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The meCUE Questionnaire. A Modular Tool for Measuring User Experience.

Michael Minge[1], Manfred Thüring[1], Ingmar Wagner[1], and Carina V. Kuhr[1]

[1] Technische Universität Berlin, Department of Cognitive Psychology and Ergonomics, Sekr. MAR 3-2, Marchstraße 23, 10587 Berlin, Germany
{Michael Minge, Manfred Thüring}@tu-berlin.de
Ingmar.Wagner@zoho.com, C.V.Kuhr@gmail.com.

Abstract. Nowadays, a satisfying user experience is the goal of any user-centered design activity and the key to success for any technical device. User experience (UX) is a holistic concept that emphasizes the importance of subjective appraisals, feelings and motivational tendencies before, during and after interacting with a technical product. It includes numerous aspects, such as usability, aesthetics, social communication of personal values, emotional stimulation and motivational support for using and reusing the product. Based on a comprehensive framework of UX, the Components model of User Experience (CUE) by Thüring and Mahlke [1], a new questionnaire for a standardized measurement of UX was developed, the meCUE questionnaire. This questionnaire consists of four separately validated modules which refer to instrumental and non-instrumental product perceptions, user emotions, consequences of usage, and an overall judgment of attractiveness. The construction of the questionnaire was based on two online data collections, in which $n = 238$ subjects participated respectively. Two laboratory experiments and a further online survey were conducted for determining the reliability and the validity of the questionnaire. Results support the assumption that both, the internal consistency of the constructed scales as well as their discriminative, criterion-related and construct validity are highly acceptable. Therefore, meCUE is a valuable and economic instrument for measuring key aspects of UX providing a promising alternative to existing questionnaires.

Keywords: User experience, usability, user emotions, aesthetics, intention of use, evaluation, questionnaire.

1 Introduction

These days, user experience (UX) is regarded as a key factor for the success of almost any product. Developers and designers who strive to create positive experiences while avoiding any negative impressions depend on a variety of data which represent the user's perspective on their product. For collecting such data, a number of questionnaires have been developed which capture different aspects of UX. For example, AttrakDiff [3] and the User Experience Questionnaire (UEQ) [4] measure product perceptions on diverse dimensions which address pragmatic and hedonic qualities. For

assessing the emotional component of experience, verbal (e.g. PANAS [5]) as well as non-verbal instruments (e.g. SAM [6], PrEmo [7], LEM-Tool [8]) are available.

All these questionnaires measure the UX components they focus upon in a valid and reliable way. However, no instrument so far assesses all these components together. Instead, questionnaires with different scales, formats and instructions must be employed in combination to achieve a comprehensive view on the UX of a product. Such a compilation of methods can be rather confusing for test persons and requires additional effort on behalf of the researcher who must select the most suitable tests and aggregate data from different scales.

To cope with this problem, a new questionnaire was developed that addresses all key components of UX in a unified way. Since it is based on an analytic framework, the Components model of User Experience (CUE) by Thüring and Mahlke [1], the questionnaire is called meCUE (modular evaluation of key Components of User Experience). The CUE model integrates a number of theories and approaches and distinguishes between the perception of instrumental and non-instrumental qualities (see Figure 1). Furthermore, it assumes that emotions mediate between both types of perceptions and influence the consequences of usage (e.g. overall judgment, acceptance, and intention to use).

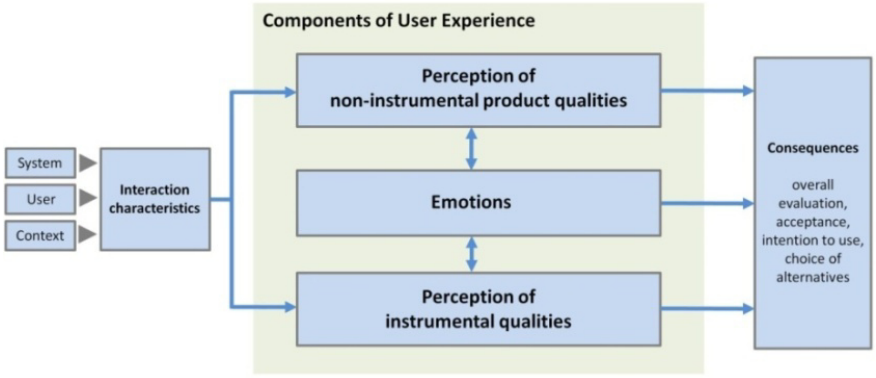

Fig. 1. Components of User Experience (CUE model) by Thüring and Mahlke [1].

The structure of meCUE corresponds to the components and subcomponents that are specified by the CUE model (see Figure 2). In order to provide a comprehensive and flexible alternative to existing questionnaires, three central modules were constructed and validated separately. Due to its modular configuration, the new questionnaire can be easily adapted to specific research goals by simply choosing those modules which are required. The modules of the intended structure are presented in Figure 2. Module one addresses product perceptions in terms of instrumental and non-instrumental qualities. According to Davis [11] instrumental qualities can be divided into perceived usefulness and perceived usability. For non-instrumental qualities, visual aesthetics, status and commitment serve as sub-constructs. Module two captures positive and negative emotions and module three assesses the consequences of usage with respect to intentions of future use.

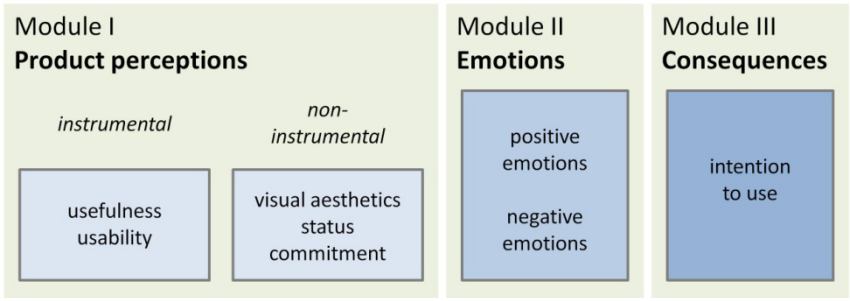

Fig. 2. Structure of meCUE derived from the CUE model.

2 Item selection

An initial pool of 67 items was generated for the modules in two brainstorming sessions, each lasting about two hours. For each dimension, six to eight items were created which were particularly characteristic for the corresponding aspect of user experience. The search for adequate items was supported by a comprehensive review of existing questionnaires measuring usability or user experience. All generated items had the format of statements and were combined with a seven-point Likert scale to capture the level of agreement. The following response labels were used: "strongly disagree", "disagree", "somewhat disagree", "neither agree nor disagree", "somewhat agree", "agree", "strongly agree" [11].

The item selection was based on two data collections which were conducted with an online version of the item pool. Participants were asked to evaluate an interactive product that they used daily. While the first survey was performed to select items of module one ('product perceptions'), the second one served to select items of module two ('emotions') and three ('consequences of usage'). Table 1 shows the characteristics of the two samples.

Table 1. Characteristics of two samples that were used in the design phase of the questionnaire.

	First sample	Second sample
Number of participants	n = 238	n = 238
(female/ male)	*(127/ 111)*	*(134/ 104)*
Mean age	28.6	28.5
(Age range)	*(19-61)*	*(17-65)*
Evaluated products (frequency)		
Mobile phone	100	106
Laptop/ computer	75	75
Digital camera/ Mobile audio player	16	23
Coffee machine	19	8
Washing machine	13	16
TV	12	0
Mobile application/ Software	3	10

The CUE model assumes that only instrumental and non-instrumental qualities represent independent dimensions, while appraisals, emotions and consequences may be correlated. For this reason three separate variance maximizing principle component analyses were carried out with the items of the three modules.

On the basis of the Minimum-Average-Partial-Test by Velicer [12] the analysis of items measuring 'product perceptions' revealed the expected number of five independent components. The initial item pool could explain 69.9 % of the total variance. According to the theoretical assumptions, these factors were named as: (1) usefulness, (2) usability, (3) visual aesthetics, (4) status and (5) commitment. Considering the item-specific parameters (selectivity, distribution of difficulty and communalities) three items with high factor loadings were selected for each of the five dimensions.

The variance maximizing factor analysis of the items measuring 'user emotions' revealed two independent main components for experiencing positive and negative emotions. These factors could explain 57.4 % of the total variance of the initial item pool. Both for the positive and for the negative dimension, six items with high factor loadings (> .4) were selected, respectively. One half of these items represent emotions that are associated with low arousal and one half those that are associated with high arousal. The third factor analysis showed that two dimensions were essential for subjective 'consequences of use', instead of one dimension as originally assumed (see Figure 2). Both factors explained 63.5 % of the total variance. Based on the pattern matrix, the labels 'product loyalty' and 'intention to use' were assigned to them ex post and module three was extended accordingly (see Figure 9). At the end of the item selection, the questionnaire consisted of 33 items measuring nine dimensions which were clustered in three modules. For determining the internal consistency and the validity of the questionnaire, two experiments and a further online survey were conducted which are summarized in the following sections.

3 Testing the internal consistency and examination of validity

The first experiment aimed at determining the internal consistency and the validity of the questionnaire. 67 participants (*Mean age*: 28.8 years) completed typical tasks with three different interactive products (mobile audio player, text-editing software and one's own mobile phone). Products were presented in counterbalanced order. After each interaction, subjects evaluated the product with six questionnaires: AttrakDiff [3], UEQ [4], PANAS [5], Self-Assessment-Manikin [6], visual aesthetics questionnaire [13] and the newly developed meCUE. The questionnaires were presented in random order. Each session lasted about 50 minutes. Participants were paid 10 Euro.

The experiment generated 201 data records which were analyzed by three principal component analyses. Results show that the assumed factorial structure of all modules could be reliably confirmed (see Table 2). The proportion of variance that is explained by the factors is even higher than in the design phase, indicating that suitable items had been selected from the pool. In the present study, we observed a higher range of variance in the ratings, due to the fact that participants also rated products that they did not use in daily life. Cronbach's alpha for each scale is listed in Table 2. All values indicate that the internal consistency of the scales is acceptable ($.8 > \alpha > .7$), good ($.9 > \alpha > .8$) or even excellent ($1 > \alpha > .9$).

Table 2. Proportions of explained variance and Cronbach's alpha for all scales.

Scale	Proportions of explained variance	Cronbach's alpha
Module I "Product perceptions"		
Usefulness	15.1	0.83
Usability	16.0	0.89
Visual aesthetics	18.1	0.89
Social Identity: Status	15.8	0.83
Social Identity: Commitment	16.1	0.86
Total	**81.1**	
Module II "User emotions"		
Positive emotions	39.5	0.94
Negative emotions	34.8	0.92
Total	**74.3**	
Module III: "Consequences of usage"		
Product loyalty	38.3	0.86
Intention to use	35.8	0.76
Total	**74.1**	

To assess the validity of the new questionnaire, correlations between the scales of meCUE and corresponding dimensions of the other questionnaires were calculated (n = 201). Since relationships were expected between ratings of pragmatic quality and objective usability criteria, correlations between scale values and the number of completed tasks while working with the text-editing software were determined (n = 67).

Table 3. Correlations between meCUE's product perceptions and other criteria; $^{**}p < .01$

		Scales of the meCUE questionnaire				
		Usefulness	Usability	Visual aesthetics	Status	Commitment
Correlations between meCUE and other questionnaires						
AttrakDiff	Pragmatic quality	.64**	**.87****	.57**	.46**	.53**
	Identification	.62**	.52**	.67**	.51**	.58**
	Stimulation	.40**	.37**	**.72****	.51**	.50**
	Attractiveness	.67**	.68**	**.77****	.55**	.64**
UEQ	Efficiency	.61**	.65**	.55**	.35**	.44**
	Perspicuity	.62**	**.85****	.48**	.37**	.44**
	Dependability	.69**	**.73****	.54**	.43**	.54**
	Stimulation	.62**	.61**	**.72****	.54**	.58**
	Novelty	.36**	.40**	.67**	.48**	.45**
	Attractiveness	.68**	**.70****	**.74****	.54**	.60**
Visual aesthetics	Classical aesthetics	.46**	.52**	**.70****	.42**	.43**
	Expressive aesthetics	.43**	.40**	**.75****	.56**	.51**
Correlations between meCUE and external criterion						
Number of completed tasks		**.32****	**.34****	.03	.04	.14

Strong correlations were expected between the two instrumental scales 'usefulness' as well as 'usability' and the respective dimensions of UEQ and AttrakDiff. Smaller correlations should be observed between the scales measuring instrumental qualities and non-instrumental dimensions, including visual aesthetics. The correlations are shown in Table 3. Due to the large sample (n = 201), even small values are significant. As expected, strong correlations (r > .7) were observed between 'usability' and 'pragmatic quality' (AttrakDiff) as well as 'perspicuity' and 'dependability' (UEQ). 'Classical' and 'expressive aesthetics' are correlated with the 'visual aesthetics' scale of meCUE ($r \geq .7$). The number of completed tasks with the text-editing software is significantly correlated with the two instrumental scales only (n = 67).

With respect to emotions, strong correlations were obtained between the dimensions for positive affect (resp. emotions) of PANAS and meCUE as well as between the dimensions for negative affect (resp. emotions). Moreover, the valence ratings captured by the Self-Assessment Manikin (SAM) highly correlated with the emotion scales of meCUE (see Table 4). Correlations between SAM's arousal scale and the meCUE scales are low (r = -.22 and r = .35). This result was expected since one half of the meCUE items represent emotions with high arousal and one half items with low arousal. Table 4 also shows relationships between consequences and emotions. For 'product loyalty' and 'intention to use' stronger correlations were found with positive affect measured by PANAS as well as with positive valence captured by SAM.

Table 4. Correlations between scales measuring emotions and consequences; *p >.05, **p <.01

		Scales of the meCUE questionnaire			
		Positive emotions	Negative emotions	Product loyalty	Intention to use
Correlations between meCUE and other questionnaires					
PANAS	Positive affect	**.51****	-.39**	**.53****	**.54****
	Negative affect	-.26*	**.63****	-.42**	-.39**
SAM	Arousal	-.22*	.35**	-.25*	-.25*
	Valence	**.66****	**-.65****	**.69****	**.67****
Correlations between meCUE and external criterion					
Number of completed tasks		.16	-.22	.28*	.21

In sum, strong correlations were found between meCUE and corresponding dimensions of other questionnaires. The empirical pattern indicates that the validity of meCUE is highly acceptable. Furthermore, all scales have good internal consistency.

4 Supplement to the questionnaire

According to the CUE model [1] an important aspect of consequences is the overall evaluation of a product. In order to assess the judgment of a product as a whole, other questionnaires like AttrakDiff and UEQ provide the subscale 'attractiveness'. In order to offer a similar opportunity, meCUE was supplemented by a further subscale. It consists of a single semantic differential with the bipolar pair "bad" / "good". Its rating scale ranges from "-5" to "5" with an increment of .5, respectively (see Figure 3).

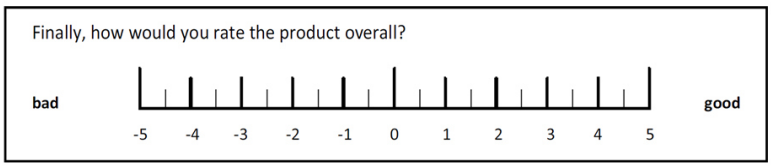

Fig. 3. Single-item for the overall judgment 'global attractiveness'.

Similarly to the procedure in chapter 2, another online study was conducted to validate the single-item 'global attractiveness'. Participants evaluated interactive products of their daily lives with AttrakDiff and meCUE. The presentation order of the questionnaires was counterbalanced. While the four modules of meCUE were assigned in a fixed order (I, II, III, IV), the respective items were assigned in a random order. 237 subjects participated in the study (*Mean age* = 29.8 years). Due to limitations of space, only the result for the overall rating is reported here (for the other findings see [14]). As expected, a strong correlation between the global judgment and the 'attractiveness' scale of AttrakDiff was found (r = .559, p > .01), supporting the assumption that the supplemented scale has an acceptable level of convergent validity.

5 Determination of discriminative and convergent validity

The aim of the second experiment was to assess the validity of the final version of the meCUE questionnaire. Instead of AttrakDiff [3] and the visual aesthetics questionnaire [13] as in the first experiment, Attrak Diff-mini [9] and VisAWI-S [10] were used as internal criteria. In particular, two research questions were addressed.

1. Can meCUE reliably discriminate between applications that differ with respect to instrumental and non-instrumental qualities (discriminative validity)?
2. Are the results obtained with meCUE in line with the results obtained with other UX questionnaires (convergent validity)?

To answer these questions, an experiment was carried out in which apps for public transportation in Berlin served as test material. In order to formulate hypotheses about differences between them, the apps were pretested in an expert review. Four German usability professionals (with at least three years of practical experience rated the usability and the visual design of six public transport applications that were chosen from the iOS appstore. Based on single-item ratings for both aspects, the results were used to detect maximum and minimum differences between the apps. Figure 4 displays the mean scores of the single-items for the three apps that were selected for the main study. Results show that the versions A and C differed greatly with regard to usability, but only little with regard to visual design. Minimal differences in usability were observed between versions A and B, highest differences in visual design between B and C. The corresponding rank order of the apps with respect to usability was A > B > C and with respect to visual design B > A > C. If the meCUE questionnaire measures product perceptions validly it should capture these differences and rank orders in tests with users of the applications.

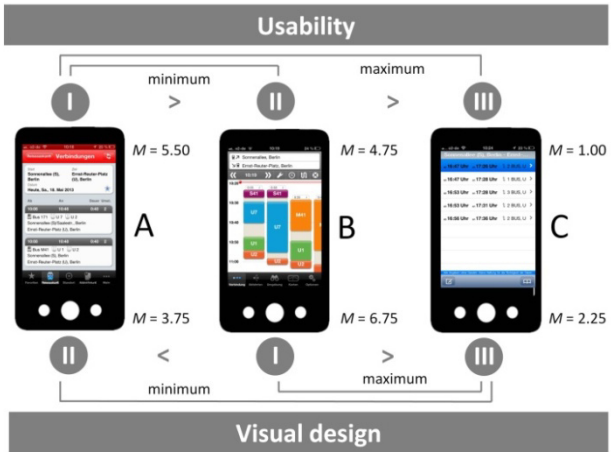

Fig. 4. Screenshots and results of the experts' ratings for the three public transport apps A, B, and C used in the main study. Latin numerals represent the ranks of the apps with respect to usability and visual design ratings, arabian numbers show the corresponding means.

Based on a one-factorial within-subject design, 24 participants (Mean age = 26.1 years) accomplished a user test that consisted of a series of tasks with all apps. The order of the apps was counterbalanced over all participants. After each app, users were asked to evaluate the interaction with five questionnaires: meCUE, AttrakDiff-mini [9], UEQ [4], PANAS [5] and VisAWI-S [10].

Discriminative validity

To answer the first research question, meCUE ratings of all instrumental and non-instrumental product qualities were analyzed by a oneway MANOVA with *Application* (Version A, B, or C) as within-subjects factor. The analysis revealed significant main effects of *Application* on all dependent variables. Subsequently, post-hoc pairwise comparisons were conducted. The *p*-values of all comparisons were Bonferroni adjusted. Mean scores and significant differences are displayed in Figure 5.

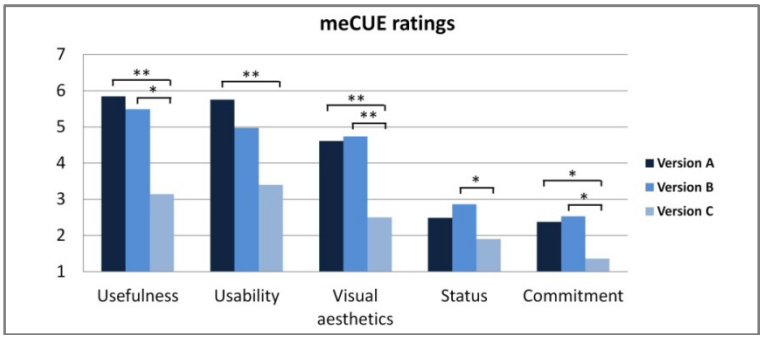

Fig. 5. Mean scores of the apps for meCUE's instrumental and non-instrumental product perceptions and significant differences between them. *$p < .05$; **$p < .01$

With respect to rank orders, the users' mean ratings show patterns that are highly compatible with those of the experts, i.e., A > B > C for the two instrumental dimension and B > A > C for visual aesthetics. As expected, not all differences between the respective means of the ranks were significant.

Usefulness and usability reached their highest value for version A and their lowest value for version C. Significant differences on these dimensions were obtained between version A and version C, but not between A and B. This pattern corresponds nicely to the experts' judgments where the usability difference was maximal between A and C and minimal between A and B.

The best visual aesthetics rating was obtained for version B and the worst one for version C. Both versions, A as well as B, were significantly different from version C. In comparison to the experts' judgments, a significant difference between B and C was to be expected, but the difference between A and C was larger than anticipated.

Ratings on the additional meCUE subscales status and commitment were comparatively low for all three apps. This is not surprising since an app for public transportation is unlikely to influence the perceived status of its owner very much, and the usage was too short and too artificial to establish a distinct bond between users and apps. Nevertheless, some significant differences between the three versions were found (see Figure 5).

Convergent validity

To answer the second research question, the values of the different questionnaires were standardized by a z-transformation. Thus the means for their subscales can be descriptively compared between versions A, B, and C (see Fig. 6). Additionally, correlations were calculated between corresponding subscales of the questionnaires.

As Figure 6 shows, version A scored highest on all subscales measuring instrumental qualities while version C showed lowest scores. MeCUE's usability ratings were highly correlated with 'pragmatic quality' of AttrakDiff (r = .900, p > .001) and the subscales of UEQ (r = .855, p > .001 for perspicuity, r = .781, p > .001 for dependability, and r = .903, p > .001 for efficiency).

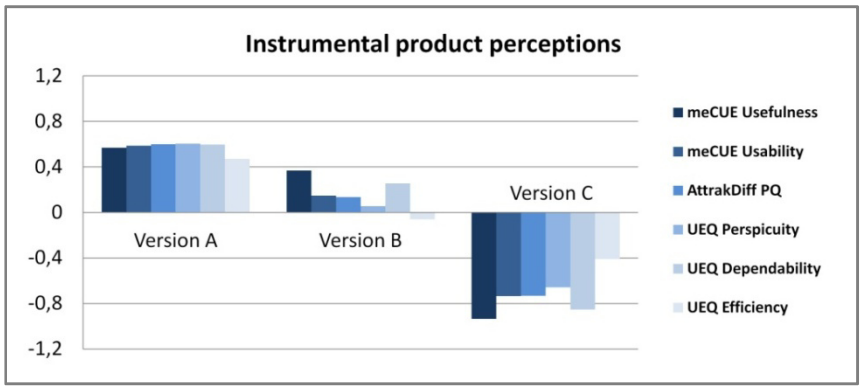

Fig. 6. Mean scores for instrumental product perceptions. All values are standardized by z-transformation.

For visual aesthetics, the meCUE ratings exhibit a pattern similar to that of the VisAWI-S (see Figure 7). The scores of both questionnaires are significantly correlated (r = .881, p > .001). Moreover, meCUE's ratings of global attractiveness correlate significantly with the dimension 'attractiveness' of AttrakDiff-mini (r = .919, p > .001) and UEQ (r = .887, p > .001). This result is in line with the relationship between the meCUE single-item and the subscale 'attractiveness' of AttrakDiff (see chapter 4).

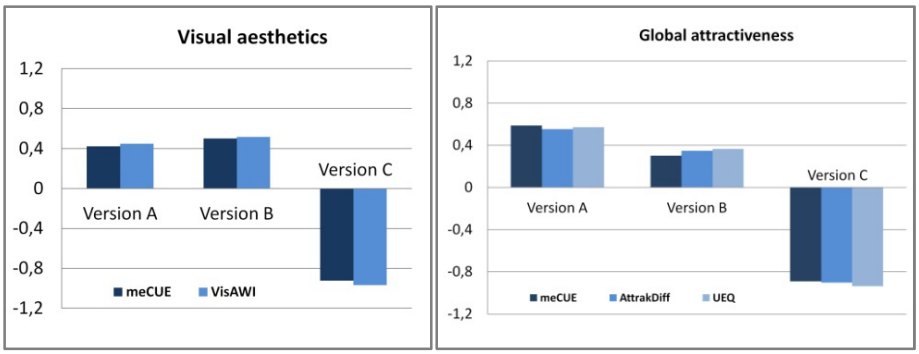

Fig. 7. Mean scores for visual aesthetics (left) and global attractiveness (right). All values are standardized by z-transformation.

Similar constellations of means and significant correlations were also found between meCUE and PANAS, both for positive emotions (r = .470, p > .001) and negative emotions (r = .717, p > .001) (see Figure 8).

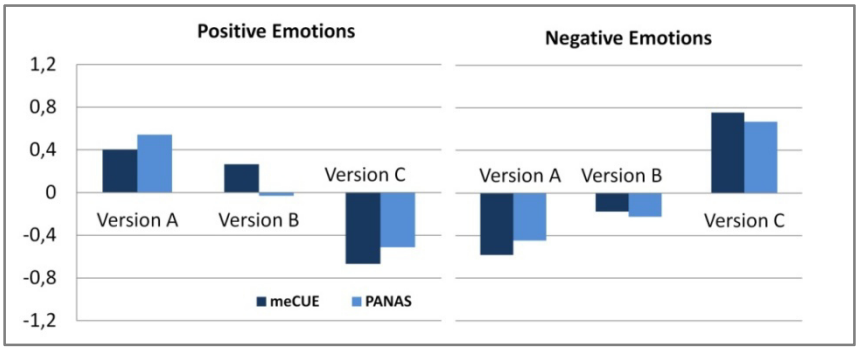

Fig. 8. Mean scores for positive (left) and negative emotions (right). Values are z-transformed.

In answer to the two research questions addressed by the experiment, the findings show that meCUE possesses both, a satisfying discriminative as well convergent validity. The questionnaire qualifies well for discriminating between different mobile apps. The results of the user test are consistent with the outcomes of the expert review conducted beforehand. Furthermore, descriptive comparisons of means and correlations indicate that the results obtained with meCUE are consistent with other validated questionnaires that measure UX or emotions.

6 Conclusion

The aim of our research was the development of a new questionnaire measuring key components of user experience in a comprehensive and unified way. Based on the CUE model, a theoretical structure of the questionnaire was deduced. This structure was validated in a series of consecutive online studies and laboratory experiments.
The final version of the questionnaire for the 'modular evaluation of key Components of User Experience' (meCUE) consists of four modules (including nine subdimensions and a single-item). The modules refer to 'product perceptions' (usefulness, usability, visual aesthetics, status, commitment), 'user emotions' (positive and negative emotions) and 'consequences of usage' (product loyalty, intention to use). The single item (module IV) enables the overall evaluation of the product (see Figure 9).

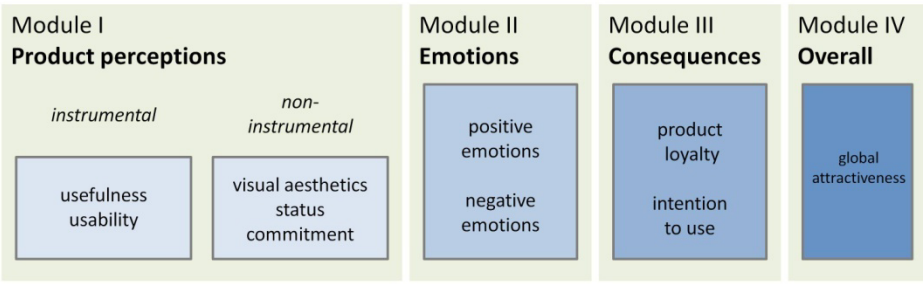

Fig. 9. Final structure of the meCUE questionnaire with four separately validated modules.

Since the modules and the single-item were separately validated, meCUE is a flexible, adaptable, lean and effective questionnaire for measuring user experience. In contrast to instruments which capture single aspects or a subset of them, meCUE addresses all central UX components together – including emotions – in a unified format using a Likert-scale. Since the questionnaire consists of only 34 items, it is also efficient to use, requiring only between two and five minutes on average to be filled in.

As demonstrated by the reported studies, meCUE can be applied in UX surveys on all kinds of interactive systems. So far, it has been successfully deployed to measure UX for consumer products, software, diverse mobile applications as well as medical products, such as lower limb ortheses [15]. meCUE is particularly suitable for comparing different products or design options and for detecting changes of experience in the course of long-term usage.

Originally, the meCUE questionnaire was developed in German, but recently an English version has been created. To ensure a proper wording, the items were repeatedly translated back and forth by three independently working native speakers. Subsequently the English version was validated in an online study with 58 participants [16]. As the German version, the English version has a good internal consistency and reliably assesses the key components of user experience.

MeCUE is freely available under the following links: www.mecue.de/english (for the English version) and www.mecue.de (for the German version). The website also provides an Excel file that supports data collection and analysis.

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