concentration. We studied how the previously mentioned factors influence the consistency of the DMs. We also aimed to emphasize the importance of an appropriately designed working environment including e.g. a well-developed GUI.

2. Methodology of Analytic Hierarchy Process

Recently, group decision processes have been receiving a serious attention. One of the most commonly used algorithms is the Analytic Hierarchy Process (AHP) developed and published by Saaty in [11] which study has already exceeded the 13000 citations. Saaty presented later in several papers how to adopt his method into group decision processes (e.g.: [12]). Most of the professional Group Decision Support Systems (GDSS) such as Expert Choice[1], Superdecision[2], MakeItRational[3] or Priest [13] implement Saaty's algorithm. Expert Choice should be highlighted because of its thirty-year history. The company's success stories include joint work with NASA.

Considering the intuitive factor on the decision making, the circumstances may have an enormous effect on the quality of the decision. How can we define the quality of a

[1] http://expertchoice.com
[2] http://www.superdecisions.com
[3] http://makeitrational.com

decision in a numerical form? Referring to the statement mentioned in the International Symposium on the Analytic Hierarchy Process that says "*Thomas Saaty is known world-wide as the person who figured out how to measure intangibles*", we can say that AHP provides a tool which can describe the quality of a human decision process through the measurable inconsistency level (see section 2.2.).

2.1. Pairwise Comparison

Pairwise comparison is an essential tool of AHP. It is a fundamental component for comparing the entities such as importance of criteria or performance of the alternatives. DM judges the alternatives ($X_1, X_2, \ldots X_n$) in a previously defined aspect and decides whether the two alternatives are identical or either of them is better. The answers of DM are structured in a quadratic matrix (i.e. a pairwise comparison matrix) $\| A \|_{n \times n}$, where a_{ij} is the result of the comparison $X_i \overset{?}{\leqslant} X_j$ and denotes how much the DM prefers X_i to X_j. As the preference relation should be a transitive relation we can introduce the following definitions.

Definition

A pairwise comparison matrix is **consistent** if

$$a_{ik} = a_{ij} a_{jk}$$

$\forall\, i, j, k = 1, 2, \ldots, n$, where $i \neq j \neq k$.

Definition

A pairwise comparison matrix is **inconsistent** if there is an i, j, k triad of indices, where $i \neq j \neq k$ and

$$a_{ik} \neq a_{ij} a_{jk}.$$

2.2. Consistency Ratio

Inconsistency appears if the evaluations of the DM were not transitive for all triads of the matrix. This could easily happen, especially in case of large number of elements that should be compered. In [11] Saaty suggested a formula to measure the inconsistency of pairwise comparison matrices. It can be proven that a positive, consistent, reciprocal pairwise comparison matrix has exactly one positive eigenvalue which is equal to the size of the matrix, i.e. $\lambda_{max} = n$. Based on this fact he gave a measure of inconsistency.

Definition

Let $\| A \|_{n \times n}$ be a reciprocal pairwise comparison matrix. **Consistency index (CI)** of A is

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (1)$$

where λ_{max} is the largest eigenvalue of A and n is the size of it.

This value should be compared to the average CI of randomly generated reciprocal matrices.

Definition

The average CI of these matrices is called **Random Consistency Index (RI)**. The following table shows the RI of sample size of matrices.

Table 1. Random Index of pairwise comparison matrices in different size

n	3	4	5	6	7	8	9
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Definition

The Consistency Ratio (CR) of a pairwise comparison matrix is

$$CR = \frac{CI}{RI}.$$

It is suggested that the inconsistency level of this matrix should be accepted if $CR \leq 0.1$.

Saaty proposed to compare the CI of a previously defined pairwise comparison matrix to RI of its size. If the ratio does not exceed 10% the matrix can be accepted else DM is suggested to do the comparison again.

Example

Let us see the following example where entries A, B, C, D should be compared. Supposed that the DM had done the pairwise comparison in the following way:

	A	B	C	D
A	1	3	2	4
B	1/3	1	1/2	1/2
C	1/2	2	1	2
D	1/4	2	1/2	1

Where $(A, B) = 3$ means that DM think so alternative A is three times better than alternative B in a particular aspect.

Maximum eigenvalue of this matrix is $\lambda_{max} = 4.1$ and $CI = \frac{4.1 - 4}{3} = 0.032$ moreover $CR = \frac{0.032}{0.9} = 0.036$. This inconsistency level (CR value) can be accepted, so DM does not need to redefine the pairwise comparison matrix in this case.

2.3. AHP process step-by-step

The increasing complexity of decision models introduced the need of a well-structured, organized decision process. Saaty's AHP uses a hierarchical structure for modeling the decision problems. The methodology of AHP can be briefly explained in the following steps:

- Step 1: ***Initialization.*** Defining the hierarchical tree of the goals, criteria, sub-criteria and alternatives. An example for this structure can be seen in Figure 1.
- Step 2: ***Evaluation.*** DM compares the alternative pairs on all criteria after each other. Evaluation process is a pairwise comparison of X_i and X_j, $i, j, = 1, \ldots, n$ in aspect of different criteria. Each pairwise comparison ends with a consistency checking. If CR is more than the accept-rate, comparison should be repeated.
- Step 3: Defining the ***criteria weights*** $(w_1, \ldots, w_n)$. Making a pairwise comparison for the criteria to define the weights of them. These weights denote the importance of the different criteria in the current decision process.
- Step 4: ***Summarizing.*** Final evaluation of the alternatives by combining the preference scores on the criteria obtained in Step 2 and the criteria weights defined in Step 3.

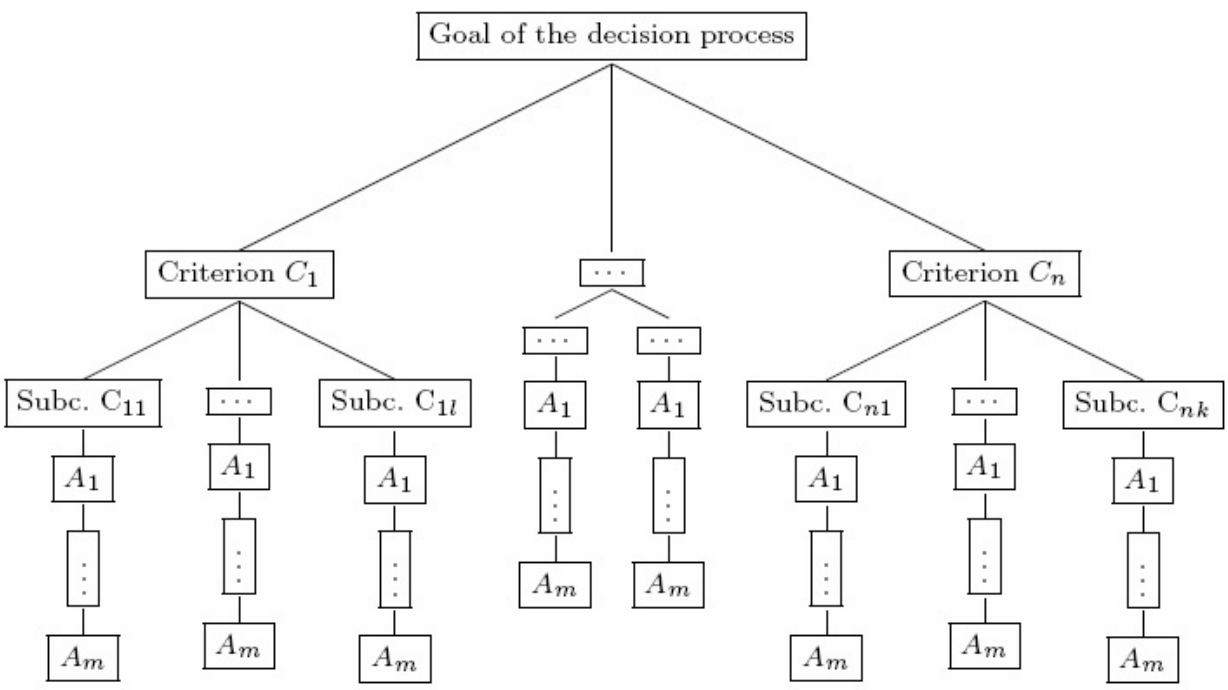

Figure 1. Hierarchical structure of a decision model in AHP

3. Experimental Factors

In this section we present the details of the experiment conducted for the previously detailed purpose.

Hence we made the participant fill the survey with pairwise comparison questions in two different situations (case *"A"* and *"B"*).

The differences are detailed in the following.

Hereinafter, we refer as case *"A"* to the case which depicts a situation in which optimal circumstances were insured for the participants; these included place, software design, adequate interior lighting and that period of the day when one is active.

We denote the case as case *"B"* when the conditions were less ideal. We shall point out that we avoided making extreme contrasts between the two cases. We focused on the usual, everyday differences of the classrooms, workplaces or the design of a survey's GUI. As a result of an expert approach in aspect of architecture and interior design two currently-in-use classrooms were appointed for the experiment. Considering the software elements we did not created differences which cannot be observed in the real life between professional systems and low quality applications.

Factors, which we studied, and which may influence the consistency level of the decision were basically the following:

3.1. Environmental Conditions

It is obvious that high level productivity requires employees' enormous and sustained concentration. It is very important to understand under what conditions employees' performance may improve. Architects have to design conditions which motivate employees to perform better at their working places and employers have to ensure these conditions.

The building as a collection of multi-sensory experiences could be a layer which provides positive or negative stimuli for our senses. Certainly, each of us is able to work with some self-discipline and thus to concentrate even under inconvenient conditions, yet there are external factors which may indeed affect our mood and ability to concentrate.

Ensuring the most appropriate environmental conditions and using the natural features of the surroundings in an optimized way could be one way to open the human mind in a positive direction. The disposition of the working place and the feelings awoken by it are essential tools for activating our intuitive inner senses. This is what we reveal and measure in an analytical way in our research.

It is very important that the working place shall be designed for the activity that we do. It must not be either ostentatious or characterless. Architects are responsible for defining the most appropriate interior and exterior design of the surrounding space.

3.2. Quality of Software Design and Development (SDD)

Although the quality of the software design and the quality of development provide basically similar functionalities, yet there is a serious competition between the GDSS. The main differences occur regarding the GUI design, the usability and certainly the price. The usual priority of these properties does not reflect the power of design elements in productivity of work.

A strict connection can be examined between the efficiency and the quality of software design (e.g. [7]). Professional software companies pay huge attention to SDD. For some companies, when they invest in GDSS, a well-designed GUI is of less significance than the functionality and price of the product. One explanation for that might be that certain companies do not believe that

the design elements can support the business processes and the productivity so much that it would be financially rewarded.

In our research we aimed to reveal the fact that the professional design does not only make the software usage easier but it can also improve the user-experience and productivity in a financial point of view as well. It is crucial especially in case of those types of applications where the outcome depends rather on the users productive or creative work with the software than the background processes of it. Here the decision support systems, the engineering- or imaging systems can be mentioned.

We implemented our questionnaire in two different qualities in aspect of software design. Based on different researches about GUI-development we aimed to grab the crucial points of the user interface development and to determine the key factors which may influence the productivity of users. Let us see some examples.

- ***Photo***. In case of the photos of the low-quality *"B"* version, we added some noise and blur and the resolution of the photos was quite bad.
- ***Graphics*** Figures were edited in black and white, their edges were "unsmoothed" in case *"B"*.
- ***Visualization*** In case *"A"* we used scripts to zoom the HD pictures in popup lightbox-windows moreover we chose professional photographs against snapshots.
- ***Editing*** We involved small editing errors like typos or non-equal linespaces in case *"B"*. We applied borders for tables in case *"A"* which made the filling clearer.

3.3. Summary

Table 2. Summary of external factors to be considered

	Case *"A"*	**Case *"B"***
Room	Natural lighting	Poor artificial lighting
	Modern hideaway computer desks	Small old-fashioned desks
	Conformity of the chairs	
	Direct visual connectivity to the external environment	
	Sunscreen and shading	
	Sense of cleanliness	
GUI	High quality, professional photos	
		Noisy pics
	Lightbox zoom effects	
	Editing	
Other	After lunch	Before lunchv
	URL in printed card with domain	URL on board given by IP address

4. Results

In this section we present the revealed results. In all the following graphs the blue columns refer to the case *"A"* and the orange ones refer to case *"B"*. We investigated the following questions:

- How large is the difference between the average CR values in the two cases?

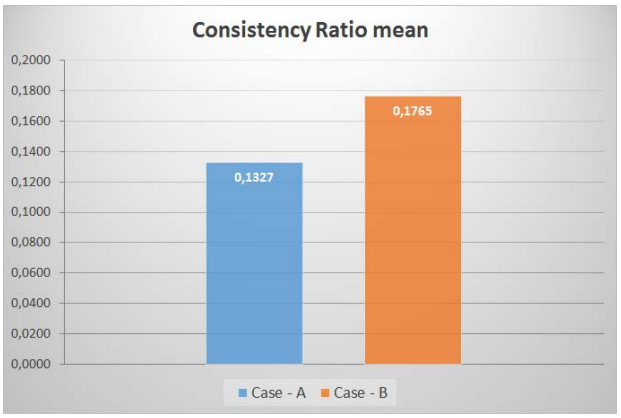

Figure 2. Average CR

Figure 2 shows an enormous difference between the average consistency ratio of the decisions in the two cases. Average CR level in case *"B"*, which denotes the case when the optimal circumstances were not ensured, is 33% larger than in case *"A"*.

- Which questions (subjective or objective) are more sensitive to the environment?

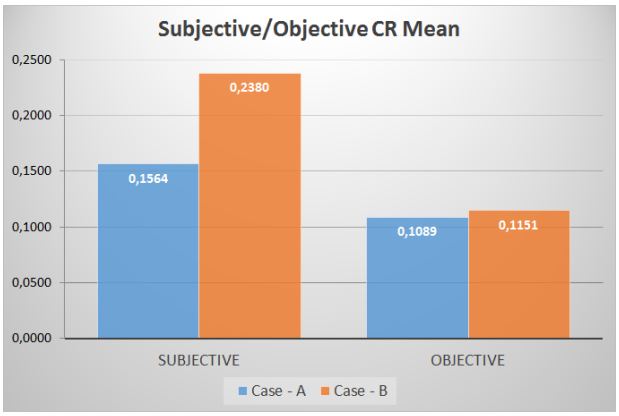

Figure 3. Average CR separately in subjective and objective questions

Personality psychology has already recognized that the situations have an effect on behavior. In [6] authors showed that in an objective situation people can be more consistent. This tendency can be observed in our results as well. The next figure shows the average CR level separately for objective and subjective comparisons. It can be seen that the difference between the average CR values is more significant in case of subjective comparisons than in case of objective questions. Participants' average CR in subjective comparisons was 52% larger in low-quality conditions than in case *"A"*.

- How large is the diversity considering the participants' consistency in the two cases?

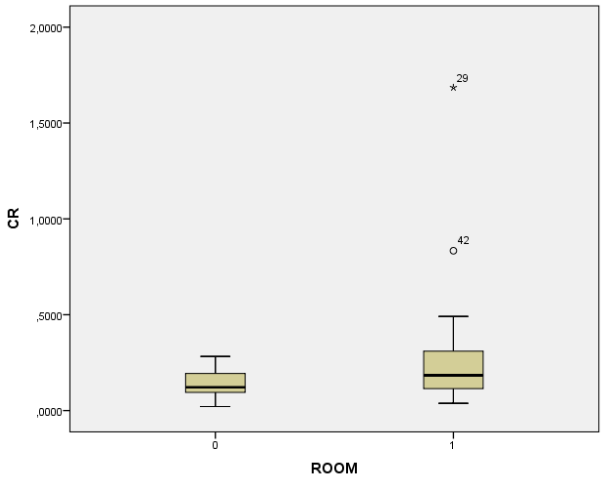

Figure 4. Boxplot on CR values in case of Question 4

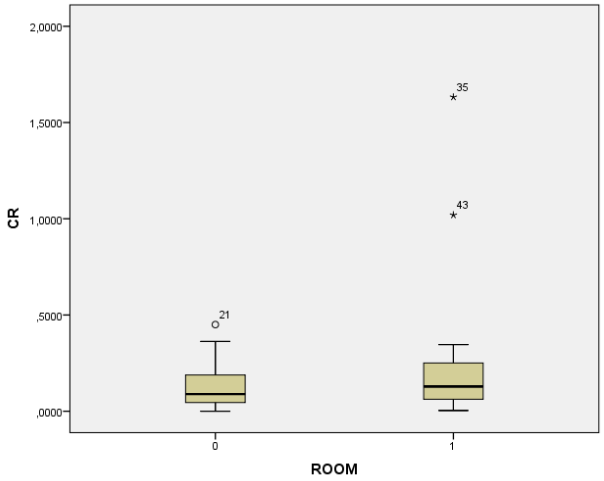

Figure 5. Boxplot on CR values in case of Question 5

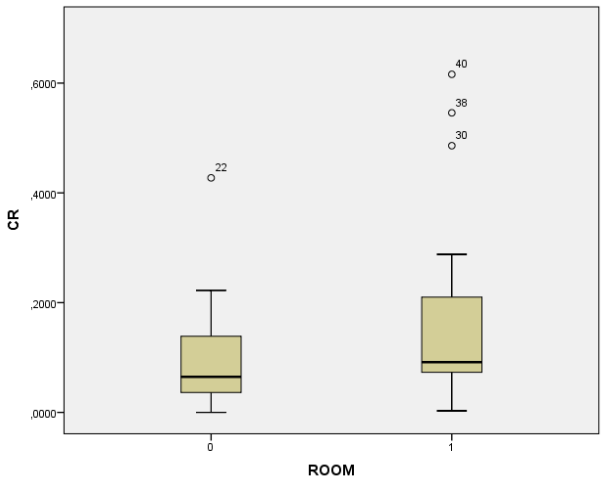

Figure 6. Boxplot on CR values in case of Question 6

Figure 4, Figure 5 and Figure 6 show the boxplot diagrams of question Q4, Q5 and Q6. These subjective questions represent the best how large the diversity of the participants CR level is in case *"B"* compering to case *"A"*. It is interesting that in an aesthetic environment the CR values of the answers were quite similar while in case *"B"* we obtained quite different results i.e. there were more extremely large CR values. This allows us to draw the conclusion that there were more participants who lost their concentration in case *"B"* than in case *"A"*. Lack of attention may cause false completion of a survey that results enormous regret in the success of the project.

5. Conclusion

In this paper we provided an analytical proof that aesthetic experiences can support the intuitive layer of human mind; thus, aesthetic experience can improve the consistent thinking and concentration as well.

Our surroundings provide a multi-sensory experience through the senses. It should always be given a high priority that these stimuli affect human performance and can heighten the work experiences. It has got to be considered that a professionally designed combination of visible and invisible aesthetics can lift our spirit and enable us to do more efficient and concentrated work.

Our experiment and analytical investigation using Saaty's consistency ratio as a measure provide a analytical evidence of that the external conditions play a determining role in the way we work and concentrate. Results demonstrate how environmental design can improve our productivity.

We tried to highlight the positive impact of the orderliness and the aesthetic. Many researches (e.g. [5]) claimed that design contributes less than 10% of the total cost of the whole life of a building. In our research we revealed that design has an enormous influence on the quality of our decisions which - especially in large corporations - have significant financial impact on our business. We showed that employees can be made more consistent if they are inspired by the quality of the environmental conditions. Inconsistent decisions implicate a chance for carrying out the process again, which means the duplication of the used financial and human resources. By ensuring the optimal circumstances for people a positive shared value can occur in the employment sector which is nearly close to the profit-oriented investor interests.

Our way for mathematical analysis and measurable revealing of the impact of surrounding factors based on a psychological decision sequence and its special feature for describing the quality.

Because of the natural limits of the human decisions, it is crucial to apply manageable artificial tools that can inspire our mind.

A complete repertory of these conditions can lead to additional positive results in case of the productive and unproductive labour as well.

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