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Engineering Better Decisions: Exploring Influencing Factors - An Empirical Study

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Abstract

Good decision-making is crucial in product development, particularly during early phases where decisions significantly impact subsequent processes. Previously, the authors identified influencing factors for decisions in the context of product development, including nudges through an extensive literature review. This study focuses on analyzing the improvement in decision quality. Two empirical studies were conducted to investigate the targeted influence of decision-making behavior in product development using influencing factors from behavioral economics. 10 out of 12 identified influencing factors demonstrated potential positive effects in influencing decision-making behavior and fulfilling identified framework conditions, such as unconstrained, transparent, and ethically justifiable use.

Keywords: Product Development; Behavioral Economics; Decision-Making; Decision Quality; Nudging

1. Introduction (Context & Motivation)

In the early stages of product development, many decisions are made under high uncertainty, making it hard to assess their outcomes. The multitude of influencing factors for decision-making (e.g., emotions, bias, and noise) makes it challenging to make good decisions, and creating an optimal decision-making framework is not always feasible. Nonetheless, making good decisions at this stage is vital to optimize resources, improve the efficiency of the product development process, and positively impact later phases. [1,2]

Several studies in behavioral economics have demonstrated that a more nuanced understanding of decision-making processes can facilitate the formulation of good decisions [3,4,5]. This raises the question of whether and how the findings from behavioral economics can be applied to influence decision-making in SGE – System Generation Engineering processes.

1.1. Decision in SGE – System Generation Engineering

The development of a new system generation requires several critical decisions, including the selection of subsystems for adoption (carryover variation), the identification of required adjustments (embodiment variation) to existing designs, and the determination of new solution principles (principle variation). [2]

This study is based on the SGE approach of Albers et al. [1], which realistically models practical product creation, with a focus on its early phase where impactful downstream decisions are made. Consequently, making good decisions at the early stages of a project, taking into account the available resources, including financial resources, time, and personnel skills and capacities, is essential to ensure an effective course of action [6,7].

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1.2. Behavioral Economics

Behavioral economics challenges traditional economic theories, such as homo economicus, which assume rational decision-making. It shows that decisions are often influenced by many influencing factors, such as emotions, biases, and noise [5,8,9,7]. The fundamental objective of behavioral economics is to identify the factors shaping human decision-making [10,8]. Decision-makers' intuitive and sometimes irrational behavior can be explained by patterns like heuristics, which can be predicted under certain conditions [10,5,8,7]. Additionally, decisions can be influenced by nudges and predicted through statistical tendencies [11]. This raises the question: can the decision-making architecture be designed to guide individuals toward better decisions with minimal interference and without restricting alternatives?

1.3. Previous research effort

In a previous research effort by Batora et al. [12], a comprehensive literature review was conducted to identify the characteristics of a good decision in behavioral economics and the SGE. Influencing factors from behavioral economics were examined to understand their impact on decision-making in SGE. These factors were structured into clusters and summarized in the IF_{BE} – Map, which was further expanded to the $IF_{BE,SGE}$ – Map. The $IF_{BE,SGE}$ – Map contains 53 influencing factors with potential application phases and application examples, which are divided into 5 clusters. [12]

These findings form the basis of this research work.

2. Research Gap & Target

This study explores the potential to enhance decision quality in SGE - System Generation Engineering by applying behavioral economics influences. Beyond factors like bias and noise, this study focuses on Sunstein and Thaler's nudging approach [13], which aims to systematically guide and influence decision-making without limiting choices, as described by Kenning et al. [14]. Nudging is widely applied in fields such as marketing, health, environmental protection, and finance [13,14,15] and has also been used in product development processes in form of feedback and defaults [14,15,16,17]. This suggests that implementing nudges and other potential influencing factors for decision-making could improve product development outcomes and align with corporate strategy.

This study examines the potential effectiveness of influencing factors from behavioral economics in the context of SGE, aiming to determine if their systematic use can enhance decision-making by positively influencing decision-makers.

2.1. Research questions

1. What characteristics define effective decisions in the product creation process, and what framework conditions and constraints influence them?
2. Where and how can influencing factors be leveraged to enhance decision quality in the product creation process by nudging, and what framework conditions and potential constraints must be considered?
3. How can the effectiveness of the identified influencing factors and nudges be validated?

2.2. Research design

This research is based on the "Design Research Methodology" (DRM) framework by Blessing and Chakrabarti [18] to address the research questions systematically. The initial phase, which clarified the research object, along with the second phase, the descriptive study I, and the third phase, the prescriptive study, were part of the previous study [12].

Building on the initial approaches to defining characteristics of good decisions, key influencing factors with strong potential to impact decision-making were identified through a literature review and summarized in the $IF_{BE,SGE}$ – Map [12]. As a result, 53 relevant influencing factors were identified that impact the decision architecture in the product development process. The determination, evaluation, and validation of the effectiveness of the influencing factors was conducted in the final phase of the DRM framework and was carried out in two comprehensive empirical studies in the form of online surveys. The results are discussed in this research effort.

3. Basis for Analyzing and Enhancing Decision Quality

In order to establish a basis for comparison, the study first summarized those characteristics that have been identified by existing research as being conducive to good decision-making. In the process of conducting a comprehensive literature review and analyzing existing empirical findings, the factors from behavioral economics that influence decision-making behaviors were also identified and summarized in the IF_{BE} – Map [12]. By identifying relevant application phases and conceptual use case approaches in the SGE, it was possible to expand the IF_{BE} - Map with direct reference to the SGE into the synergetic $IF_{BE,SGE}$ – Map [12].

3.1. Characteristics defining effective decisions in the product creation process and framework conditions

Yates et al. [19] define a decision as favorable if it meets at least one of the following criteria: The aim criterion, the need criterion, the aggregated outcomes criterion, the rival options criterion, and the process cost criterion.

According to this framework, a decision-making process is considered good if it not only aims to meet the criteria of a good decision but also clearly defines the goal, considers preferences and requirements, incorporates relevant information, considers different perspectives, and thoroughly analyzes all options and alternatives [21]. Decisions should be consistent and coherent, and account for factors such as uncertainties, risks, opportunities, and long-term consequences [5,20,21]. Furthermore, it is essential to continuously reflect on decision-making behavior and associated emotions to establish a strong foundation for good decisions [22].

In the SGE, decisions related to the advanced system triple approach must align with the requirements and product specifications of the target system, while optimally utilizing the available knowledge, technical capabilities, and resources within the action system [23]. The emphasis is thus placed on economic factors including product specifications, resource management,

effectiveness, efficiency, and stakeholder needs [24]. Compliance with regulatory requirements, such as political, social, and legal regulations and standards, represent exemplary framework conditions and the associated constraints for decision-making in the context of SGE [25,26,27].

3.2. Leveraging nudges and influencing factors to enhance decision-making in SGE

In a previous research effort, 53 factors from the field of behavioral economics were identified that can significantly influence decision-making in SGE [12]. Given the demonstrated effectiveness of the nudging approach in various contexts of behavioral economics [14,16], integrating these factors into SGE decision-making processes, using examples from the $IF_{BE,SGE}$ - Map, is expected to offer substantial benefits. The identified influencing factors are likely to be effective due to the logical causal relationship between decision-making influences in behavioral economics and similar effects in system development, with human decision-makers in both contexts showing comparable relevance and impact.

In addition to the application suggestions for using nudges and influencing factors of the $IF_{BE,SGE}$ - Map, it outlines potential application phases for SGE. Assigning these factors to specific phases proved challenging, as their effectiveness requires empirical testing and evaluation. Therefore, a directional categorization was carried out, assigning influencing factors to phase sections such as “Early phases of a development process (with example phase)”, “Entire development process (rather early phases of the development process)” and “Entire development process”, based on where the greatest impact is anticipated. This categorization is indicative, as these factors may also be effective in other process stages than those selected in the $IF_{BE,SGE}$ – Map [12]. The relevance and significance of the application phases were validated through expert interviews and guiding questions. The efficacy of the proposed applications was assessed and evaluated in the two empirical studies.

The characteristics that favor a good decision can be seen as a 'measured value' for decision quality. The influencing factors, meanwhile, act as tools for shaping the decision architecture to promote desired decision behavior in product development, as observed in behavioral economics [12]. However, when applying these tools, it is crucial to consider framework conditions and constraints such as transparency, voluntariness, emotional intelligence, and ethics, which significantly impact decision architecture design [12,28,29,30]. Additionally, understanding decision-makers' personalities and backgrounds can enhance the effectiveness of the design of the decision architecture using the influencing factors, offering the potential for more successful influence [31,32].

4. Aim and Design of the Empirical Studies

To examine the impact of influencing factors, such as Thaler and Sunstein's nudges [13], on decision-making patterns in both behavioral economics and product development, two empirical online surveys were conducted as studies. The first study assesses the effectiveness of the influencing factors from behavioral economics on the predicted decision-making behavior using case studies and questions on behavioral scenarios. The second study refines the survey to align with the product development context, analyzing the targeted use of influencing factors in decision architecture and their impact on decision quality in development processes.

Both empirical studies were conducted through quantitative online surveys. The schematic structure of both surveys includes a welcome page, a final page with contact details for optional feedback, and three sections. The structure of both studies is identical, with the second study featuring more detailed content related to the product-specific context of product development. The surveys are structured to randomly assign probands into two groups. One group is exposed to the selected influencing factors, while the other serves as a control group, receiving no treatment or opposite effects. This design ensures the validity and reliability of the study results.

In the initial section, case studies are presented in which probands are asked to adopt the perspective of individuals in the scenarios and engage in decision-making. For example, when analyzing the simplification factor, probands were asked to choose their preferred format for presenting a list of requirements. Figure 1 illustrates this decision-making scenario, with Figure 1A showing no nudging, and Figure 1B demonstrating the use of the nudge ‘simplification’.

A) Without the Use of Simplification

Supplier	Prototype 1	Requirements	…
1	Siemens	completely	…
2	Philips	partially	…
3	Samsung	mostly	…
4	HTC	barely	…
5	Apple	unsatisfying	…

B) Use of Simplification

Supplier	Prototype 1	Requirements	…
1	Siemens	★★★★★	…
2	Philips	★★★☆☆	…
3	Samsung	★★★★☆	…
4	HTC	★★☆☆☆	…
5	Apple	★☆☆☆☆	…

Figure 1: Exemplary illustration without the nudge ‘simplification’ (1A) and a possible view with the targeted use of simplification (1B).

The "nudging approach" has been successfully integrated and proven effective in a range of areas within behavioral economics [13]. Therefore, it is expected that integrating these elements into the decision-making processes of SGE could also yield significant success. This hypothesis will be investigated in the second study, which adapts the survey to the product-specific context of product development.

The second part of the study, presented as a questionnaire using a four-level scale, explores additional influencing factors that are difficult to capture through online case studies. These responses aim to provide insights into probands' personality traits and identify potential biases. The questions are designed to reveal insights into decision-making patterns and the influencing factors at play. The response scale includes "disagree," "rather disagree," "rather agree," "agree," and "I cannot categorize". The latter option helps prevent evaluative responses, minimizing potential distortion. The 4-level scale, excluding the "I cannot categorize" option from the rating, enables trend visualization and captures the intensity of responses.

In the final phase of the study, demographic data including age, education level, employment sector, and responsibility (in terms of personnel management) were collected. This information allows to conclude specific groups of people. Furthermore, the data can be employed for additional findings and analysis of relevant correlations.

The probands were recruited through a professional social network for business connections and personal acquisition, ensuring a diverse sample representing various industries, professions, company types, and areas of responsibility. This is intended to guarantee a diverse sample that provides insight into different industries, professional fields, company types, and areas of responsibility.

5. Design of the Empirical Study I & II and Findings

The objective of the studies was twofold: first, to determine the general effectiveness of the identified influencing factors; second, to examine their impact during the early stages of product development. Based on the study results, the influencing factors and specific application examples were categorized according to their effectiveness. The values were determined using the arithmetic mean of the probands' responses. The following ranking for the influencing factors was applied: The Effectiveness of influencing factors (IF_{Eff}) > |1| indicates sufficient effectiveness to classify the influencing factors as significant, IF_{Eff} > |0.5| shows a tendency toward effectiveness, and IF_{Eff} < |0.5| indicates non-significance or inconclusive results. Section 5.3 briefly addresses the assessment of decision quality.

The effectiveness of influencing factors is assessed based on the respective case structure and application options analyzed. Different case study designs or alternative application proposals for influencing factors and can result in disparate outcomes in terms of effectiveness. This is demonstrated by the excerpt in Appendix A.1, which is based on the influencing factor Precommitment Strategy. For the empirical studies I & II, an influencing factor is deemed effective if at least one application proposal demonstrates the desired impact, qualifying it as an actual influencing factor for designing the decision architecture.

The analysis of the correlations and their effect is discussed in Section 6, Conclusion. The multiple assignment of '✓' (see Tables 1 and 2) can be justified in accordance with the above explanation of the different application possibilities of the respective influencing factors analyzed. Both studies will consider an influencing factor to be the actual influencing factor for the targeted design of the decision architecture if one of the application proposals demonstrates the desired effectiveness. The multiple assignments of ✓ can be justified according to the above explanation of the different application possibilities of the respective analyzed influencing factors.

Beyond evaluating the effectiveness of the influencing factors, the study also analyzed statistically significant correlations between probands' decisions and the associated influencing factors. Figure 2 (see Appendix A.1.) illustrates an example of the results and correlation effects of this study.

5.1. Empirical Study I

The primary goal of the initial empirical investigation was to evaluate the overall effectiveness of the influencing factors from behavioral economics (IF_{BE} - Map) on the predicted decision-making behavior. 70 probands participated in the initial online survey, with 43 aged 30-39 years). 67% of the probands had obtained at least a bachelor's degree or an advanced academic degree, representing 21 different sectors, with the majority hailing from small and medium-sized enterprises (SMEs) and large companies/groups. The service sector (17%), mechanical engineering (10%), and IT (8%) were predominantly represented. 39% of the probands work in technical sectors, including automotive, mechanical engineering, IT or medical technology.

In the first study, 21 distinct influencing factors of the IF_{BE} - Map were evaluated, as shown in Table 1. 9 factors exhibited (slight) effectiveness > |1| (e.g., anchor effect, simplification, feedback), 9 factors demonstrated (slight) tendency > |0.5| (e.g., competence, information, stress), and 3 factors exhibited no significant effectiveness < |0.5| (e.g., relation and knowledge).

Table 1: Summarized visualization of the influencing factors examined in the initial study and the resulting effectiveness.

Influencing Factors – First Empirical Study																					
	1.1 Anchoring Effect	1.2 Image Priming	1.3 Relation (Contrast Effect)	1.4 Herding Behavior (Social Norms)	1.5 Simplification	1.6 Default	1.7 Easy and Convenience	1.8 Feedback	1.9 Reminder	1.10 Experience	1.11 Competence	1.12 Knowledge	1.13 Information	1.14 Risk aversion	1.15 Stress	1.16 Emotions	1.17 Intuition	1.18 Leadership	1.19 Authority Bias	1.20 Endowment Effect	1.21 Personality
Effectiveness (IF_{Eff}) $x \geq \lvert 1 \rvert$	✓	✗	✗	✗	✓	✗	✓	✓	✓	✓	✗	✗	✗	✓	✗	✗	✗	✓	✓	✗	✗
$\lvert 0.5 \rvert \leq x < \lvert 1 \rvert$	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✗	✗	✓
$0 < x < \lvert 0.5 \rvert$	✗	✓	✓	✓	✓	✗	✗	✓	✓	✗	✗	✓	✓	✗	✗	✓	✓	✗	✗	✓	✓

5.2. Empirical Study II

The second study was designed to investigate whether the application of the identified influencing factors in the development of SGE has causal relationships similar to those observed in behavioral economics. For this purpose, the case studies and questionnaire were adapted to a product-specific context to illustrate decision-making processes in the early stage of SGE. Additionally, selected application suggestions from the $IF_{BE,SGE}$ - Map were integrated to evaluate the potential impact of these factors on decision-making behavior within product development processes.

In the second online survey, 42 participants were involved, with 48% aged between 30 and 39 years. Notably, 62% held at least a bachelor's or an advanced academic degree. The participants represented 20 different sectors, predominantly from SMEs and large companies/groups. The evaluation highlighted the service sector as the most represented (21%), followed by healthcare and medical technology (14%), mechanical engineering and automotive (12%), and construction and building (7%). The remaining participants were distributed across various other sectors. Notably, 38% were directly linked to technical fields, including automotive, mechanical engineering, IT, and medical technology.

The results of the second study, which evaluated 11 influencing factors from the $IF_{BE,SGE}$ – Map, are summarized in Table 2. The anchor effect is included for comparison because it could be analyzed as part of the SGE in the initial study. Among the 11 factors, 6 showed (slight) effectiveness > |1| (e.g., simplification, feedback and reminder), 3 demonstrated (slight tendency) > |0.5| (e.g., framing and herd behavior / social norms), and 2 exhibited no significant effectiveness < |0.5| (relation and priming).

Table 2: Summarized visualization of the influencing factors examined in the second study and the resulting effectiveness.

Influencing Factors - Second Empirical Study													
		Anchoring Effect	Framing	Risk aversion	Image Priming	Relation (Contrast Effect)	Herding Behavior (Social Norms)	Simplification	Easy and Convenience	Feedback	Expecting Errors	Reminder	Precommitment Strategy
		1.1	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11
Effectiveness (IF_{BE})	$x \geq \lvert1\rvert$	✓	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
	$\lvert0.5\rvert \leq x < \lvert1\rvert$	✗	✓	✓	✗	✗	✓	✗	✓	✗	✗	✗	✓
	$0 < x < \lvert0.5\rvert$	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✓	✓

5.3. The assessment of decision quality

Analyzing the characteristics of good decisions in SGE processes reveals a need to move beyond basic criteria and explore ways to enhance decision quality. To increase decision quality, it is essential first to establish a baseline for decision quality without applying nudges and influencing factors. After implementing nudges and influencing factors, the difference between the baseline and the observed outcomes can indicate if an improvement in decision quality occurred. Development simulators, field studies, or field experiments could be suitable for carrying out this type of measurement.

This paper primarily evaluates the quality of decisions based on findings from behavioral economics and the expected success of using targeted influencing factors and nudges within SGE. Given their demonstrated effectiveness, these factors and nudges are expected to positively influence decision-making behavior in product development and help decision-makers meet criteria for good decisions while adhering to relevant constraints. When criteria, framework conditions, and constraints are observed in the implementation of effective influencing factors and nudges, the theoretical foundation for achieving high-quality decisions is established.

Nevertheless, both studies provided findings that indicate a trend toward improved decision quality. The analysis of the data concerning the anchor effect revealed that this factor can be used to observe not only the influence on decision-making behavior but also a direct influence on spending behavior. Probands with lower budgets were found to spend less on the same product compared to those with higher budgets, indicating a direct improvement in decision quality (reduction in spending). However, the impact of other influencing factors on the desired increase in decision quality, which is not immediately apparent, requires further investigation in future studies.

6. Conclusion

This study examined 24 of the 53 identified influencing factors, with 12 specifically analyzed within the context of SGE. The evaluation revealed that for 10 of these 12 factors, the anticipated effects (anchor effect, simplification, feedback, or self-commitment strategy) or at least a slight tendency (framing, risk aversion, or social norms) were observed in alignment with the product-specific context of SGE.

In addition, the application suggestions for the identified influencing factors from the $IF_{BE,SGE}$ - Map were partially tested for effectiveness within the context of SGE. The evaluation revealed both positive and negative outcomes. For instance, supportive behavior demonstrated a positive effect, while negative feedback yielded adverse outcomes. This highlights that the targeted use of influencing factors can result in either positive or negative behavioral effects, depending on their implementation. Furthermore, the literature review supports the assertion that a deeper understanding of the decision-maker enhances the effectiveness of decision architecture design [32]. Additionally, some influencing factors, such as image priming or contrast effect (relation), were identified that did not have a significant effect on decision-making in the context of this study.

It should also be noted that the numerous significant correlations in the respective studies suggest that the decision-making processes are highly dependent on interactions with other influencing factors, which can lead to a strengthening or weakening of these effects. It must also be assumed that various unwanted effects such as noise, bias, or the halo effect (e.g., due to the order in which the case studies and questions were presented) may have influenced the probands' decision-making behavior, which could affect the accuracy of the results. As a result, the efficacy scores should be regarded as approximate and directional as an indicator of positive or negative impact.

However, the analysis of the results leads to the conclusion that the identified effective influencing factors (effectiveness > |1|) and the effective application approaches have the potential to systematically influence the decision-making behavior of decision-makers in SGE, potentially leading to a sustainable improvement in product development decisions.

7. Outlook

Further research could provide a deeper understanding of correlation effects and the true effectiveness of individual influencing factors. This could involve isolating these factors to eliminate overlaps, counter-effects, and reductions in effectiveness caused by interactions. Additionally, exploring the impact of varying levels of involvement in decision architecture design could yield valuable insights. For instance, analyzing the effectiveness of influencing factors when only a subset (e.g., the team lead), all members (entire team), or none (e.g., an external team member) participate in the design process would be informative. Furthermore, the concept of 'self-nudging' merits attention, as its effectiveness may diminish when the decision-maker is also the decision architect, compared to scenarios where the architect is a separate individual [12].

References

[1] Albers A, Hünemeyer S, Kubin A, Pfaff F, Schlegel M, Rapp S. Modelling Technical Systems in the Early Phase: Proposing a Formal Definition for the System Concept. Proceedings of the Design Society, 3; 2023. p. 2695-2704. https://doi.org/10.1017/pds.2023.270

[2] Albers A, Rapp S. Model of SGE: system generation engineering as basis for structured planning and management of development. In Design Methodology for Future System Driven, Agile and Flexible. Cham:

Springer International Publishing; 2021. p. 27-46, https://doi.org/10.1007/978-3-030-78368-6_2
[3] Kahneman, D, Tversky A. Prospect Theory: An Analysis of Decision Under Risk. In L. C. MacLean & W. T. Ziemba (Ed.), World Scientific Handbook in Financial Economics Series. Handbook of the Fundamentals of Financial Decision Making; 2013. (Bd. 4, p. 99–127). WORLD SCIENTIFIC. https://doi.org/10.1142/9789814417358_0006
[4] Gächter S. Vorwort des Gastherausgebers Experimentelle Ökonomie: Neue Wege, neue Erkenntnisse? Perspektiven der Wirtschaftspolitik, 10(Supplement); 2009. p. 1–13. https://doi.org/10.1111/1468-2516.0303
[5] Ariely D. Predictably irrational. HarperCollins. 2009.
[6] Albers A, Rapp S, Birk C, Bursac N. Die Frühe Phase der PGE-Produktgenerationsentwicklung. In: Stuttgarter Symposium für Produktentwicklung. 2017. ISSN: 2364-4885.
[7] Bursac N, Tanaiutchawoot N, Rapp S, Albers A, Breitschuh J, Eckert C. Decision heuristic in pge-product generation engineering. In: Proceedings of TMCE. 2018. p. 7-11. ISBN: 978-94-6186-910-4.
[8] Kahneman D. Thinking, fast and slow. Allen Lane. 2011. ISBN: 978-1-84614-055-6
[9] Kahneman D, Sibony O, Sunstein CR. Noise: a flaw in human judgment. UK: Hachette UK. 2021. ISBN: 978-0-316-45140-6
[10] Hochman G, Ariely D. Behavioral economics. Emerging Trends in the Social and Behavioral Sciences: An Interdisciplinary, Searchable, and Linkable Resource. 2015. p. 1–14. ISBN 978-1-118-90077-2.
[11] Hummel D, Maedche A. How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. In: Journal of Behavioral and Experimental Economics, 80, 2019. p. 47–58. https://doi.org/10.1016/j.socec.2019.03.005.
[12] Batora M, Ognevoj R, Schock M, Ritzer K, Bursac N. Engineering Better Decisions: Exploring Influencing Factors of Behavioral Economics on SGE-System Generation Engineering. DS 130: Proceedings of NordDesign 2024, Reykjavik, Iceland, 12th-14th August 2024. 2024. p. 888-897. DOI: 10.35199/NORDDESIGN2024.94.
[13] Thaler RH, Sunstein CR. Nudge: Improving decisions about health, wealth and happiness. Yale University Press. 2008. ISBN: 978-0-300-12223-7.
[14] Kenning P, Reisch LA, Wertenbroch K. Nudge: Psychologie zum Wohl des Verbrauchers nutzen. In: Absatz Wirtschaft, 9. 2016. p. 44–49.
[15] Mirsch T, Jung R, Rieder A, Lehrer C. Mit Digital Nudging Nutzererlebnisse verbessern und den Unternehmenserfolg steigern. In: Controlling: Zeitschrift für erfolgsorientierte Unternehmenssteuerung 30(5). 2018. p. 12–18. DOI: 10.15358/0935-0381-2018-5-12.
[16] Tanaiutchawoot N, Bursac N, Rapp S, Albers A, Heimicke J. NUDGES: an assisted strategy for improving heuristic decision in PGE-Product Generation Engineering. Procedia CIRP, 84(84). 2019. p. 820–825. https://doi.org/10.1016/j.procir.2019.04.294
[17] Goldstein DG, Johnson EJ, Herrmann A, Heitmann M. Nudge your customers toward better choices. Harvard Business Review, 86(12). 2008. p. 99–105.
[18] Blessing LT, Chakrabarti A. DRM: A design reseach methodology. Springer London. 2009. (DOI 10.1007/978-1-84882-587-1; ISBN 978-1-84882-586-4).
[19] Yates JF, Veinott ES, Patalano AL. Hard decisions, bad decisions: On decision quality and decision aiding. Emerging perspectives on judgment and decision research. 2003. p. 13–63. ISBN: 0-521-80151-6.
[20] Huettel SA. Behavioral economics: When psychology and economics collide. The Teaching Company. 2014. ISBN: 978-1629970295.
[21] Kahneman D, Tversky A. Choices, values, and frames. American Psychologist, 39(4). 1984. p. 341–350. https://doi.org/10.1037/0003-066X.39.4.341.
[22] Lerner JS, Li Y, Valdesolo P, Kassam KS. Emotion and decision making. Annual review of psychology, 66, Artikel 66. 2015. p. 799–823. https://doi.org/10.1146/annurev-psych-010213-115043.
[23] Albers A, Walter B, Gladysz B, Reiß N, Dörr M, Hinkelmann M. Ansatz zur situations-und bedarfsgerechten Methodenauswahl in der Produktentstehung basierend auf dem Systemtripel aus Zielsystem, Handlungssystem und Objektsystem (12. Gemeinsames Kolloquium Konstruktionstechnik 2014). 2014.
[24] Krishnan V, Ulrich KT. Product Development Decisions: A Review of the Literature. Management science, 47(1). 2001. p. 1–21. https://doi.org/10.1287/mnsc.47.1.1.10668.
[25] Majava J. Product development: Drivers, stakeholders, and customer representation during early development. UNIVERSITY OF OULU, Finland. 2014. ISBN: 978-952-62-0505-2.
[26] Pohl K. Requirements engineering : fundamentals, principles, and techniques. Springer. 2010. https://doi.org/10.1007/978-3-642-12578-2.
[27] Ulrich KT, Eppinger SD. Product design and development. McGraw-hill. 2019. ISBN: 978-1-260-04365-5.
[28] Hess JD, Bacigalupo AC. Enhancing decisions and decision - making processes through the application of emotional intelligence skills. Management Decision, 49(5). 2011. p. 710 – 721. https://doi.org/10.1108/00251741111130805.
[29] Reichertz J. Paul Ekman: Gefühle lesen. In K. Senge, R. Schützeichel & V. Zink (Hrsg.), Schlüsselwerke der Emotionssoziologie. Springer Fachmedien Wiesbaden. 2022. p. 145-151. https://doi.org/10.1007/978-3-658-37869-1_16.
[30] Diederich J, Goeschl T, Waichman I. Self-nudging is more ethical, but less efficient than social nudging. Vorab-Onlinepublikation. 2023. https://doi.org/10.11588/heidok.00033230.
[31] Hofstede, G. (2011). Dimensionalizing Cultures: The Hofstede Model in Context. Online readings in psychology and culture(2), Artikel 1, 2307-0919. https://doi.org/10.9707/2307-0919.1014.
[32] Thaler, R. H. & Sunstein, C. R. (2021). Nudge: The final edition. Yale University Press. ISBN: 978-0-300-26228-5.

Appendix A.

Hypothesis (independence) tests were conducted using the chi-square test to identify significant correlations. The null hypothesis, "There is no correlation between statement A and statement B" was tested against the alternative hypothesis "There is a correlation between statement A and statement B". The significance level was set at 0.05. Correlations that did not reveal a discernible connection are considered for future studies and were not further explored in this research. An example of the identified correlations and a detailed analysis of the effectiveness and correlations from the second empirical study is presented in Figure 2.

Cluster - Nudging									
Designation	FT03_01	FT03_02	FT03_03	FT04_01	FT04_02	FT04_03	FT05_01	FT05_02	FT05_04
Influencing factor	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy	Precommitment Strategy
Description	Responsibility for a task	Reward	Awards (e.g. employee of the month)	Purpose of the task	Create a vision (identification with corporate goals)	Integration into a decision-making process	Clear and fixed schedule	External pressure	External pressure
Effectiveness	1,05	0,5	-0,6	1,64	1,4	1,48	1,02	0,29	-0,07
Correlation **(1) Proportional relationship** **(2) Inverse proportional relationship** **p-value < 0,05 = significant** **Cramér's V (effect size):** **0,1 = small** **0,3 = medium** **0,5 = large**	(1) FT04_02; p = 0,049, Cramér's V = 0,37 FT04_03; p = 0,009, Cramér's V = 0,45	(1) FT05_02; p = 0,007, Cramér's V = 0,42 FT04_03; p = 0,031, Cramér's V = 0,41 FT04_02; p = 0,004, Cramér's V = 0,44	---	---	(1) FT03_02; p = 0,004, Cramér's V = 0,44 FT04_03, p – <0,001, Cramér's V = 0,66 FT07_01 (Reminder "visual aids"); p = 0,002, Cramér's V = 0,45 …	(1) FT03_01; p = 0,009, Cramér's V = 0,45 FT03_02; p = 0,031, Cramér's V = 0,41 FT04_02; p = <0,001, Cramér's V = 0,66	(1) FT02_03 (Easy and Convenience "Support from superiors"); p = 0,031, Cramér's V = 0,38 …	(1) FT03_02; p – 0,007, Cramér's V = 0,42 FT05_04; p = <0,001, Cramér's V = 0,55	(1) FT05_02; p = <0,001, Cramér's V = 0,55

Figure 2: An exemplary overview of the various potential applications of the influencing factor 'precommitment strategy' as illustrated in the $IF_{BE,SGE}$ – Map.