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The balance between a usable and emotional product design - a comparison of different methods for prioritising relevant influencing factors

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Abstract

Designing an equally usable and emotionally appealing product remains a challenge for product developers, not least due to conflicting goals. Product developers need to constantly map the affective user requirements to the product, whereby the requirements for the emotional and usable product design often cannot be equally addressed. The systematic approach presented can help product developers in conflicting decision-making situations to represent these affective user requirements by selecting and prioritising context-relevant influencing factors using multi-criteria decision-making methods.

Keywords: user-centred design, emotional engineering, user experience, decision making

1. Introduction

In the context of user-product interaction, the human being is understood as the sum of various physiological and psychological constructs (Schröppel *et al.*, 2019). The expression of both constructs is highly individual when customers use a product, e.g., the perception of pleasure and displeasure. This can be summarized by the neuro-psychological state called 'affect', as proposed by Russell (2003). On the basis of this state, affective engineering deals with evoking positive affective reactions. Affective user demands are therefore requirements that result from the individual, subjective expectations of the user towards a product. Such subjective expectations can take different forms and usually originate from different sources. They include the satisfaction of needs (Rudolph, 2020), the desire for positive emotions when using a product (Desmet, 2012) and conformity with one's own personal preferences and attitudes (Govers and Mugge, 2004). The following section therefore discusses emotional and usable product design (section 1.11.1), which external factors have an influence on the two constructs (section 1.2) and shows how the most relevant factors are identified in the state of the art (section 1.3).

1.1. Emotionality and usability

According to Khalid (2006), traditional cognitive approaches to product usability tend to underestimate the influence of emotional factors and thus also affective user demands. Thereby, usability is defined as the utility value of a product on a physiological and cognitive level, i.e. regarding how efficiently, effectively and satisfactorily a product can be used in a specific context (DIN EN ISO 9241-11, 2018). However, studies suggest that satisfaction in the user experience is highest for products that are both usable and emotionally appealing. Mahlke (2008), for example, was able to confirm this in a study on the evaluation of audio players. Overall, reflecting users´ perceived importance of the relationship between usability and emotional product design is thus crucial for market success and a user-centred product experience. In today's world, besides product functionality, marketing strategies or trends in product design place a high value on user experience in order to bind customers to a product or brand. Good usability and an emotionally appealing product design are two central components of the user experience (Demirbilek and Sener, 2003). Emotional product design, encompasses an emotional user-product bond, e.g., through factors such as aesthetics, product fidelity or originality (Thüring and Mahlke, 2007). Kurosu and Kashimura (1995) showed in a study that the apparent user-friendliness is influenced more by aesthetic aspects than by the inherent user-friendliness. In most cases, usability and emotionality cannot be taken into account in equal measure, as the associated product requirements resulting from affective user demands are often accompanied by inherent conflicting goals (Buker *et al.*, 2022b). In a smartphone, for example, this is manifested by the fact a slim design for appealing aesthetics and a thicker housing for a better grip are juxtaposed. Thus, there are external factors that influence the weighting and balance between these different requirements.

1.2. External influencing factors on emotionality and usability

Although, this knowledge is necessary to reflect the perception of the users, especially when solving such conflicting goals in product design. Otherwise, insufficient consideration of user preferences can lead to product rejection (Shinohara and Wobbrock, 2011). To avoid this, it is necessary to find out which factors influence the relationship between emotional product design and usability and how this must be taken into account in the respective context of use.

Nevertheless, previous studies on product design have focused on customer needs in terms of functionality and usability. Traditional cognitive approaches to product usability tend to underestimate the influence of emotional factors (Khalid, 2006). However, the market success of a product is often determined by the aesthetic appeal, pleasure and satisfaction of the user. As user groups tend to be more diverse, it becomes increasingly difficult to identify a prototypical user (Khalid, 2006). According to Norman (2004) good design focuses on satisfaction of user needs, but the challenge to identify the unmet and unexpressed user needs exists. So far, user studies mostly focus on individual factors and their influence on the weighting of the usability and emotional product design. The connection between the two constructs emotionality and usability has been sufficiently investigated by several studies in the literature, i.e., Mahlke (2008), Quinn and Tran (2010), Tractinsky *et al.* (2000), or Trathen (2014).

In the state of the art, however, few factors and their effect on the perception of usability and emotional product design have been investigated. Sonderegger *et al.* (2012), for example, showed in a study on time dependence as an influencing factor that the positive effect of an aesthetically pleasing product on perceived usability diminished with increasing duration of exposure. Hassenzahl (2018) points out that the mode of use also acts as an influencing factor on the emotional reactions of users. Buker (2023) deals with the imbalance between the usability and emotional product design and its influencing factor 'stigma sensitivity' while focussing on protective, assistive or medical products. In these cases, emotional factors like aesthetic needs or individual preferences are rarely taken into account. By shifting the balance towards emotional product design, improvements regarding product acceptance, the user's identification with the product and product-specific stigma triggers can be achieved (Buker, 2023).

1.3. Prioritising influencing factors

Product development is characterized by several decisions that have to be made. When it comes to the decision for the balance between emotional and usable product design, the influencing factors addressed in the previous section can be seen as relevant criteria to determine the balance. Depending on the use case, different influencing factors as well as their relations amongst each other may be relevant. Therefore, methods from decision-making are needed for selecting and prioritising those factors regarding the emotionality and usability, which lastly co-determine the user experience. For example, the approach based on the directed graphs according to Gräßler *et al.* (2019) can be used. It is based on the PageRank algorithm by Brin and Page (1998). Using this algorithm, a directed graph of the cross-linking matrix is created. For each influencing factor, the page rank is calculated for the active and passive values, which transforms them into so-called active and passive ranks. Subsequently, these are

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placed in a system grid and prioritised with determined ordinal numbers. However, this method cannot be used to map the strength and direction of the impact of the influencing factors.
Here, multi-criteria decision-making (MCDM) methods can provide further assistance. One such method is the Analytical Hierarchy Process (AHP) developed by Saaty (1987). AHP consists of five steps. First, a hierarchy is required, which is established on the basis of the underlying decision problem and contains the goal of the decision and the respective criteria and alternatives. In the second step, the elements of the hierarchy are evaluated with pair comparisons with regard to the overall objective. After all elements of the decision model have been evaluated, they are weighted with regard to the common superordinate criteria. According to Saaty (1987), inconsistencies in the results occur. In order to nevertheless achieve a correct and constant calculation of the element weights, the eigenvalue problem of the pair comparison matrix is solved as a solution procedure. Afterwards, a consistency check of the decision model and the evaluated pair comparisons is carried out. Lastly, the relative local weights calculated are merged with the global weights of the higher level in the decision hierarchy.
Another MCDM technique is Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE). In PROMETHEE, the first step is to establish and define the preferences of the decision-maker. Consistent with AHP, the analysis and evaluation of criteria and alternatives is also based on pairwise comparisons. However, the elements are compared by means of preference functions. The elements take values in the interval [0,1]. Zero stands for indifference between the elements, while one expresses a strict preference. The greater the difference between two elements and their values with regard to a higher-level criterion, the stronger the preference of the decision-maker. Brans *et al.* (1986) provide six general preference functions that can be used depending on the specific decision problem. After a corresponding preference function has been determined for each element, the criteria to which the individual alternatives relate must be weighted. In the following step, the output and input flows of the alternatives are calculated. To create a preference graph, the outranking relations (OR) are now calculated. Finally, the OR are evaluated and thus the final evaluation of the set of alternatives.
Studies such as Taherdoost and Madanchian (2023) show that AHP in particular, but also PROMETHEE, are very widely used and therefore represent promising approaches for prioritising factors due to the systematic approach to prioritising.

2. Preliminaries

van Remmen *et al.* (2023) applies Gräßler's approach (Gräßler *et al.*, 2019) to the scenario technique to prioritise the influencing factors. The underlying methodology for supporting product developers in conflictual decision-making situations is depicted in Figure 1 and detailed in the subsections 2.1 to 2.3.

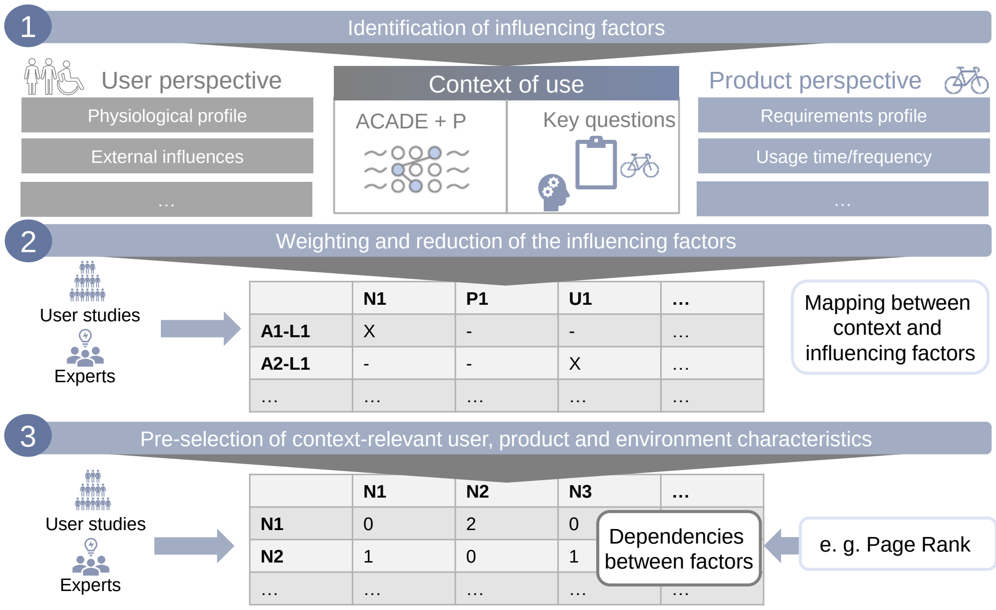

Figure 1. Methodical approach to prioritise influencing factors by van Remmen *et al.* (2023)

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2.1. Identification of influencing factors

First, all relevant external user, product and surrounding characteristics are identified that have an influence on the relationship between usability and emotional product design. These characteristics are derived, for example, from the user studies presented in the state of the research and can be expanded as desired. Subsequently, the context of use is defined by guiding questions (e.g., "Do the users have physical limitations?") as well as impression profiles (e.g., semantic differentials to determine physiology) and the influencing factors are assigned to these and thus reduced. The context of use is defined according to DIN EN ISO 9241-210 (2010) and VDI/VDID 2424 (2023).

2.2. Weighting and reduction of influencing factors

The product developers then check the other influencing factors for correlation with the respective semantic differentials defined on the basis of the profile of the target user for answering the key questions. The semantic differentials, especially for physiology and psychology, are oriented towards ACADE and ACADE+P (Zöller and Wartzack, 2017; Buker *et al.*, 2022a). Especially the semantic differential for the psychology of the end-user enables an initial assessment of whether the end-user is more design- or function-oriented and consequently which factors are perceived as potentially more important from the user's point of view. Influencing factors that are not relevant to any of the differentials and are therefore independent of the context of use are not considered further. The aim is only to prioritise context-relevant influencing factors, as otherwise the same factors will always be prioritised the highest. However, in conflictual decision-making situations, the factors that would otherwise not be considered by the product developers are the most relevant.

2.3. Pre-selection of influencing factors

The pre-selection and reduction of the influencing factors is done via the method of directed graphs according to Gräßler *et al.* (2019) respectively Brin and Page (1998). Without the prior context reduction, the same factors would always be prioritised as important, which is why the prior reduction via the context of use (cf. 2.2) is essential. The initial set of influencing factors is thus reduced via the context of use and now in the third step via the method of directed graphs. In the following, the strongest active and strongest passive factors are considered further, i.e., those that are most interconnected.

3. Objective and research question

In order to prevent form overlooking or wrongly prioritising relevant factors in the multitude of influencing factors and interactions between the two constructs mentioned, it is necessary to methodically support product developers in conflicting decision-making situations. Studies such as Buker (2023) show this on the basis of isolated influencing factors, such as stigma in their case, but come to the realisation that prioritisation and weighting have a positive influence on the development result (product). In particular, covering all stakeholder needs and reflecting the user's perceived importance of the relationship between usability and emotional product design is crucial for market success and a user-centred product experience. With the approach based on a directed graph, van Remmen *et al.* (2023) succeeds in prioritising the influencing factors and thus transfers a method of the scenario technique to the field of user-centred product development. In addition to the subjective evaluation of the interaction of the influencing factors in the networking matrix, the method used and the creation of a networking matrix only provides information about the influence on the ratio between usability and emotional product design. Using this methodology, it is not possible to consider the influencing factors with regard to the two criteria of usability and emotional product design independently and subsequently prioritise them. Accordingly, no statements can be made as to which factor influences which of the two criteria more strongly, less strongly or even in which direction. Therefore, another approach to decision-making is needed, which makes it possible to prioritise criteria (influencing factors) with regard to the goal of a balanced ratio between emotionality and usability. Furthermore, the methodology does not provide a consistency evaluation. In this respect, MCDM offers great potential, as decision makers are methodologically guided to set up consistent preferences of criteria. The aim of this paper is to apply the MCDM methods to the present use case of user-centred

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product development, namely AHP by Saaty (1987) in section 4.1 and PROMETHEE by Brans *et al.* (1986) in section 4.2. In addition, the results from the MCDM methods are compared with the ones acquired by the approach by van Remmen *et al.* (2023) and discussed in section 4.3. Consequently, the following research question (RQ) is answered:
How can the influencing factors regarding the two criteria usability and emotional product design be considered and prioritised independently from each other?

4. Methodology to prioritise and select influencing factors

In accordance with the presented problem, the large number of possible influencing factors represents a particular challenge for an approach to support product developers in determining the relevant factors. Such an approach should be expandable with new findings as research progresses in the context of empirical investigation of the influencing factors. Therefore, the gap between current prioritisation of the methodological approach described in section 2 and the unused potentials coming along with MCDM methods are closed by an analysis on whether AHP or PROMETHEE are applicable in this context. The methodology for the present contribution is summarized in Figure 2 and detailed below.

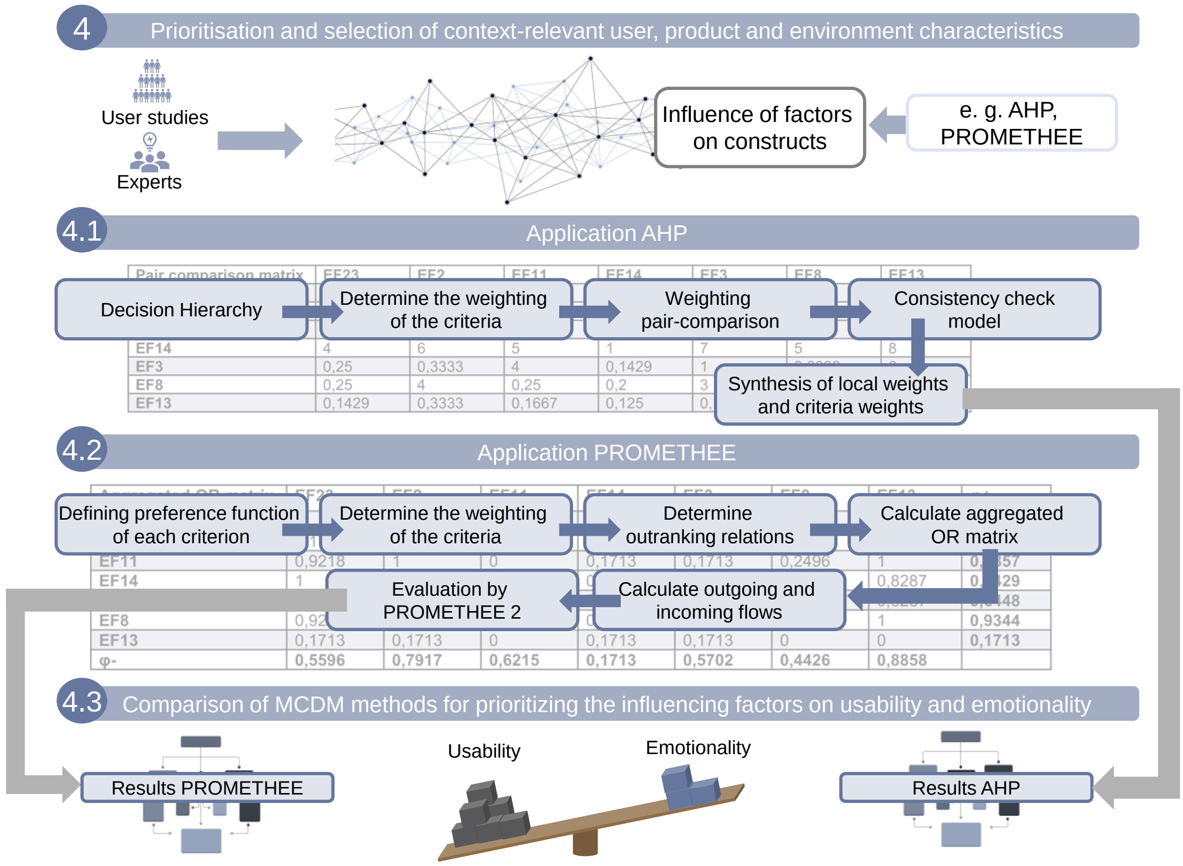

Figure 2. Methodological approach for selecting and prioritising context-relevant influencing factors with MCDM methods (EF: external influencing factor)

At first, analogous to the methodology described in section 2, the data source of possible influencing factors is reduced in a first step (1) to such an extent that they become manageable for subsequent steps. Again, the set of factors by Buker *et al.* (2022b) is used for this purpose. In a second step (2), the influencing factors are reduced in terms of their importance for the development context. In a third step (3), the pre-sorted factors are prioritised with methodological support and prepared for selection by product developers. The influence factors are then reduced by the method of directed graphs based on their activity in the networking matrix. The subsequent application of MCDM methods in step (4) requires a pair-wise evaluation of the influencing factors with respect to each criterion. With the existence of multiple criteria in the decision hierarchy, it is crucial to reduce the number of influencing

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factors according to Buker *et al.* (2022b). The reduced number of factors are then prioritised with the help of both MCDM methods in order to be able to make a statement about the strength and direction of the influence on the two constructs usability and emotional product design, in contrast to the methodological approach by van Remmen *et al.* (2023) (cf. section 2). The result of step (4) of the method is a ranking of context-relevant user, product and environmental characteristics and their effect on the two constructs usability and emotional product design.

In this work, the aim is to improve the user-product interaction, which is based on the criteria of usability and emotional product design. In order to evaluate influencing factors with regard to these, a product with a defined target group is chosen, in this case a game console is selected. It is assumed, that this product type serves the entertainment of the user and is designed for a rather younger target group. Applying AHP and PROMETHEE requires a pair-wise evaluation of the influencing factors in relation to each criterion. With the existence of three criteria in the decision hierarchy, it is necessary to reduce the influencing factors according to Buker *et al.* (2022b) . This is justified, among other things, by the consistency within the networking matrix, which is a measure of the rationality of the evaluations. The more pairwise comparisons are considered, the less meaningful the evaluation of the MCDM methods is due to the increasing inconsistency in the evaluation. With method proposed by Gräßler *et al.* (2019), the influencing factors were ranked according to section 2.3. As a result, seven factors emerge as active elements that have the greatest influence on the relationship between usability and emotionality. By choosing the game console as an exemplary product, a concrete use case was created for the evaluation of the criteria and elements. In order to make reliable evaluations, the seven active elements are examined with regard to the context of use and, if necessary, replaced by the most interconnected and context-relevant influencing factors. The final list of the influencing factors is summarised in Table 1.

Table 1. Final list of influencing factors considered

Abbreviation	Title	Characteristics
EF23	Limitation	User feature
EF2	Environment of use	Environmental feature
EF11	Consequences for physical well-being	Product feature
EF14	Complexity	Product feature
EF3	Duration of use	User feature
EF8	Financial resources	User feature
EF13	Stigma potential	Environmental feature

4.1. Results from AHP

The state of the art describes the process and the theoretical steps for carrying out the AHP in detail. The first step requires the creation of a tiered hierarchy that correctly and completely represents the decision problem. The overall goal and thus the top level of the hierarchy in this paper is the improvement of the user-product-interaction using the product example of the game console. The two parameters usability and emotional product design are defined in the decision hierarchy as criteria according to which the influencing factors are later evaluated. However, as the two criteria cannot be considered completely independently of each other, the third criterion summarises usability and emotional product design.

Once the decision problem has been structured hierarchically, all elements are evaluated against the higher-level element using pairwise comparisons and a weighting of the elements is determined accordingly. In a first step, the selected criteria are evaluated with regard to their influence on the overall objective of improving the user-product-interaction. As the games console is a product that serves exclusively to entertain the user, the emotionality of the product design, for example, is rated as slightly more important than usability. In order to determine the influence of the three criteria on the overall objective from the pair comparison matrix and thus determine the associated relative weighting, the priority vector of the matrix must be calculated. The consistency is also calculated. With a consistency

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ratio (CR) below 0.1, a consistent evaluation can be assumed. In the next step, the selected influencing factors are evaluated in pairs with regard to the three criteria. A consistency evaluation is also carried out here. With a CR of 0.2497 (usability), 0.1570 (emotionality) and 0.1086 (both), the consistency threshold is thus exceeded, but pair comparison matrices with higher consistency ratios can be categorised as rational and valid according to Westphal (2016). Analogous to the weighting of the criteria, the eigenvalue problems of the three pair comparison matrices are then solved and the priority vectors determined. These in turn reflect the relative weights of the influencing factors per criterion. The priority vectors of the alternatives are shown in Table 2.

Table 2. Priority vectors of the alternatives for all three criteria

Relative weighting of EF	Usability	Emotionality	Usability and emotionality
EF23	0,2356	0,0343	0,1249
EF2	0,0609	0,0581	0,0357
EF11	0,1059	0,3206	0,1170
EF14	0,3898	0,1980	0,4017
EF3	0,0883	0,0364	0,0795
EF8	0,1007	0,1713	0,2091
EF13	0,0187	0,1813	0,0322

The final step for a complete weighting of the influencing factors with regard to an improvement of the user-product-interaction is the synthesis between the weights of the criteria and the relative weights of the alternatives. Therefore, all weights of the influencing factors from Table 2 are multiplied by the weight of the corresponding criterion (usability: 0.0782; emotionality: 0.1713; both: 0.7504) and then added up line by line to obtain the results for each influencing factor. Based on this, a ranking (cf. Table 4) is created and interpreted in the context of the sample product.

4.2. Results from PROMETHEE II

Since comparability between AHP and PROMETHEE II should be ensured, the decision problem is structured in the same way as for AHP. The first task of the decision-maker is to define and specify the preferences with regard to each criterion in preference functions. Since the same influencing factors are compared using pairwise comparisons with regard to the criteria of usability, emotionality and the joint consideration of both parameters, the usual criterion is selected as the preference function. A distinction is made between strict preference (1) and indifference (0) within the pair comparisons, which is mapped on the interval [0,1]. The second step of PROMETHEE involves determining a subjective criteria weighting. The method does not specify a procedure for determining the weightings, but merely requires a standardised weighting vector. As the use case and therefore the influence strength of the criteria is the same as that of AHP, the weighting of the criteria is adopted in PROMETHEE. Once the criteria weighting has been determined, the influencing factors must be compared with regard to the criteria and the stronger influencing factor identified. This is done according to the previously defined preference function. The individual ORs result from the AHP according to the selected evaluations of the influencing factors. All values of the pair comparison matrix of the AHP greater than one are replaced with the value one, i.e. strict preference. All values less than or equal to one become the value 0, which corresponds to indifference. In PROMETHEE, an aggregated matrix is formed from the three OR matrices, taking the specified criteria weights into account. To do this, each OR matrix is multiplied by the corresponding weight of the associated criterion and the three matrices are then added together. In the next step, PROMETHEE uses the OR to create the basis for evaluating and determining the prioritisation. For this purpose, the input and output influences of the influencing factors are calculated. These indicate the extent to which an influencing factor dominates others or how strongly it is dominated by other influencing factors. These results are shown in Table 3.

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Table 3. Calculation of the input and output flows of the influencing factors

Aggregated OR matrix	EF23	EF2	EF11	EF14	EF3	EF8	EF13	φ+
EF23	0	0,8287	0,0782	0	0,8287	0,0782	0,8287	0,5285
EF2	0,1713	0	0	0	0,2496	0	0,8287	0,4165
EF11	0,9218	1	0	0,1713	0,1713	0,2496	1	0,5857
EF14	1	1	0,8287	0	1	1	0,8287	0,9429
EF3	0,1713	0,7504	0,8287	0	0	0	0,8287	0,6448
EF8	0,9218	1	0,7504	0	1	0	1	0,9344
EF13	0,1713	0,1713	0	0,1713	0,1713	0	0	0,1713
φ-	0,5596	0,7917	0,6215	0,1713	0,5702	0,4426	0,8858	

The evaluation by PROMETHEE 2 then presents a clear ranking of the influencing factors. To do this, the net flow of each influencing factor is determined from the difference between the input and output flow and then ranked in descending order (cf. Table 4).

4.3. Comparison of methods

By applying the AHP and PROMETHEE, two independent rankings were determined according to the strength of influence of the factors under consideration. In order to compare the results of these prioritisation approaches, the rankings according to both methods are shown in Table 4.

Table 4. Prioritised ranking of influencing factors according to AHP and PROMETHEE 2

Abbreviation	Title	Ranking AHP	Ranking PROMETHEE 2
EF14	Complexity	1	1
EF8	Financial resources	2	2
EF3	Duration of use	5	3
EF23	Limitation	4	4
EF11	Consequences for physical well-being	3	5
EF2	Environment of use	6	6
EF13	Stigma potential	7	7

The prioritisation results from both methods differ in ranks three and five for the influencing factors of duration of use and consequences for physical well-being. In the AHP, consequences for physical well-being are rated third highest when it comes to the influence on the user-product interaction of the game console, while the same influencing factor is only assigned fifth place by PROMETHEE II. This is due to the difference in the evaluation of the pair comparisons between the two methods. While the AHP differentiates between the intensity of preferences using the scale introduced by Saaty (1987), PROMETHEE in this paper only differentiates between preference and indifference. This means that high intensities of preference, i.e. a "much more important" preference, are equated with weak preferences in PROMETHEE. As already mentioned, preferences in the AHP can also be mapped in terms of their strength using the scale of 1-9 defined by Saaty (1987). This is not the case with PROMETHEE due to the choice of preference functions in this case. Robustness describes the ability of a method to retain its structure in the face of subsequent changes. With regard to this, it can be said that rank reversions are possible with both methods. Rank reversion refers to the change in the prioritisation ranking of criteria and alternatives if, for example, a new alternative is added. It is argued that this represents a distortion of rationality within a decision problem. However, rank reversions rather reflect the complexity of a decision problem. AHP also integrates the step of checking the consistency of each matrix created in order to ensure a certain degree of robustness and to recheck preferences assigned in the case of an exceptionally high CR. AHP is also easier to use than PROMETHEE in terms

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of the degree of complexity. With the aim of also supporting inexperienced product developers during the process in critical decision-making situations, the AHP therefore offers advantages.

5. Conclusion and outlook

All in all, an evaluation of the individual influencing factors according to several criteria offers advantages, especially for the joint consideration of emotionality and usability. Thus, at the end of the respective MCDM process, synthesised results for an overall objective are obtained. By evaluating the influencing factors separately according to the criteria, the characteristics of the influencing factors can be differentiated in terms of the usability or emotionality of the product. Compared to the method of directed graphs according to Gräßler *et al.* (2019) and its application by van Remmen *et al.* (2023), significantly more precise statements can be made about the influencing factors than with a mere evaluation according to both parameters in relation to each other. AHP and PROMETHEE can be used to determine the weightings for each criterion, allowing the analysis of the influencing factors and their separate effect on the constructs of emotionality and usability (cf. Table 2 and Table 3). This is particularly necessary for mapping the balance of the constructs perceived by the user in order to identify the influencing factors that have the greatest leverage effect on this balance, depending on the use case. Overall, the approach by van Remmen *et al.* (2023) can help in the first step in order to reduce the number of influencing factors to ensure consistency. All in all, however, the prioritisation of the factors must be more detailed to ident, so that the extension of the method by an MCDM method makes sense. On the one hand, this enables a more differentiated view of the influencing factors and, on the other hand, a more detailed statement about the direction and strengthening of the constructs of emotionality and usability. MCDM methods allow the effect of the influencing factors on the constructs to be analysed separately and independent of the product category, thus providing a suitable method in relation to the RQ. With regard to the MCDM methods, AHP can be identified as more suitable primarily due to its simple application and the possibility of checking consistency. In addition, compared to PROMETHEE, it enables finer scaled preferences in this case.
In addition to compensating for the subjectivity of the evaluation of pairwise comparisons by experts or user studies, another objective is to improve the selection of influencing factors, especially in real-life applications in companies or for specific products. Interpretive Structural Modelling (ISM) by Watson (1978), for example, which uses pair-evaluations in matrices to work out a hierarchy of influencing relationships between elements, would be suitable for this purpose.

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