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To cite this article: Dimitrios Raptis, Anders Bruun, Jesper Kjeldskov & Mikael B. Skov (2016): Converging coolness and investigating its relation to user experience, Behaviour & Information Technology, DOI: [10.1080/0144929X.2016.1232753](https://doi.org/10.1080/0144929X.2016.1232753)

To link to this article: <http://dx.doi.org/10.1080/0144929X.2016.1232753>



Published online: 06 Oct 2016.



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Converging coolness and investigating its relation to user experience

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ABSTRACT

Recently a number of studies appeared that operationalised coolness and explored its relation to digital products. Literature suggests that perceived coolness is another factor of user experience, and this adds to an existing explosion of dimensions related to aesthetics, hedonic quality, pragmatic quality, attractiveness, etc. A critical challenge highlighted in prior research is to study the relationships among those factors and so far, no studies have empirically examined the relationship between coolness and other established user experience factors. In this paper, we address this challenge by presenting two studies one that focuses on factors from two cool questionnaires, and one that compares them against existing User eXperience (UX) factors. Our findings show that factors from the two cool questionnaires converge and they also converge to existing, established UX factors. Thus, 11 distinct cool and UX factors converge into 5 for the case of mobile devices. Our findings are important for researchers, as we demonstrate through a validated model that coolness is part of UX research, as well as for practitioners, by developing a questionnaire that can reliably measure both perceived inner and outer coolness as well as the overall coolness judgement based on 5 factors and 21 items.

ARTICLE HISTORY

Received 24 February 2016
Accepted 30 August 2016

KEYWORDS

Coolness; inner cool; outer cool; user experience; dimensionality explosion; questionnaires

1. Introduction

For more than a decade, User eXperience (UX) has been applied as a broad notion to describe experienced qualities of interactive products and UX research focuses on exploring the experiential, affective, meaningful, and valuable aspects of product use (Vermeeren et al. 2010). UX goes beyond the instrumental emphasis of usability (Bargas-Avila and Hornbæk 2011) and although the satisfaction part of usability is considered as a relevant dimension for UX (Law et al. 2009), UX qualities are not limited to that. In this paper we focus on factors that, according to the literature, contribute to coolness and we study, firstly, how they converge and shape the cool perception and, secondly, how they relate to other subjective, measurable UX factors, such as affect, enjoyment, fun, aesthetics, appeal, attractiveness, hedonic quality, engagement, flow, enchantment, and frustration (Bargas-Avila and Hornbæk 2011).

The challenge for UX research is that the sheer volume of factors has reached such a large number where it is critical to start discussing the extent these are converging. Bargas-Avila and Hornbæk (2011) apply the term 'dimensionality explosion' to denote this phenomenon within UX research. There is a need for the UX research community to study this explosion, for example, the relation between hedonic quality and attractiveness. Are we referring to the same or a similar factor with two

different names? In every context? For every product? Bargas-Avila and Hornbæk (2011) suggest that dimensionality explosion occurs, firstly, because many of these factors are not established as they have not been tested for their reliability and validity (*many researchers use self-made items without providing them*), and, secondly, because several proposed factors are not positioned in relation to the rest (*the main problem of this dimensionality explosion is that the relation to established constructs is rarely made clear*). For example, no one to our knowledge has compared hedonic quality and attractiveness and produced specific results on if (or how) they converge into one factor. Besides this research challenge, this situation also creates significant problems for practitioners too, as there is no agreement on which questionnaires to use, and under which conditions.

A recent example of an emerging new perceived UX factor is coolness. In the past five years, the human-computer interaction (HCI) community has increased its focus on determining coolness of digital products, and 'designing for cool' is becoming an essential criterion when developing new applications, interfaces, and devices (Sundar et al. 2014). The main driving force behind this research effort was the fact that the term coolness has often been used by people to positively describe their experiences with various products such as cars, home appliances, mobile phones, etc. (Raptis, Kjeldskov, and Skov 2013).

Until recently, relatively few studies investigated coolness within HCI. Holtzblatt (2011) discussed the concept of cool and emphasised that coolness contributes to our personal feelings of accomplishment, connection with others, identity, and delightful experiences. Read, Horton, and Fitton (2012) developed a framework on 'Being Cool', by 'Doing Cool Things' and by 'Having Cool Stuff'. The aim of that framework is to facilitate the design of cool products for teenagers based on factors such as being rebellious, antisocial, retro, authentic, rich, and innovative. Culén and Gasparini (2012) argued that product coolness is related to fun, mastery, adding value, useful, successful, self-presentation, and innovation. A more comprehensive overview on coolness can be found in Raptis, Kjeldskov, and Skov (2013).

In the above-mentioned studies, the identified coolness characteristics were derived on the basis of literature reviews, which have made considerable contributions in shaping our initial understanding of coolness. McCrickard, Barksdale, and Doswell (2012) moved a step further and explicated the need for a 'cool engineering' approach to support designing for coolness. The aim of such an approach would be to understand how target users perceive coolness of products in various contexts of use. In order to define a cool engineering approach, firstly, there is a need to produce reliable tools and techniques for measuring coolness. Towards this end, two similar studies recently focused on breaking down the concept of cool into smaller entities and produced questionnaires that reliably measure perceived coolness (Bruun et al. 2016; Sundar et al. 2014). Sundar et al. (2014) produced a questionnaire with 15 items that measures coolness through factors related to subculture, attractiveness, and originality. The COOL Questionnaire proposed by Bruun et al. (2016) consists of 16 items and it builds on a distinction between inner and outer coolness. Bruun et al. (2016) measured the perceived inner coolness of interactive products through factors related to usability, desirability, and rebelliousness and they also suggest that perceived outer coolness is related to attractiveness and aesthetics.

Consequently, at this moment there are two questionnaires that measure coolness through differently labelled factors. Since some of these factors are seemingly comparable (e.g. subculture and rebelliousness) and by taking into consideration the problem of the dimensionality explosion, there is a need both to examine the extent of convergence between proposed coolness factors, and to examine how coolness and existing UX factors converge. Thus, the aim of our paper is twofold:

(1) To make a systematic comparison of the underlying factors of the two recently proposed coolness questionnaires;

(2) To compare these coolness factors against established UX factors.

In this paper we report two studies, one for each aim. In the following, we provide an overview of existing questionnaires for measuring perceived coolness and other UX-related factors (Sections 2 and 3). In Section 4, we outline a set of hypotheses on how we expect the coolness factors to converge and how we expect them to converge with other UX factors. Section 5 describes the method, and then Sections 6 and 7 highlight our results. In Section 8, we discuss our findings against our research hypotheses as well as their implications for research and practice. Finally, in Section 9 we conclude our paper by highlighting the most important findings.

2. Established questionnaires for measuring coolness

In this section, we present in detail two recently published questionnaires for measuring perceived coolness and their underlying factors.

2.1. 'Capturing cool'

In 2014, the paper 'Capturing cool: Measures for assessing perceived coolness of technological products' was published by Sundar et al. The aim of that study was to produce a questionnaire for measuring coolness. Through the literature, Sundar et al. (2014) identified a set of four factors that characterised coolness. The first factor is based on the work by Kerner, Pressman, and Essex (2007) and Levy (2006) and relates to the uniqueness of a product over competing products. A second factor is related to product attractiveness, which has its roots within aesthetics. Its theoretical underpinning was based on the work of Levy (2006) and Tractinsky (1997). According to Sundar et al., attractiveness encompasses the externally visible aesthetic appeal, but is also related to the social acceptability of a given style, for example, whether or not a product makes the owner look good in relation to others. Their third factor deals with the subcultural aspects of products. Based on the work by Dar-Nimrod et al. (2012) and Horton et al. (2012), the authors suggest that subculture includes an element of rebelliousness, for example, that a product appeals to a minority (and not the mainstream consumer group) by being 'edgy'. According to Sundar et al. (2014), subculture also deals with the utility of a product for a particular group of persons. So, a product can be considered cool if it is useful for a specific group, while indicating one's affiliation to this particular group. Their

fourth and final factor relates to genuineness. Based on Conan (2008), Kerner, Pressman, and Essex (2007), and Levy (2006), this factor is about authenticity and the sincere nature of a product. Thus, a product, of which the underlying intentions of its designer are to really improve the lives of its users, is perceived as genuine.

Sundar et al. applied these 4 factors as an offset to create 35 evaluative statements of coolness, for example, 'The designers of this product primarily want to create better products' (related to genuineness). An exploratory study with 315 participants was conducted and key factors within the 35 question items were extracted. This was followed by an additional 2 studies based on 1150 respondents assessing the coolness of various products such as USB drives, Nintendo Wii, Prezi, Warcraft, etc. The statistical techniques of exploratory and confirmatory factor analyses (CFAs) were applied throughout the studies, and Figure 1 shows their final three-factor structure of perceived coolness, which can be measured through the factors of subculture, attractiveness, and originality and 15 items. Each item is represented on a nine-item Likert scale (1 = Strongly disagree, 9 = Strongly agree). Furthermore, they demonstrated that these three factors do contribute to the overall coolness judgement for a product by comparing them to a set of nine items that measured overall coolness (Table 1).

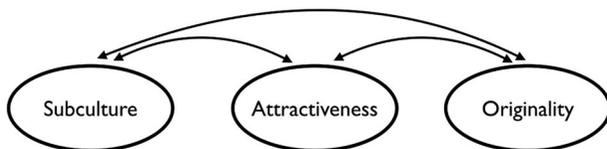


Figure 1. Three-factor structure of cool (Sundar, Tamul, and Wu 2014).

Table 1. Factors and items from the 'Capturing cool' questionnaire (Sundar, Tamul, and Wu 2014).

Subculture	Attractiveness	Originality
This device makes people who use it different from other people	This device is stylish	This device is original
If I used this device, it would make me stand apart from others	This device is hip	This device is unique
This device helps people who use it to stand apart from the crowd	This device is sexy	This product is novel
People who use this product are unique	This device is hot	This device is out of the ordinary
People who use this device would be considered leaders rather than followers	This device is on the cutting edge	This product stands apart from similar products

2.2. 'The COOL questionnaire'

Bruun et al. (2016) similarly focused on breaking down the concept of cool into smaller entities and used them as building blocks to produce the 'COOL Questionnaire'¹ (Bruun et al. 2016). The process is similar to what Sundar et al. (2014) used to create their 'Capturing Cool' questionnaire, where factors are derived on a theoretical basis followed by a set of statistical studies.

Bruun et al.'s (2016) study differs from the Sundar et al. (2014) study as they propose that coolness is decomposed to inner cool and outer cool. They base this distinction on a literature review presented in Raptis, Kjeldskov, and Skov (2013). According to Nancarrow, Nancarrow, and Page (2001) and MacAdams (2001), inner coolness deals with the personality of someone, that is, how others perceive intra-person characteristics. As an example, a person can be perceived as cool if he or she keeps his or her calm under pressure. Inner cool in relation to products refers to the perceived personality traits, which are assigned to products by users, for example, a product can be considered as cute or tough (Janlert and Stolterman 1997; Jordan 1997). Outer cool relates to how something or someone is presented through a certain style in physical appearance (Gioia 2009). For products, this is a matter of aesthetic design, for example, physical shape, materials, colours, and so on.

The questionnaire presented in Bruun et al. (2016) measures the perceived inner coolness of products, but not outer coolness. Authors suggest that outer cool is directly related to aesthetic attributes and thus it can be measured by existing UX factors, for example, by using questionnaires that measure attractiveness or aesthetics such as the one proposed in Lavie and Tractinsky (2004). In a similar matter as the Sundar et al. (2014) study, Bruun et al. (2016) start the process of creating their questionnaire by identifying relevant characteristics that contribute to inner coolness. Informed by a literature review (Raptis, Kjeldskov, and Skov 2013), they identified 11 characteristics that contribute to inner coolness, namely, being rebellious and antisocial, embracing authenticity and innovation, seeking exclusivity, pleasure and personal development, being/appearing in control, making hard things appear easy, being detached/emotionally neutral, and being strongly tight to a group. The majority of the 11 characteristics emerged from the work of Pountain and Robbins (2000), MacAdams (2001), and Nancarrow, Nancarrow, and Page (2001). For more details, we refer to Raptis, Kjeldskov, and Skov (2013).

Bruun et al. derived their questionnaire using an initial pool of 143 items related to the eleven inner

Table 2. Factors and items from the 'COOL questionnaire' (Bruun et al. 2016).

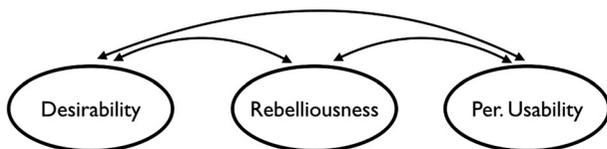
Desirability	Rebelliousness	Perceived usability
This device can make me better	This device moves against the current	This device is easy to operate
This device is meant for people like me	This device is unconventional	This device is easy to use
This device can make me happy	This device is different	This device is easy to learn
This device can make me look good	This device is outside the ordinary	This device is simple to use
This device totally connects with me	This device is rebellious	This device is effortless to use
This device can make me look in control of things		

cool characteristics. Through an iterative process with a total of 2236 respondents and by repeatedly applying the statistical techniques of exploratory and confirmatory factor analyses, they ended up having a questionnaire with 16 items (Table 2) distributed to three factors of desirability, rebelliousness, and perceived usability (Figure 2). All items are measured on a 7-point Likert scale (1 = Strongly disagree, 7 = Strongly agree). Additionally and similarly to Sundar et al. (2014), Bruun et al. also demonstrated that these three factors shape the overall coolness judgement, which was measured through the item 'This device is cool'.

3. Questionnaires for measuring established UX factors

As mentioned in the introduction of the paper, Bargas-Avila and Hornbæk (2011) point towards the existence of a 'dimensionality explosion' in relation to measuring UX. A critical question here is whether coolness further fuels this explosion and if its factors, to some extent, overlap with existing factors. In order to answer this question, a set of established UX factors are presented in the following paragraphs.

Many widely considered UX factors concern the aesthetic appeal of interaction designs (Bargas-Avila and Hornbæk 2011). Lavie and Tractinsky (2004) proposed a questionnaire for assessing the level of website aesthetics. Their questionnaire has since then been applied to evaluate UX of various products, such as mobile phones (Sonderegger et al. 2012). The questionnaire is based on the two factors of classic and expressive

**Figure 2.** Three-factor structure of inner cool (Bruun et al. 2016).**Table 3.** Factors and items from the aesthetics questionnaire (Lavie and Tractinsky 2004).

Classic aesthetics	Expressive aesthetics
<i>This device has:</i>	<i>This device has:</i>
Aesthetic design	Creative design
Pleasant design	Fascinating design
Clear design	Use of special effects
Clean design	Original design
Symmetric design	Sophisticated design

aesthetics. Items of the classic aesthetics factor consist of a set of adjectives such as 'Pleasant', 'Clean', and 'Symmetric'. Lavie and Tractinsky (2004) state that this factor deals with traditional notions of aesthetics. The expressive aesthetics factor represents qualities that go beyond the classical design principles and includes items such as 'Creative', 'Fascinating', and 'Sophisticated'. Table 3 shows all the questionnaire items, which are rated on a 7-point Likert scale (1 = Strongly disagree, 7 = Strongly agree).

Attrakdiff (Hassenzahl, Burmester, and Koller 2003) is also a widely recognised questionnaire for measuring UX (Bargas-Avila and Hornbæk 2011). Like the aesthetics questionnaire, it was created with a focus on websites, but it has also been successfully applied to assess the UX of various types of products, for example, culturally adaptive applications (Reinecke and Bernstein 2011). The shortened version of this questionnaire (Attrakdiff2) is based on a two-factor structure concerning hedonic and pragmatic qualities and two evaluative constructs (Van Schaik, Hassenzahl, and Ling 2012). The hedonic quality factor deals with the overall appeal of a product and includes items related to aesthetics (e.g. 'I judge the product to be stylish') as well as items about excitement (e.g. 'I judge the product to be captivating'). The pragmatic quality factor revolves around utilitarian and usability aspects with underlying items such as 'I judge the product to be confusing/structured' or 'I judge the product to be impractical/practical'. All items (Table 4) are assessed on a 7-point scale (e.g. 1 = dull, 7 = captivating).

Finally, attractiveness is also considered as an established UX factor and since it was identified as a core factor in the Sundar study, we chose to include a reliable

Table 4. Factors and items from Attrakdiff2 questionnaire (Van Schaik, Hassenzahl, and Ling 2012).

Hedonic quality	Pragmatic quality	Evaluative constructs
<i>I judge the device to be:</i>	<i>I judge the device to be:</i>	<i>I judge the device overall to be:</i>
Dull-Captivating	Confusing-Structured	Bad-Good
Tacky-Stylish	Impractical-Practical	Ugly-Beautiful
Cheap-Premium	Unpredictable-Predictable	
Unimaginative-Creative	Complicated-Simple	

Table 5. Items from the attractiveness questionnaire (Quinn and Tran 2010).

Attractiveness (UX)
<i>I judge the device to be:</i>
Attractive-Unattractive
Beautiful-Ugly
Eye catching-Plain
Interesting-Boring
I like the way this phone looks

questionnaire that measures it. Quinn and Tran (2010) developed a five 7-point scale to measure the attractiveness of a product and they used it to assess the attractiveness of mobile phones. The underlying items (Table 5) not only deal with aesthetic notions similar to those suggested in Lavie and Tractinsky (2004), but they also relate to the hedonic factor of Van Schaik, Hassenzahl, and Ling (2012). In order to differentiate between the attractiveness factor of Sundar et al. (2014) and the attractiveness factor of Quinn and Tran (2010), we will refer to the first as attractiveness(cool) and the latter as attractiveness(UX).

4. Research hypotheses

As pointed out by Bargas-Avila and Hornbæk (2011), when a new UX factor is proposed, the tools that measure it should be tested for their reliability and validity, and the factor should also be compared against other established UX factors. In this paper, we report two studies that follow this suggestion. Firstly, we compared the two existing cool questionnaires alone (study 1), and then we compared them against the established UX factors presented in the previous section (study 2). In the following, we discuss our hypotheses in relation to how cool factors and UX factors converge.

4.1. Study 1: Converging factors of coolness

At a first glance, the factors of attractiveness (Sundar et al. 2014), desirability, and usability (Bruun et al. 2016) seem different; that is, they represent different aspects of coolness. Based on their items, attractiveness deals with aesthetic appeal (e.g. ‘This device is stylish’),

while desirability relates to personal desires (e.g. ‘This device can make me happy’). Perceived usability is different from these as it concerns perceived learnability, utility, and operability of the device (e.g. ‘This device is effortless to use’).

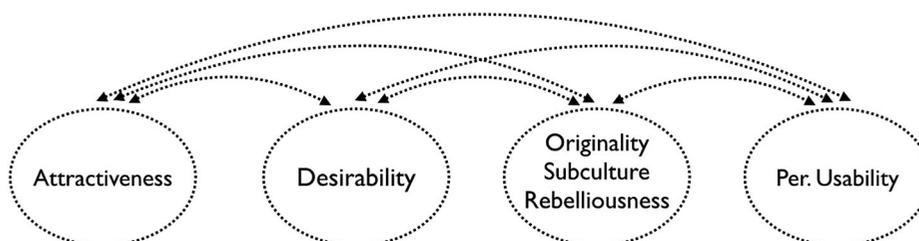
However, there is some overlap between the questionnaires. In particular, we find the originality (Sundar et al. 2014) and rebelliousness (Bruun et al. 2016) factors to be similar as they both deal with unconventional and novel aspects of a product, for example, ‘This device is unconventional’ vs. ‘This device is out of the ordinary’. The subculture factor from Sundar et al. relates more to the people using a product than the product itself. Yet, the topic of being different and unique is essential (e.g. ‘This device makes people who use it different from other people’).

Figures 1 and 2 present the two existing models for evaluating coolness of products, each with three factors. Based on the seemingly comparable factors of originality/subculture and rebelliousness, we hypothesise that a four-factor structure would emerge when combining the items from the two questionnaires (see Figure 3). Thus, we hypothesise that the combination of items from Sundar et al. (2014) and Bruun et al. (2016) would lead to the following:

- H1. Coolness can be measured through the four factors of attractiveness, desirability, perceived usability, and originality/subculture/rebelliousness.

4.2. Study 2: Converging factors of coolness and established UX factors

We will start this section with our hypotheses on overlapping factors among established UX factors and we will continue with their relation to the cool factors. From Lavie and Tractinsky’s classic and expressive factors, there are items such as ‘Pleasant design’, or ‘Fascinating design’, which seem to overlap with items from Van Schaik et al.’s hedonic factor, for example, ‘I judge the product to be captivating’. These in turn are similar to the items presented in Quinn and Tran’s attractiveness(UX) factor, for example, ‘I judge the product to be interesting’. Thus, the factors of classic aesthetics,

**Figure 3.** Hypothesised converging factors of cool when combining Sundar, Tamul, and Wu (2014) and Bruun et al. (2016).

expressive aesthetics, hedonic quality, and attractiveness (UX) all deal with observable aesthetic characteristics. This is in line with Hassenzahl and Monk (2010) and Diefenbach, Kolb, and Hassenzahl (2014), who argue that hedonic quality is similar to expressive aesthetics in specific contexts. The pragmatic factor in Van Schaik, Hassenzahl, and Ling (2012) seems to stand apart with items related to the perceived usability of a product, for example, ‘I judge this product to be complicated’.

Compared to the coolness questionnaires, we do see similar items to those posed in the established UX questionnaires. The attractiveness(cool) factor suggested in Sundar et al. (2014) deals with outer appearance and its items seem comparable to those from classic/expressive aesthetics/hedonic quality/attractiveness(UX) presented above. Also, the pragmatic quality factor of AttrakDiff2 relates to the instrumental aspects of a product, which is similar to the perceived usability factor presented in Bruun et al.’s (2016) coolness questionnaire. As an example, consider the item ‘I judge the product to be simple’ (Van Schaik, Hassenzahl, and Ling 2012) versus ‘This device is simple to use’ (Bruun et al. 2016). The hypothesised structure of coolness in Figure 3 also suggests factors of originality/subculture/rebelliousness and desirability. Respectively, these factors deal with unconventional notions of a product and personal desire, and, thus, seem to be independent from other established UX factors.

On the basis of this discussion, we hypothesise that a four-factor structure will emerge when comparing the suggested factors of coolness (Bruun et al. 2016; Sundar et al. 2014) and the established UX factors (Lavie and Tractinsky 2004; Quinn and Tran 2010; Van Schaik, Hassenzahl, and Ling 2012). This hypothesised four-factor structure is shown in Figure 4, along with two-way arrows indicating suggested correlations between factors.

Thus, our second hypothesis (H2) relates coolness to established UX factors:

H2a. The coolness factor of attractiveness(cool) converges on established UX factors of classic/expressive aesthetics/hedonic quality/attractiveness(UX).

H2b. The coolness factor of perceived usability converges on the established UX factor of pragmatic quality.

H2c. The coolness factors of originality/subculture/rebelliousness and desirability do not converge on any of the established UX factors.

5. Method

In order to test our research hypotheses, we applied the statistical techniques of exploratory factor analysis (EFA) and CFA using SPSS v. 23 and AMOS v. 22, respectively. EFA is based on an iterative process where items are removed from an initial pool of items, based on how much they contribute to measuring a particular factor. We conducted two EFA studies, where we used the Bartlett Test of Sphericity to test the homogeneity of variances, the Kaiser–Meyer–Olkin Measure (KMO) to test sampling adequacy, and Principal Axes Factoring as an extraction method using an oblique rotation (as recommended in the literature, e.g. Bulmer (1979) and Field (2009)). The number of extracted factors was determined through a Scree test and through parallel analysis (using Monte Carlo principal components analysis (PCA), Watkins). In the two EFA studies, we removed items by applying two criteria: low communalities (<.5) and low factor loadings (<.65).

CFA is, as the name implies, of confirmatory nature and it is used to validate the factor structure that emerged though an EFA. In CFA there are not only item loadings on factors, but also covariances between factors, denoting how variances between any two pairs of factors are correlated. The goodness of a factor model is determined by a range of fit indices, which collectively indicate whether or not the factor structure is appropriate and reliable (Schreiber et al. 2006). In the following sections, we present the used indices for each CFA.

We conducted two CFAs to test our hypotheses based on Structural Equation Modelling (SEM) with Maximum Likelihood Estimation. When conducting SEM, it is necessary to conduct a pre-analysis to examine whether

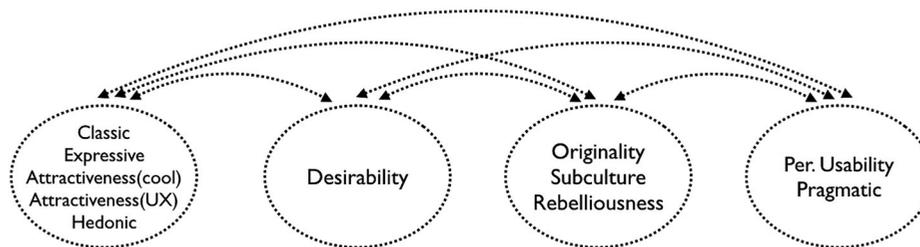


Figure 4. Hypothesised converging factors when combining coolness questionnaires (Bruun et al. 2016; Sundar, Tamul, and Wu 2014) and established UX questionnaires (Lavie and Tractinsky 2004; Quinn and Tran 2010; Van Schaik, Hassenzahl, and Ling 2012). Attractiveness(UX) refers to the factor from Quinn and Tran (2010) and attractiveness(cool) refers to Sundar, Tamul, and Wu (2014).

SEM assumptions are met in the data sample. These assumptions are related to missing data, normality, linearity, and multicollinearity (Schreiber et al. 2006). We had no missing data and the CFA datasets had univariate normality with skewness values between -1 and $.43$ and kurtosis values between -1.4 and $.6$. These are within acceptable thresholds to assume that data are normally distributed (Tabachnick and Fidell 2013). Due to the strong factor loadings ($>.6$) identified during all EFAs, we also assume linearity between latent and manifest variables. The level of multicollinearity was also acceptable according to Kutner, Nachtsheim, and Neter (2004) with Variance Inflation Factor levels between 1.5 and 4.5 . Therefore, in both CFA studies all the necessary assumptions were met.

In our studies, we included a large number of participants to be able to do a statistical analysis. We recruited these participants from Amazon Mechanical Turk (MTurk). MTurk participants have been used successfully in other studies within HCI and have been shown to provide valuable results (e.g. Boujarwah, Abowd, and Arriaga 2012; Heer and Bostock 2010; Heimerl et al. 2012). We limited our selection to people living in the USA to avoid language barriers and to follow the recommendations of Ross et al. (2010) and Huff and Tingley (2015). Ross et al. (2010) conducted a profiling study of MTurk workers and collected data for their gender, age, income, and level of education. Their findings show that the sample of US MTurk workers is balanced in relation to income and gender, while there are slightly more workers of younger age. Their education level is similar to that of the whole US population (OECD 2016). Huff and Tingley (2015) compared a large sample of US MTurk workers to a nationally representative sample. They focused on age, gender, race, ideology,

occupation, and the areas participants live. The MTurk sample was identical to the representative one in relation to ideology, occupation, and the areas participants live, and slightly imbalanced in relation to age, gender, and race. As an additional quality measure, we only recruited MTurk workers with 95% approval ratings, as recommended by Ross et al. (2010).

The need for a large pool of participants was satisfied through MTurk also informed our experimental set-up. Since it is not possible to interact physically with MTurk workers and show them physical artefacts, we were inspired by other studies in HCI where participants made ratings based on images. For example, Lindgaard et al. (2006) used images of websites that were shown to the participants through a PC for 50–500 milliseconds. Their aim was to study how fast people shape a judgement for a website's visual appeal. Tractinsky (1997) used a projector and collectively showed images of different ATM layouts to his participants, while asking them to rate their perceived usability and beauty. Hoegg, Alba, and Dahl (2010) used images of cookware and electric mixers that varied aesthetically to test the belief that 'what is beautiful is good'. In a similar manner to these previous studies, we chose as evaluation objects mobile devices and we created a website, which on the left side showed an image of a mobile device and on the right side listed the questionnaire items. Using images also allowed us to experimentally control for external parameters. The included 13 mobile devices were of the same colour, were presented without any indication of their brand, and had their screens turned off to exclude any effect from the operating system (Figure 5).

A total of 2239 MTurk workers participated in our studies, used our website, and filled in the two established cool questionnaires (Bruun et al. 2016; Sundar et al. 2014)



Figure 5. The 13 mobile devices used in the studies.

and the three established UX questionnaires (Lavie and Tractinsky 2004; Quinn and Tran 2010; Van Schaik, Hassenzahl, and Ling 2012). All questionnaire items were presented randomly and were rated on a 7-point Likert scale from 'strongly disagree' to 'strongly agree'. Each participant was asked to assess only one mobile device and participated in one EFA or CFA study. Participants were paid an incentive ranging between 0.25\$ and 0.35 \$, which was in line with MTurk's guidelines on how to fairly pay them. From the 2239 participants, we removed responses where participants had a considerably lower completion time than the average, which is in line with Kittur, Chi, and Suh (2008). We also removed all participants who reported prior experience with the mobile device they were asked to evaluate, as prior experience may significantly affect UX factors, and in particular perceived usability (Sauro 2011). This left us with a sample of 1790 participants that was balanced in relation to gender (892 females), had a large variety of age groups (18–72 years old, $M = 33.6$, $SD = 10.8$), and included a variety of races (self-identified as Caucasian, African, Hispanic, Asian, Arab, etc.). In all, 1251 of them participated in the EFAs and 539 in the CFAs, with an average of 156.4 participants per device in the EFAs and 107.8 participants per device in the CFAs.

6. Study 1: Convergence of coolness factors (H1)

In this section, we present how we addressed our first research hypothesis (H1) by examining the convergence of factors from the two cool questionnaires.

6.1. EFA – Exploring the coolness factor model

To study H1, we asked 822 participants to rate one mobile device each and we included three devices (274 participants per device). All participants rated the device based on the 56 question items, that is, all items from all questionnaires (EFA1, Table 6).

Initially we examined the reliability of each individual factor. With the exception of pragmatic quality, all factors had exceptional Cronbach α scores, indicating that, for the case of mobile devices, all individual factors can be reliably measured through their respective items (Table 7).

Table 6. EFA1. n = number of participants, i = number of items used as input.

Study	n	Devices	i
EFA1	822	Samsung Galaxy S6, Blackberry Priv, and Vertu Signature Touch	56

To define the factor model of the two combined coolness questionnaires, we relied on the EFA. Combined, the coolness questionnaires (Bruun et al. 2016; Sundar et al. 2014) consist of 31 of the total 56 items (with the remaining 25 representing items from the other established UX questionnaires). We removed items by applying the cut-off criteria (low communalities ($<.5$) and low factor loadings ($<.65$)), and in the end 18 items remained. The final four-factor structure was identified through Scree tests and Parallel Analysis (Monte Carlo PCA, Watkins). This model explained 74.84% of the variance, KMO was .930, and the Bartlett Test of Sphericity was significant.

Factor A contains items that emerged from attractiveness (Sundar et al. 2014) and Factor B mainly from rebelliousness (Bruun et al. 2016). Items from originality and subculture (Sundar et al. 2014) mostly converged on rebelliousness, but were removed using the cut-off criteria. Factor C is about usability (Bruun et al. 2016), while Factor D deals with desirability (Bruun et al. 2016). Details are presented in Table 8.

6.2. CFA1 – Confirming the coolness factor model

In order to confirm the four-factor structure of coolness as emerged from EFA1, we conducted a CFA study. This included the 18 items that emerged from EFA1, and 206 participants rated one device each (Table 9).

In the first run, all indices suggested acceptable values; that is, it was not necessary to go through modification indices to increase model fit. Table 10 shows the respective item loadings and model-fit indices obtained in CFA1 where all loadings are significant. We also validated the model by examining the matrix of standardised residuals. A model with a good fit will have residuals centred around zero and we found none larger than

Table 7. Reliability analysis of factors from all questionnaires, i = number of items.

Questionnaire	Factor	i	Cronbach
			α
Capturing cool (Sundar, Tamul, and Wu 2014)	Subculture	5	.913
	Attractiveness	5	.911
	Originality	5	.921
Cool questionnaire (Bruun et al. 2016)	Desirability	6	.902
	Rebelliousness	5	.886
	Perceived usability	5	.918
	Classic aesthetics	5	.869
Aesthetics (Lavie and Tractinsky 2004)	Expressive aesthetics	5	.872
	Hedonic quality	4	.892
Attrakdiff2 (Van Schaik, Hassenzahl, and Ling 2012)	Pragmatic quality	4	.705
	Attractiveness	5	.937

Table 8. Pattern Matrix with item loadings per factor in EFA1 containing only the cool questionnaires.

Factor:	A	B	C	D
<i>Eigenvalue:</i>	7.361	1.780	3.518	0.813
<i>Cronbach α:</i>	.911	.918	.912	.812
Attractiveness				
This device is stylish ^a	.919	.016	-.051	-.062
This device is hip ^a	.861	-.030	-.027	.077
This device is sexy ^a	.780	.011	.027	.040
This device is hot ^a	.779	.023	.026	.133
This device is on the cutting edge ^a	.730	.054	.153	.026
Perceived usability				
This device is simple to use ^b	-.065	.916	-.023	.010
This device is easy to use ^b	.046	.890	.004	-.023
This device is easy to learn ^b	-.055	.882	.030	-.014
This device is easy to operate ^b	.001	.882	-.017	.034
This device is effortless to use ^b	.084	.759	.004	.015
Rebelliousness				
This device is different ^b	.062	-.002	.887	-.062
This device is outside the ordinary ^{a,b}	.076	.022	.861	-.019
This device is unconventional ^b	-.106	-.014	.845	.022
This device is unique ^a	.181	.032	.831	-.077
This device moves against the current ^b	-.093	-.019	.824	.137
Desirability				
This device can make me better ^b	-.059	-.005	.043	.917
This device can make me happy ^b	.099	.089	-.088	.778
This device can make me look in control of things ^b	.234	.004	.102	.618
Sum of Squared Loadings (Total variance explained):	74.84%			

Note: A = Attractiveness, B = Perceived Usability, C = Rebelliousness, D = Desirability.

^aOriginates from Sundar, Tamul, and Wu (2014).

^bOriginates from Bruun et al. (2016).

± 2 , hereby indicating a good model fit (Schreiber et al. 2006).

Based on the model-fit indices, we found that our data support a four-factor model representing coolness. Table 11 shows the correlation matrix between the four factors. The diagonal elements in bold represent the square root of average variance extracted (AVE) and the Cronbach α values (in parentheses). Since the square roots of AVEs are bigger than all factor correlations, we can conclude that the discriminant validity is more than adequate. The same is the case with internal consistency (construct reliability) with high Cronbach α values.

6.3. Study 1 results

In this section, we present our results in relation to the research hypothesis H1:

Table 9. CFA1. n = number of participants, i = number of items used as input.

Study	n	Devices	i
CFA1	206	Apple iPhone 6s Plus, and Huawei Ascend Y530	18

Table 10. Item loadings per factor and model-fit indices for the CFA1 study.

CFA1 – Coolness Factor Model		
Attractiveness	This device is stylish ^a	.74
	This device is hip ^a	.83
Perceived usability	This device is sexy ^a	.76
	This device is hot ^a	.75
	This device is on the cutting edge ^a	.72
	This device is simple to use ^b	.91
Rebelliousness	This device is easy to use ^b	.86
	This device is easy to learn ^b	.87
	This device is easy to operate ^b	.88
	This device is effortless to use ^b	.72
Desirability	This device is different ^b	.83
	This device is outside the ordinary ^{a,b}	.84
	This device is unconventional ^b	.63
	This device is unique ^a	.79
Model-fit Indices	This device moves against the current ^b	.63
	This device can make me better ^b	.78
	This device can make me happy ^b	.86
	This device can make me look in control of things ^b	.72
Ratio of χ^2 to df (CMIN/df, acceptance threshold ≤ 3)		1.5
Normed Fit Index (NFI, acceptance threshold $\geq .95$)		.92
Incremental Fit Index (IFI, acceptance threshold $\geq .95$)		.97
Tucker–Lewis Index (TLI, acceptance threshold $\geq .95$)		.96
Comparative Fit Index (CFI, acceptance threshold $\geq .95$)		.97
Goodness-of-Fit Index (GFI, acceptance threshold $\leq .95$)		.9
Adjusted Goodness-of-Fit Index (AGFI, acceptance threshold $\leq .95$)		.87
Root Mean Square Error of Approx. (RMSEA, accept. threshold $\leq .06$)		.05
p of close fit (PCLOSE, acceptance threshold $> .05$)		.43

Note: All are within acceptable thresholds, indicating good model fit.

^aOriginates from Sundar, Tamul, and Wu (2014).

^bOriginates from Bruun et al. (2016).

H1. Coolness can be measured through the four factors of attractiveness, desirability, perceived usability, and originality/subculture/rebelliousness.

We confirm this hypothesis. Findings from the EFA1 and CFA1 show the existence of 18 items distributed over four factors for measuring perceived coolness: attractiveness, perceived usability, rebelliousness, and desirability. Attractiveness stems exclusively from Sundar et al. (2014), while perceived usability and desirability stem from Bruun et al. (2016). The rebelliousness factor includes items from both questionnaires. Thus, we confirm H1 for the case of assessing the perceived coolness of mobile devices.

7. Study 2: Convergence of coolness on UX factors

In the previous section, we confirmed the factor structure related to coolness, where the total of six factors from Sundar et al. (2014) and Bruun et al. (2016) converged on four factors. In the following, we examine the emerging factor structure when combining the factors identified across the coolness studies as well as the other established UX factors related to aesthetics (Lavie and Tractinsky 2004), attractiveness(UX) (Quinn and

Table 11. Factor correlation matrix for CFA1. Values in bold indicate the square root of AVE and Cronbach α (in parentheses).

	Attractiveness	Per. Usability	Rebelliousness	Desirability
Attractiveness	.761 (.874)			
Perceived usability	.35	.850 (.923)		
Rebelliousness	.55	.2	.750 (.861)	
Desirability	.74	.42	.41	.789 (.829)

Tran 2010), and hedonic and pragmatic quality (Van Schaik, Hassenzahl, and Ling 2012). By examining the convergence of these factors, we seek to test the second set of hypotheses (H2a, H2b, and H2c). In the following, we present our findings from two EFA studies exploring possible factor structures describing the relation between coolness and established UX factors.

7.1. EFA – Exploring the cool-UX factor model

We started our analysis using the same dataset as before (EFA1, Table 6), but this time we included all 56 items (31 from the cool questionnaires and 25 from the other established UX questionnaires). Through an EFA, we

produced a total of five models with four- and five-factor structures. Items were removed by applying the cut-off criteria and only if they did not belong to any factors in any model. In all five models, the KMO was $>.925$, fulfilling the criteria for sampling adequacy and the Bartlett Test of Sphericity was significant ($<.001$). In the end, the initial 56 items were reduced to 33.

Given the remaining relatively large number of items, we chose to conduct an additional EFA study (EFA2). In EFA2 we had 429 additional participants rate one device each and we included a total of 5 devices (~ 86 participants per device, Table 12).

The 429 participants in EFA2 rated the remaining 33 items and a 5-factor structure was identified through Scree tests and Parallel Analysis (Monte Carlo PCA, Watkins). By applying the cut-off criteria, the number of items was reduced from 33 to 22 and our final model had a KMO of .954. Cumulatively this five-factor model explained 79.39% of the variance. In Table 13 we present the emerged five-factor structure after EFA2, along with the loadings of each item on factors.

Table 12. EFA2. n = number of participants, i = number of items used as input.

Study	n	Devices	i
EFA2	429	HTC One M8, OnePlus One, Tag Heuer Meridiist, Nokia 222, Philips Fluid	33

Table 13. Pattern matrix with item loadings per factor in EFA2.

		Factor:	A	B	C	D	E
		Eigenvalue:	7.862	5.184	2.284	1.346	0.790
		Cronbach α :	.946	.933	.921	.790	.905
Hedonic	I find this device: plain/eye catching ^a		.909	-.003	.127	-.005	-.079
	I judge this device to be: cheap/premium ^b		.879	-.082	-.092	-.073	-.006
	I judge this device to be: dull/captivating ^b		.865	.010	-.009	.026	.123
	I find this device: boring/interesting ^a		.851	.015	.035	-.045	.092
	I judge this device to be: unimaginative/creative ^b		.767	.037	.236	-.009	.006
Perceived Usability	This device is simple to use ^c		-.004	.924	-.003	.002	-.033
	This device is easy to use ^c		-.005	.924	-.006	.010	-.018
	This device is easy to operate ^c		.058	.919	-.057	-.035	-.039
	This device is easy to learn ^c		-.106	.842	.084	-.103	.005
	This device is effortless to use ^c		.024	.799	-.025	.034	.118
Rebelliousness	This device moves against the current ^c		-.039	.106	.910	.059	-.097
	This device is outside the ordinary ^{c,d}		.057	-.009	.866	-.013	.051
	This product stands apart from similar products ^d		.015	-.033	.833	-.068	.116
	This device is different ^c		.093	-.076	.815	-.013	.046
	This device is unconventional ^c		.071	-.069	.802	.015	-.014
Classic Aesthetics	This device has clear design ^e		-.065	.043	.055	-.922	.001
	This device has clean design ^e		.116	.032	-.090	-.840	.016
Desirability	This device can make me better ^c		-.101	.035	.015	.091	.938
	This device can make me look in control of things ^c		-.023	-.047	.120	-.112	.810
	This device can make me look good ^c		.067	-.111	.086	-.127	.779
	This device can make me happy ^c		.138	.132	-.110	-.005	.755
	This device totally connects with me ^c		.289	.115	-.114	.003	.678
		Sum of Squared Loadings (Total variance explained):	79.39%				

A = Attractiveness, B = Perceived Usability, C = Rebelliousness, D = Classic Aesthetics and E = Desirability.

^aOriginates from Quinn and Tran (2010).

^bOriginates from Van Schaik, Hassenzahl, and Ling (2012).

^cOriginates from Bruun et al. (2016).

^dOriginates from Sundar, Tamul, and Wu (2014).

^eOriginates from Lavie and Tractinsky (2004).

Throughout the EFA studies, we observed a trend on how items converged on the five factors. Items from the two attractiveness factors (Quinn and Tran 2010; Sundar et al. 2014), expressive aesthetics (Lavie and Tractinsky 2004), and hedonic quality (Van Schaik, Hassenzahl, and Ling 2012) converged around Factor A (hedonic). Furthermore, items from pragmatic quality (Van Schaik, Hassenzahl, and Ling 2012) converged on Factor B (perceived usability) with low factor loadings, which led to their removal. Thus, Factor B consists of items from the perceived usability factor identified in Bruun et al. (2016). Items from subculture and originality (Sundar et al. 2014) and rebelliousness (Bruun et al. 2016) converged on Factor C (rebelliousness). Items from the classic aesthetics factor (Lavie and Tractinsky 2004) solely define Factor D (classic aesthetics), with no convergence on other factors. Finally, a few specific questions from expressive aesthetics, classic aesthetics, and attractiveness converged on Factor E (desirability) with low factor loadings. Thus, Factor E is defined by items from desirability (Bruun et al. 2016).

7.2. CFA – Confirming the cool-UX factor model

To confirm the proposed five-factor model from EFA2, we had 333 participants rate one mobile device, and we included 3 different devices in total (CFA2, Table 14), that is, each device was assessed by 111 participants on average. None of the participants had taken part in the previous studies.

To obtain an acceptable model fit, we went through four iterations where we removed one item at a time based on the largest modification indices. After that point all indices suggested a good model fit; that is, it was not necessary to go through further iterations. Through these iterations, we removed four items from the 22 identified in EFA2. Thus, the final CFA model consists of 18 items. Table 15 shows the respective item loadings and model-fit indices obtained in CFA2 where all loadings are significant. We also validated the model by examining the matrix of standardised residuals. A model with a good fit will have residuals centred around zero and we found none larger than ± 2 , hereby indicating a good model fit (Schreiber et al. 2006).

Table 16 presents the correlation matrix between the five factors, which shows that none of the factors have a 1–1 correlation. The diagonal elements in bold

Table 14. CFA2. n = number of participants, i = number of question items used as input.

Study	n	Devices	i
CFA2	333	Nexus 6P, North Face M8, and Blackberry Classic	22

represent the square root of AVE as well as the Cronbach α values (in parentheses). Since the elements exceed all factor correlations except one, discriminant validity is adequate. That said, the hedonic and desirability factors do have a correlation of .79, which indicates that these factors are closely related and one can be used to predict the other. Nevertheless, all factors are consistently separated throughout our EFA and CFA studies, that is, they are measuring different UX factors. Furthermore, in relation to internal consistency (construct reliability), Cronbach α values are high, which shows that the items can reliably measure the five factors.

7.3. Study 2 results

Our second hypothesis related coolness to other established UX factors and is divided into three parts (H2a, H2b, and H2c). We will address each hypothesis individually.

H2a. The coolness factor of attractiveness(cool) converges on established UX factors of classic/expressive aesthetics/hedonic quality/attractiveness(UX).

Table 15. Item loadings per factor and model-fit indices for the CFA2 study.

CFA2 – Cool-UX Factor Model		
Hedonic	I find this device: plain/eye catching ^a	.89
	I judge this device to be: dull/captivating ^b	.88
	I find this device: boring/interesting ^a	.90
	I judge this device to be: unimaginative/ creative ^b	.84
Perceived Usability	This device is simple to use ^c	.87
	This device is easy to use ^c	.88
	This device is easy to operate ^c	.91
Rebelliousness	This device is easy to learn ^c	.83
	This device moves against the current ^c	.7
	This device is outside the ordinary ^{c,d}	.86
	This product stands apart from similar products ^d	.79
Classic aesthetics	This device is different ^c	.87
	This device has clear design ^e	.73
	This device has clean design ^e	.76
Desirability	This device can make me better ^c	.78
	This device can make me look in control of things ^c	.74
	This device can make me look good ^c	.86
	This device can make me happy ^c	.78
Model-fit Indices		
Ratio of χ^2 to df (CMIN/df, acceptance threshold ≤ 3)		1.9
Normed Fit Index (NFI, acceptance threshold $\geq .95$)		.95
Incremental Fit Index (IFI, acceptance threshold $\geq .95$)		.98
Tucker–Lewis Index (TLI, acceptance threshold $\geq .95$)		.97
Comparative Fit Index (CFI, acceptance threshold $\geq .95$)		.97
Goodness-of-Fit Index (GFI, acceptance threshold $\leq .95$)		.93
Adjusted Goodness-of-Fit Index (AGFI, acceptance threshold $\leq .95$)		.9
Root Mean Square Error of Approx. (RMSEA, accept. threshold $\leq .06$)		.05
p of close fit (PCLOSE, acceptance threshold $> .05$)		.42

Note: All are within acceptable thresholds, indicating good model fit.

^aOriginates from Quinn and Tran (2010).

^bOriginates from Van Schaik, Hassenzahl, and Ling (2012).

^cOriginates from Bruun et al. (2016).

^dOriginates from Sundar, Tamul, and Wu (2014).

^eOriginates from Lavie and Tractinsky (2004).

Table 16. Factor correlation matrix for CFA2. Diagonal values in bold indicate: the square root of AVE and Cronbach α (in parentheses).

	Hedonic	Per.Usability	Rebelliousness	Classic Aesthetics	Desirability
Hedonic	.878 (.929)				
Per. Usability	.29	.873 (.927)			
Rebelliousness	.66	.14	.806 (.878)		
Classic Aesthetics	.47	.66	.14	.745 (.712)	
Desirability	.79	.41	.48	.55	.791 (0.868)

This hypothesis is not supported. As in previous studies (Diefenbach, Kolb, and Hassenzahl 2014; Hassenzahl and Monk 2010), our results showed that expressive aesthetics and hedonic quality converge. We also identified that these also converged with the two attractiveness factors (Quinn and Tran 2010; Sundar et al. 2014). At the same time, classic aesthetics (Lavie and Tractinski 2004) formed an independent factor. Thus, even though we expected all five factors to be merged into one, they merged into two: A) a hedonic factor which consisted of two question items from Quinn and Tran's (2010) attractiveness factor, and two items from Van Schaik, Hassenzahl, and Ling's (2012) hedonic quality factor, and B) a classic aesthetics factor that emerged solely from Lavie and Tractinsky (2004). For these reasons, we falsify hypothesis H2a.

H2a. The coolness factor of perceived usability converges on the established UX factor of pragmatic quality.

Table 15 shows that the emerged perceived usability factor consists exclusively of question items stemming from the perceived usability factor as suggested by Bruun et al. (2016). This happened because even though all items from Van Schaik, Hassenzahl, and Ling's (2012) pragmatic quality factor consistently followed the perceived usability items, they all had loadings below the cut-off level. Additionally, since we did not observe any of the pragmatic items converging on any other factor, we verify hypothesis H2b.

H2a. The coolness factors of originality/subculture/rebelliousness and desirability do not converge on any of the established UX factors.

Finally, in relation to H2c, both factors of rebelliousness and desirability that emerged during the EFA studies were retained in the five-factor model from CFA2. Items from originality and subculture did converge on the rebelliousness factor, but with lower loadings. Thus, hypothesis H2c is also verified.

8. Discussion

Our purpose with this paper was twofold. Firstly, we wanted to make a systematic comparison of the underlying factors between the recently proposed questionnaires for measuring perceived coolness. Thus, in our

first study, we examined the extent of convergence between the suggested coolness factors and we demonstrated that there are differences as well as overlaps. Secondly, we also wanted to position the coolness factors in relation to established UX ones and thus contribute to the dimensionality explosion challenge (Bargas-Avila and Hornbæk 2011). Through our research effort in our second study, we managed to combine all factors into a single model, thus we strengthened the position of coolness within UX research. In the following subsections, we discuss the implications for research and practice.

8.1. Implications for UX research

When studying the two cool questionnaires (Bruun et al. 2016; Sundar et al. 2014), we produced a model that narrowed down the initial six factors into four (Table 8: attractiveness, perceived usability, rebelliousness, and desirability). When we followed the same process by including established UX questionnaires, a new model emerged that contained not 11, but 5 factors (Table 15: hedonic quality, classic aesthetics, desirability, perceived usability, and rebelliousness). What we believe is interesting for our research community is to understand the relation among these factors.

In this part of the discussion, we contribute to understanding the relation among these factors by linking back to theory. According to the literature, when people observe a product (or a person), they immediately make a judgement on its overall coolness (Pountain and Robbins 2000). When there is no actual usage with a product, as was the case in our study, this judgement is initially based on the externally observable aesthetic attributes (outer coolness), which people use to infer a judgement of personality characteristics (inner coolness). Then, both inner coolness and outer coolness shape the overall judgement of coolness (Bruun et al. 2016; Pountain and Robbins 2000; Raptis, Kjeldskov, and Skov 2013). Figure 6 shows the theoretical relation among perceived inner coolness, perceived outer coolness, and overall coolness judgement.

We took this theoretical model one step further by including the emerged five factors of hedonic quality, classic aesthetics, desirability, usability, and

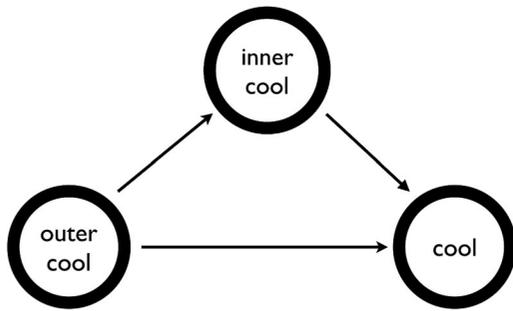


Figure 6. Theoretical relationships among perceived inner cool, perceived outer cool, and overall coolness judgement.

rebelliousness. We hypothesise a UX inference model in a similar manner as Hassenzahl and Monk (2010) and Van Schaik et al. (2012), who showed what we perceive as beautiful is also perceived as good, which in turn is perceived as usable, that is, ‘What is beautiful is good and what is good is usable’. In order to validate our proposed inference model, we used inferential statistics (Partial Least Squares, Vinzi et al. 2010). Based on our analysis, we argue that hedonic quality and classic aesthetics contribute to outer coolness, since they both relate to the aesthetic attributes of a product, while perceived usability, rebelliousness, and desirability contribute to inner cool. In the Appendix, the final validated inference model is presented along with standardised regression coefficients, *T*-statistics, the percentage of explained variance, as well as details on the process followed. In the following figure, we present a simplified version of this model that depicts how the emerged five factors are clustered around inner cool and outer cool, and how they both contribute to the overall coolness judgement.

The proposed inference model of users’ experiences with mobile devices through outer, inner, and overall cool (Figure 7) is a valid and useful tool for researchers. Firstly, it demonstrates the existence of an inference rule: ‘The perception of product aesthetics influences perceived product personality characteristics, and both shape the overall coolness judgement’. Secondly, it shows that people do infer inner cool from outer cool when they believe that it is a relevant rule for the situation (e.g. during first impression with mobile devices, i.e. without actual usage). Thirdly, it demonstrates that overall coolness cannot be inferred only by factors related to externally observable attributes. Inner coolness is also needed. Fourthly, our inference model strongly positions coolness within UX research, and it can be used to explain and/or predict the relationship among the five emerged factors.

Another important implication of our research work is that we showed that the established UX factors we use in

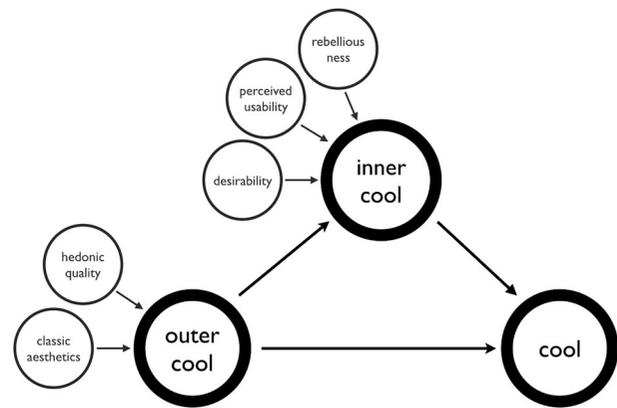


Figure 7. Simplified inference model showing that hedonic quality and classic aesthetics cluster around outer cool, while desirability, rebelliousness, and perceived usability cluster around inner cool. Both perceived outer and inner cool shape the overall coolness judgement. All paths are significant (details in the Appendix).

our research community converge. This leads to some factors being more prevalent than others, while others converge, for example, pragmatic quality and perceived usability. This reduces the number of factors that are relevant to consider. This finding taps directly into the UX community discussion of the dimensionality explosion. Bargas-Avila and Hornbæk (2011), for instance, mention: ‘the main problem of this dimensionality explosion is that the relation to established constructs is rarely made clear’. Our study provides a way of dealing with this through the proposed measurement model for the case of assessing perceived UX of mobile devices.

Of course, further research is needed for other products than mobile devices, for different contexts of use (e.g. after long-term usage), and for different cultural groups, in order to test the applicability of inferring inner-cool from outer-cool rule and its performance (e.g. is the direction of the effect always the same?). Furthermore, we find it of particular interest to compare our inference model with existing ones, (e.g. Van Schaik, Hassenzahl, and Ling 2012), as such comparisons may provide answers to important research questions such as: Are these models applicable in all contexts? For all products? Furthermore, an important research activity that we believe our community needs to pursue is to continue the study of convergence of the rest of the UX factors. Do other established UX factors that we did not include in our studies (such as pleasure) converge to the five we managed to identify in this paper? Are there other influential UX factors which are currently unknown?

Finally, we believe there is a need for more research on the relation between hedonic quality and classic aesthetics. Since both of them emerged as unique and

distinct factors and both measure aesthetic attributes, it is crucial to understand what they actually measure. We consider this challenge as important since it was also identified in previous research work (Bruun et al. 2016). Based on our findings, we propose that the two items of classic aesthetics that remained in our study (clean/clear design) are related to the cognitive process of recognition, while the four hedonic items relate to an intentional (or even unintentional) evaluation process of a product's aesthetic appeal that occurs afterwards. As an example, we believe our participants recognised the product they experienced in our study as a mobile device, and then they evaluated its appeal. More studies with this emphasis are needed in order to verify our assumption and we consider them as important as they may shed light on the cognitive mechanisms people use to aesthetically evaluate our produced designs.

8.2. Implications for UX practice

Our findings also have implications for practice. Firstly, we reconfirmed that all five established questionnaires we included in our studies can reliably measure their pertinent factors for the case of perceived UX of mobile devices (Table 7). The interesting issue though for practitioners is how to use these questionnaires in practice.

If practitioners want to measure a specific perceived UX factor, that is, the perceived usability of a produced design, then any of these questionnaires that measures perceived usability can be used, as it will provide reliable results. A challenge though exists if the purpose is to have a holistic evaluation of a product's perceived attributes. In such cases, practitioners should administer combinations of all these questionnaires in efforts to assess various aspects of UX. However, measuring all UX factors would mean that participants will have to answer a relatively large set of questions (56 in case of the questionnaires included in this study alone). Our findings help practitioners deal with dimensionality explosion and the large number of question items through the proposed five-factor model (Figure 7) and its items (Table 15). We demonstrated that the two established UX factors that converge on outer coolness (hedonic quality and classic aesthetics) can be measured using six items. Inner coolness can be measured through 11 items from the Cool Questionnaire (Bruun et al. 2016) and 1 item from the Capturing Cool questionnaire (Sundar et al. 2014). Finally, the overall coolness judgement can be measured by three items (details on how they emerged can be found in the Appendix). Thus, instead of answering 56 items which are related to several perceived UX factors that practitioners do know that they overlap, participants can answer the more manageable

21 items, which belong to factors that are independent. The final questionnaire that measures both perceived inner and outer coolness and the overall coolness judgement as well as their resulting items is shown in Figure 8.

Furthermore, we argue that our questionnaire/model will be more useful to practitioners if combined with qualitative methods. For example, if a product scores low on rebelliousness and this has a negative impact on its overall coolness, then practitioners can through, for example, in-depth interviews, identify specific design elements in relation to rebelliousness that need to be changed, produce redesigns, and then re-evaluate them. Thus, coolness becomes an essential design criterion, which not only can be measured, but also understood in relation to other established UX factors.

Finally, we define three challenges for our combined questionnaire/model that practitioners need to be aware of, which should be researched more in order to increase its applicability. The first is related to its performance. At this moment, we do not know what it means for a product to score, for example, 5 on usability or 3.5 on rebelliousness; that is, we do not know if such scores are good or bad for a particular product. In order to understand the behaviour of the model, research approaches that were used for other questionnaires in the past should be applied. For example, for the System Usability Scale (SUS) scale, Bangor, Kortum, and Miller (2008) conducted a meta-analysis of previous studies, and concluded on the meaning of an SUS score in relation to a product's usability. Secondly, since coolness is deeply rooted in the cultural communities people belong to (O'Donnell and Wardlow 2000), we need to test the model's behaviour in different communities. For example, we may have different results not only in Asian, or European, cultures, but also within different subcultures. Finally, we need to study the model's behaviour in relation to time. For example, it is known that users who interact with products for long periods of time change their perception of usability (Sonderegger et al. 2012). To what extent do the rest of the factors have similar behaviour? Such knowledge can be extremely useful for practitioners as it will allow them to understand how users' experiences develop over time, hereby leading to decisions, for example, on when to redesign products.

9. Conclusions

In this paper, we explored how a large set of cool and UX factors converge. Our paper contributes to the dimensionality explosion discussion (Bargas-Avila and Hornbæk 2011) in two ways. Firstly, we showed that the two existing questionnaires for measuring perceived

Desirability	This device can make me better	strongly disagree	<input type="radio"/>	strongly agree						
	This device can make me look in control of things	strongly disagree	<input type="radio"/>	strongly agree						
	This device can make me look good	strongly disagree	<input type="radio"/>	strongly agree						
	This device can make me happy	strongly disagree	<input type="radio"/>	strongly agree						
Rebelliousness	This device moves against the current	strongly disagree	<input type="radio"/>	strongly agree						
	This device is different	strongly disagree	<input type="radio"/>	strongly agree						
	This device is outside the ordinary	strongly disagree	<input type="radio"/>	strongly agree						
	This device stands apart from similar devices	strongly disagree	<input type="radio"/>	strongly agree						
Per. Usability	This device is simple to use	strongly disagree	<input type="radio"/>	strongly agree						
	This device is easy to use	strongly disagree	<input type="radio"/>	strongly agree						
	This device is easy to operate	strongly disagree	<input type="radio"/>	strongly agree						
	This device is easy to learn	strongly disagree	<input type="radio"/>	strongly agree						
Classic	This device has clear design	strongly disagree	<input type="radio"/>	strongly agree						
	This device has clean	strongly disagree	<input type="radio"/>	strongly agree						
Hedonic	I find this device	plain	<input type="radio"/>	eye catching						
	I find this device	boring	<input type="radio"/>	interesting						
	I judge this device to be	dull	<input type="radio"/>	captivating						
	I judge this device to be	unimaginative	<input type="radio"/>	creative						
COOL	This device is cool	strongly disagree	<input type="radio"/>	strongly agree						
	When I think of cool things, devices like this come to mind	strongly disagree	<input type="radio"/>	strongly agree						
	If I made a list of cool things, this device would be on it	strongly disagree	<input type="radio"/>	strongly agree						

Figure 8. Final perceived inner cool and outer cool questionnaire. Measured inner cool and outer cool factors and their items as well as the three evaluative items for the overall coolness judgement. The word ‘device’ can be replaced with a suitable product.

coolness converge on four factors (Table 8). Secondly, we established coolness within UX research by comparing it against established UX factors. Our resulting model shows that eleven distinct cool and UX factors (Table 7) converge on five (Figure 7 and Table 15).

Our research identified a number of implications for researchers and practitioners. In relation to UX research, first, we positioned coolness within UX by demonstrating how it relates to established UX factors. Additionally, we moved a step further by proposing an inference model, which is based on the emerged five factors and has a strong theoretical foundation that distinguishes between outer cool (the perceived aesthetic characteristics of a product) and inner cool (the perceived personality characteristics of a product). The model can be used

to explain and/or predict people’s judgemental mechanisms in relation to perceived coolness of mobile devices.

In relation to practice, firstly, we demonstrated that each of the deployed questionnaires in our two studies is reliable. Secondly, we compared the two cool questionnaires and produced a valid tool for measuring perceived inner coolness (Table 10). Finally, we produced a questionnaire (Figure 8) that measures both perceived inner and perceived outer coolness through 5 distinct factors with 18 items, and 3 evaluative items for the overall cool judgement. Both the model and the final questionnaire can be used to holistically assess users’ experiences with mobile devices.

One of the limitations of our study is that participants were asked to evaluate images and not the actual mobile

phones. As others have also used this approach, it would be interesting to investigate if the use of images as test objects leads to differences in results when compared to the use of physical artefacts. Furthermore, we believe that both our model and its resulting questionnaire are applicable to other types of digital artefacts, as it was the case with most established UX questionnaires (such as Attrakdiff2), by replacing the word ‘device’ with the product under evaluation. Nevertheless, further research is needed to test them in different conditions and for different products, to verify their generalisability and applicability.

Note

1. Tools for deploying the COOL questionnaire as well as for analysing collected data can be found in: <http://thecoolquestionnaire.weebly.com/>

Acknowledgements

We would like to thank Dr Veronica Hinkle for her invaluable help as well as all the people who participated in our studies.

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Appendix: Developing the PLS inner cool–outer cool inference model

In order to test the inferential relationship between outer cool, inner cool, and the overall coolness judgement, we applied a Partial Least Squares (PLS) analysis (Vinzi et al. 2010). This is an ideal technique for models with high complexity and when a theoretical understanding of a domain needs to be tested (Jöreskog and Wold 1982; Falk and Miller 1992).

In order to have enough data to conduct PLS, we merged the data from EFA1, EFA2, and CFA2 (1584 participants) and we focused only on final 18 items that emerged from the CFA2 (Table 15). These had to be compared with an overall coolness judgement. Bruun et al. (2016) measured overall coolness judgement through the item ‘This device is cool’, while Sundar, Tamul, and Wu (2014) did the same using the same item and eight additional ones. All nine of them were measured throughout all EFAs and CFAs. In order to narrow down their number, we conducted a reliability analysis on the overall coolness judgement, which resulted in three items: ‘When I think of cool things, devices like this come to mind’, ‘This device is cool’, and ‘If I made a list of cool things, this device would be on it’ (Cronbach $\alpha = .904$).

The dataset was analysed using the SmartPLS v2.0 software (Ringle, Wende, and Will 2006). Since we had two second-level formative factors (perceived inner and outer cool), we used the hierarchical components approach, which is the most popular when estimating higher order factors with PLS (Chin, Marcolin, and Newsted 2003; Tenenhaus et al. 2005; Wilson 2010). PLS produces the standardised regression coefficients (path estimates) between factors and we assessed the significance of path coefficients through bootstrap analysis (with $N = 5000$, as proposed by Henseler, Ringle, and Rayner 2009).

In the first step, we applied the standardised regression coefficients between desirability, perceived usability, and rebelliousness to reflect the inner cool factor, followed by the coefficients between hedonic and classic aesthetics to reflect the outer cool factor. The second step in the process was to analyse coefficients between the inner cool and outer cool factors on the overall coolness judgement for a mobile device. The final inference model can be found in the following figure.

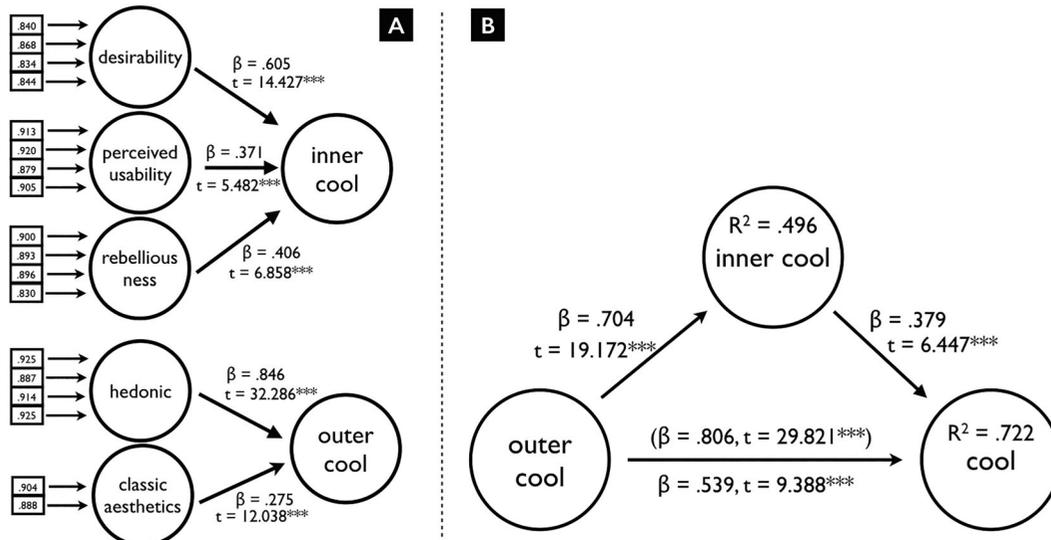


Figure A1. (A) PLS measurement and structural model for the first-order formative constructs of outer cool and inner cool with factor loadings per item and (B) PLS structural model for the second-order formative constructs of inner and outer cool and the overall judgement about the coolness of a mobile device. Values in parentheses indicate effects without inner cool. β stands for standardised regression coefficients, t for T -statistic, and R^2 for percentage of explained variance. $***p < .001$.

Two parameters are usually applied for assessing the goodness of such models: the strength of each path coefficient and the percentage of explained variance (R^2). All path coefficients in our model were statistically significant ($p < .001$) and we had one substantial and one moderate R^2 value (Chin 1998). As a last step in the process, we tested the significance of the mediation effect of inner cool, that is, whether inner cool could be excluded from the model, through a Sobel test (Sobel 1982) as recommended by Lowry and Gaskin (2014). The Sobel test value (6.206) was statistically significant ($p < .001$), which means that inner cool partially mediates outer cool in determining the overall coolness judgement of a product, and thus it cannot be ignored.