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RESEARCH PAPER

Measuring the Experience of Eudaimonic Virtues in Technology Interaction

Development and Validation of the Eudaimonic Interaction Inventory (EII)

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ABSTRACT

A growing emphasis on well-being in technology development raises the need for adequate measurement methods to quantify technology's influence on individuals' well-being. Psychological research has identified different well-being orientations, including hedonia (seeking comfort, relaxation, and pleasure) or eudaimonia, which emphasizes personal growth, excellence, meaningfulness, and authenticity. In particular, promoting eudaimonic well-being (EWB) continues to be a challenge in human-computer interaction as it manifests itself as a multidimensional construct. This paper presents the Eudaimonic Interaction Inventory, a scale for quantifying the experience of four core aspects of eudaimonic virtues (authenticity, meaning, excellence, growth) in interaction with technology. The inventory was validated through six steps across three distinct studies, resulting in twelve items categorized into four subscales. With this inventory, we hope to contribute to EWB research in technology by making future interactions with technology measurable in terms of EWB.

1 Introduction

Technology devices are daily companions in all facets of life. Not only do they serve as "a channel of information" (Calvo et al., 2020, p. 32), but they also impact the way we learn, behave, and interact with the world by influencing memorization (Fisher et al., 2022), learning (Jeno et al., 2021), and decision-making (Eisikovits & Feldman, 2022; Robbins, 1995). Decision-making has been argued to be the main source of being able to "attain a state of eudaimonia, or human flourishment" (Robbins, 1995, p. 4). Accordingly, technology could be said to impact eudaimonic well-being or even prevent humans from flourishing in the first place (Robbins, 1995). As such, human–computer interaction (HCI) research has attempted to analyze these consequences by addressing eudaimonic-oriented individuals' different demands and attitudes toward technology (Frison et al., 2017; Mekler & Hornbæk, 2016; Müller et al., 2015; Rasmussen et al., 2022). These previous works have indicated these individuals' distinct expectations towards technology, leading to the challenge of ensuring eudaimonic well-being in HCI and human-centered artificial intelligence (HCAI) (Garibay et al., 2023; Stephanidis et al., 2019; Dritsa et al., 2024). The multidimensionality of eudaimonic well-being (Huta, 2016) exacerbates the complexity of this challenge.

With the help of a comprehensive literature review on eudaimonic well-being and its conceptual understanding, Huta's (2016) four eudaimonic core concepts of orientation have been used to derive a scale for measuring the experience of these virtues in interaction with technology: The perception of the user's causal relationship between technology and the process of creation or goal fulfillment (*meaning*), the perceptions of flow within system interactions and of concentrated activities (*excellence*), the fostering of intrinsic motivation and providing sufficient authenticity perceptions during the interaction (*authenticity*), and the perception of such self-actualizing aspects as inspiration and curiosity during the interaction (*growth*). The aim of the Eudaimonic Interaction Inventory (EII) is to measure the experience with technology concerning eudaimonic-oriented individuals and their virtues.

Section 2 thus provides the theoretical foundation for the development of these four dimensions. In addition, it outlines the novelty of our scale compared to previous measurement methods, thereby justifying the scale's development. In Section 3, the process of the inventory development is described. Section 4 discusses our findings in the course of the inventory development, its limitations, and possible use cases. Lastly, Section 5 presents the conclusion to this work.

2 Related Work

Let us first outline a theoretical background and related work to illustrate the need to address the problem of eudaimonic well-being in HCI. The question of what leads to happiness can be traced back to Hellenic philosophy. Aristippus of Cyrene argued for hedonia (Waterman, 1993), namely striving for pleasure, relaxation, and comfort, which forms the doctrine of one's actions (Kraut, 1979). In *Nicomachean Ethics*, Aristotle emphasized that well-being does not fully equate to feeling good or satisfying appetites (Ross, 1999). Declaring that other factors beyond relaxation, comfort, or pleasure should contribute to individuals' well-being, the Aristotelian concept of "eudaimonia," a virtue ethic, demands that individuals strive for greater "goods," such as authenticity, excellence, meaning, and growth (Huta, 2016). These stimulate the psychological needs for autonomy, environmental mastery, personal growth, purpose in life, self-acceptance, and positive relations with others (Ryff, 2014). To create a more comprehensive understanding of the complexity of eudaimonic well-being, Huta's (2016) four dimensions of eudaimonic well-being (eudaimonic orientations, specific behavior, experiences, and functioning) are here presented.

The orientation dimension (I) – on which we focus in this article – includes the analysis of motives and values of eudaimonic-oriented individuals. As illustrated in Section 1, there are four core aspects of eudaimonic orientation: authenticity, excellence, meaning, and growth (Huta, 2016). Authenticity includes the pursuit of one's own identity and the consideration of one's self in a larger context (Pearce et al., 2021). Eudaimonic-oriented individuals strive for excellence by taking risks, striving for higher standards, and mastery orientation, rather than focusing exclusively on competition or outcome (Walker et al., 2012; Huta, 2018). This is consistent with the findings that eudaimonic-oriented individuals are less interested in demonstrative achievements than hedonic-oriented individuals, but more in the process of achievement (Walker et al., 2012). The pursuit of meaning encompasses the evaluation of one's actions according to significance, value, and resonance, but also broad implications for oneself and society (Huta, 2016). The last core aspect of eudaimonic orientation, namely growth, encompasses all forms of personal development (Ryff, 2014), such as enhancing different forms of intelligence, strengthening judgment, seeking challenges, and personal improvement.

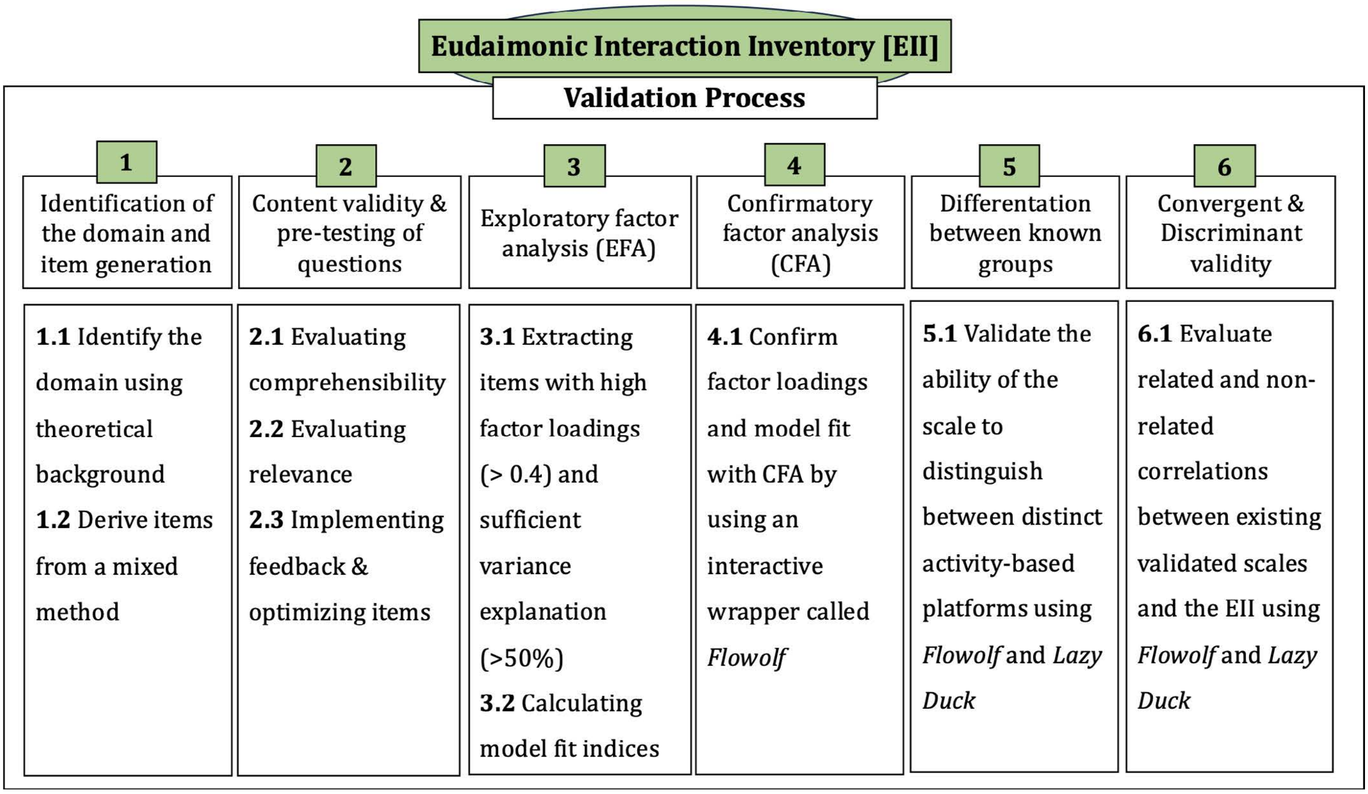
Besides eudaimonic orientations, Huta (2016) defines specific behavior (II) as another distinguished dimension. Previous studies have shown significant differences in chosen activities between eudaimonic- and hedonic-oriented individuals (Walker et al., 2012; Zuo et al., 2017). Concrete examples of specific behavior include the search for struggle and challenge (Vittersø et al., 2009), reflectiveness and reasoning (Ryan et al., 2008), maintaining close relationships (Ryff, 2014), altruism (Zuo et al., 2017), and striving for exceptional achievement (Zuo et al., 2017). The third dimension contains the analysis of cognitive-affective perceptions, understood as eudaimonic experiences (III). For example, the conceptual framework for eudaimonic emotions specifies forms of experiences, such as hope, gratitude, nostalgia, pride, awe, and adoration (Landmann, 2021). Nostalgia promotes the perception of an authentic personality of one's self (Wulf & Baldwin, 2020). Finally, the fourth dimension, eudaimonic functioning (IV), represents an overall perception of one's eudaimonic well-being in life. The individual evaluates "indices of a person's overall positive psychological functioning, mental health, and flourishing, that is, how well a person is doing" (Huta, 2015, p. 217). Experiences and functioning result from certain orientations and behaviors of eudaimonic-oriented individuals that are important for their well-being, or, as Huta (2018) argued, "Orientations and behaviors reflect the choices a person makes, whereas experiences and functioning are often outcomes of those choices" (p. 2). HCI researchers have already formulated theoretical considerations taking eudaimonic theory into account, such as "Positive Technology," "Positive Computing," and "Eudaimonic Gameplay Experience" (Riva et al., 2012; Calvo et al., 2014; Cole & Gillies, 2022). In games research in particular, contributions can be found regarding eudaimonic experiences, including complex and meaningful decision-making, meaningful interactions, or more profound emotion design (Daneels et al., 2021, 2023; Gomez & Lankes, 2023; Koek et al., 2022; Possler et al., 2023; Seaborn, 2016; Seaborn et al., 2020). However, initial studies can also be found on the general use of technologies by eudaimonic-oriented individuals. In a work-in-progress by Müller et al. (2016), a distinction has been analyzed between personal expressiveness (eudaimonic experience) and hedonic enjoyment in interaction with technology, more generally indicating distinguished experiences regarding competence, security, or the perception of autonomy. Furthermore, Mekler and Hornbæk (2016) clearly distinguished between eudaimonic and hedonic experiences of technology. Frison et al. (2017) had their participants rate the experience of different forms of autonomous and manual driving using items for eudaimonic and hedonic experiences.

However, the majority of these studies primarily measured certain experiences as dichotomous outcomes (e.g., this game mechanism felt meaningful (eudaimonic) or was simply fun (hedonic)). These studies did not aim to define meaningfulness as a construct, but more as a conceptual boundary to temporary pleasure. Furthermore, modified items of the Hedonic and Eudaimonic Motives for Activities (HEMA) Scale were used to assess the experience that has been developed to measure orientations on a state level, risking possible cross-dimensional argumentation (Huta, 2020).

Finally, it would be pertinent for us to outline why the development of the EII is justified from our perspective, alongside the Eudaimonic Technology Experience Scale (ETES), an existing scale for eudaimonic experience with technology. The ETES primarily measures a system's eudaimonic experiences using a conceptual model consisting of two dimensions (eudaimonic goals and self-knowledge). Referring to their own limitation in their work, Woźniak et al. (2023) explained that the development of a scale based on these four eudaimonic-oriented dimensions (authenticity, excellence, meaning, and growth) would imply the "assumption of a dystopian technology-saturated reality" (p. 1912), and no four-factor loading would result from the empirical data. However, to deny the derivation of the dimensions only from a basic dystopian attitude of mind did not seem reasonable to us to decline the development of the items for all dimensions and to assume a reduced conceptual model in consequence. The results of the convergent validity in particular show that the EII measures two additional levels compared to the ETES (authenticity and excellence), meaning that it can certainly be positioned as an alternative.

The development of an inventory was thus justified in order to more precisely understand the facets in which eudaimonic virtues can be experienced in interaction with technology.

Figure 1: The development of the EII in six steps



Note: This figure is intended to provide orientation throughout the paper.

3 Inventory Development

We followed best practices for scale development (Boateng et al., 2018; DeVellis & Thorpe, 2021) in the process of developing the EII. The structural process consisting of six validation steps can be seen in Figure 1. Before developing the scale items, it was necessary to first define the conceptual understanding of eudaimonic as experienced virtues in interaction with technology.

3.1 The Eudaimonic How of Technology

As per Boateng et al. (2018), the domain that serves to develop the scale should first be named. Our inventory is intended to measure the experience of four eudaimonic aspects during interactions with technology. Based on an extensive review of the HCI and psychology literature, we chose to focus on the following four core concepts of eudaimonic orientations as experienced virtues: the experience of meaning, excellence, authenticity, and growth. The characteristics of these conceptual dimensions from an HCI perspective are outlined in the following:

Meaning in Interaction: There is a strong association between eudaimonia as an orientation and the level of effort we invest in activities (Waterman, 2005). Based on the classification of different interpretations of meaning in HCI (Mekler & Hornbæk, 2019), an interaction's meaningfulness is here understood as a form of *significance*; that is, "the sense that our experiences and actions at a given moment feel important and worthwhile, yet also consequential and enduring" (Mekler & Hornbæk, 2019, p. 6). In the context of this scale development, we thus understand the eudaimonic orientation toward meaning as a virtue for a significant contribution through one's actions with the help of the technology used. When formulating the items, the main focus was on causal relationships between the user, the technology, and the outcome.

Excellence in Interaction: Ryff and Singer (2008) defined eudaimonia as "the idea of striving toward excellence based on one's unique potential" (p. 14). Huta (2015) presented a detailed characterization of the concept of excellence. Aspects of an experience of excellence in behavior, performance, or accomplishment are primarily indicated by the effort and process involved. It describes moments in which "something has culminated because you've given it your all" (Huta, 2015, p. 230). In this interpretation, it comes close to the character of flow processes (Dwight et al., 2021). Moreover, Orlick and Partington (1988) declared full focus, distraction control, and mental readiness as three of the seven elements of excellence. For Waterman et al. (2010), flow activities can be understood as activities of intense involvement being connected to such aspects as deep concentration, curiosity, and capacity to discover new perspectives, and the perception of challenge (Csikszentmihalyi, 1999; Pace, 2004). Thus, we define the experience of an activity with technology that enables a state of excellence in one's tasks through the experience of intense involvement and deep concentration. In line with the related work, we argue that flow experiences may be closely aligned with the shape of a eudaimonic experience, thus, the experience of intense involvement in an interaction may evoke a eudaimonic experience with technology where the excellence of one's activities is perceived.

Authenticity in Interaction: Huta (2016) defined authenticity as a eudaimonic virtue with the process of "clarifying one's true self and values, and acting in accord with them" (p. 216). Authenticity is also referred to in line with identity, personal expressiveness, autonomy, constitutive goals, and integrity (Huta & Waterman, 2014). Smallenbroek et al. (2017) argued that authenticity includes acting in accordance with intrinsic motivations that fulfill psychological needs. In line with the interpretation and analysis of Brühlmann et al. (2018), intrinsic motivation is the highest form of self-determination that correlates with experience of autonomy in the use of technology. The perception of authentic and autonomous instances in an interaction with technology may thus represent a form of eudaimonic experience that is resonant with eudaimonic-oriented individuals. Accordingly, this dimension should also be included in the EII.

Growth in Interaction: Self-improvement, learning, seeking challenges, striving for inspiration, curiosity, and working on one's personal best are associated activities with the eudaimonic orientation toward personal growth (Ryff, 1989; Huta & Water-man, 2014; Waterman et al., 2010; Huta, 2015). The aim is not to measure the learning success or experience of an activity, but whether the technology enables forms of learning and personal growth in the first place. From this, we can conclude that technology in interaction should also evoke experiences of personal growth – that is, the awakening of curiosity and creativity or the initiation of reflection processes.

3.2 Item Generation

To generate the items, we proceeded both deductively and inductively. During the deductive analysis, the items were generated on the basis of a literature review on eudaimonic well-being in general and on HCI research in particular. Moreover, we took existing scales into account to enable an adequate formulation of the items. These included the Psychological Well Being scale (Ryff, 1989), the HEMA scale (Huta & Waterman, 2014), the Questionnaire for Eudaimonic Well-Being (Waterman et al., 2010), or the Flourishing Scale (Diener et al., 2010). Related scales on feelings of flow, autonomy, competence, engagement, or perception of causality also served as the basis for developing the items (Burnell et al., 2023; Peters et al., 2018; Brühlmann et al., 2018; Watson & Tellegen, 1988; O'Brien et al., 2018; Norsworthy et al., 2023; Goudas et al., 1994). During the inductive analysis, we discussed possible extensions of the existing items in multiple sessions. As many items as possible were considered on the assumption that items would be eliminated in the planned two-stage item reduction analysis so as to be left with a plausible number of items to analyze. Finalizing the first step (see Figure 1), a total of 152 items were derived (35 items for meaning, 26 items for excellence, 37 items for growth, and 54 items for authenticity).

3.3 Item Reduction Analysis

In the second step (see Figure 1), we reduced the item set based on (1) comprehensibility and (2) relevance in two distinct stages to analyze both aspects. According to the development guidelines, it is necessary to achieve a consistent understanding of all items (Boateng et al., 2018). To evaluate comprehensibility, a total of six participants were asked to rate the items using a 4-point Likert scale (ranging from (1) fully not comprehensible to (4) fully comprehensible), and subsequently, the Content Validity Index (I-CVI) was calculated. The professional backgrounds of the participants were as follows: one professor of HCAI and another professor of behavioral economics, one psychologist, one social scientist, and two computer scientists. The diversity of the occupation profiles should ensure that the scale is valid and understandable in its formulations across research areas and domain expertise. Therefore, our procedure accorded with the best practices calling for a mix of experts and the target population (Boateng et al., 2018). Our minimum I-CVI value for an item was 0.83 (5 out of 6 reviewers rated an item with a minimum of 3 or 4), meaning that we achieved excellent content validity by solely allowing a minimum I-CVI for an item of 0.78 (Lynn, 1986). The initial list of items (n = 152) was reduced to 68 (–44.74%). After each submission of the ratings, we received brief feedback from the reviewers, which was used to optimize the items – for instance, we removed unsuitable comparatives, such as "very" and "highly." Technical aspects of the items were occasionally not understood; these were then simplified or removed if the I-CVI for said item was insufficient.

In the next step of evaluating relevance (2), three computer scientists with eudaimonic-related expertise checked the items for relevance to assess the experience of eudaimonic virtues in HCI in particular. Two of the three experts were external and not directly involved in writing the article. For the final relevance assessment of the remaining 68 items, only an I-CVI of 100% was accepted – that is, only if all three reviewers gave a 3 or 4 on a Likert scale (ranging from (1) fully not relevant to (4) fully relevant) for an item. This process of relevance evaluation reduced the set to a total of 38 items (–55.88%). In the final step, all authors reviewed the item pool regarding items with high similarity. One item was removed due to high content similarity to another. In total, the item pool contained 37 items, with 12 items for meaning, 10 items for growth, 8 for excellence, and 7 for authenticity. We rephrased all items with a placeholder; for example: *I don't feel passive in the interaction with [the system]*.

3.4 Exploratory Factor Analysis

The items obtained had to be validated with a larger group of participants as part of the exploratory factor analysis (EFA) (see Figure 1). According to the recommendations for EFA, 200–300 subjects are sufficient for a plausible degree of reliability of the results (Comrey, 1988; Guadagnoli & Velicer, 1988; Howard, 2016). The collection of items for the dataset was realized via Prolific, a platform that makes it possible to conduct anonymized, paid surveys. Furthermore, we used SoSci, a solution for academic online surveys to evaluate the items in the inventory. In HCI research, online studies are a common technique for scale development (Woźniak et al., 2023; Brühlmann et al., 2018). In the first study, 236 participants took part. Within the survey, they were asked to rate their experience with a freely chosen technology using the 37 items on a 7-point Likert scale (ranging from (1) strongly disagree to (7) strongly agree). The free choice of technology was allowed with regard to ensuring internal consistency and stable factor loadings of the items across diverse technology types. Simply put, the scoring of the items should be consistent in both directions (in the case of low experience of eudaimonic virtues, all items should be scored consistently in the same directions and vice versa).

All items were presented in a randomized order. They had to share a completion code to prove that they had reached the end of the survey. We followed common instructions for excluding questionable submissions via Prolific (Curran, 2016), such as answering all items with the exact same value or answering the survey very quickly in relation to others. Furthermore, an attention check was used: There was an additional item inserted (1): "[the system] helps me work fourteen months in a year" (adapted and modified from Huang et al., 2015). The answer to this is to be marked accordingly with 1 (strongly disagree) due to its being nonsensical. Finally, we evaluated 202 submissions as valid. The average processing time was 4:59 minutes. The age range was 18 to 68, with a gender proportion of 50.99% (n = 103) women and 49.01% men (n = 99). In the sample, 137 people defined themselves as White, 46 as Black, and 19 were subsumed as Others. In total, 31% of participants were students. A total of 35 nationalities participated. The five most frequently mentioned technologies were Microsoft Word (10.40%, n = 21), Instagram (7.92%, n = 16), ChatGPT (6.93%, n = 14), Facebook (5.94%, n = 12), and Netflix (5.94%, n = 12). The answers were checked for factorizability. The Kaiser-Meyer-Olkin's Test (KMO) showed optimal conditions for factorability (KMO = 0.88 > 0.8) (Kaiser, 1974). To confirm a four-factor solution, we used the Kaiser criterion (eigenvalues greater than 1) and generated a scree plot to visually evaluate the solution (Braeken & van Assen, 2017). Items with factor loadings below 0.40 were removed to reduce the dataset. In the analysis, we assumed correlations among the items (i.e., between such aspects as excellence and growth). A flow experience (in the sense of our interpretation of excellence) seems to be related to the experience of growth (Finneran & Zhang, 2005). An oblimin rotation allowing these correlations was thus chosen. For an easy application of the inventory, only three items per subscale were considered, so that the minimum number was provided and an efficient application with reliable results could be guaranteed (Boateng et al., 2018). In total, 69.75% of the variance was explained by the 4 factors and the 12 items.

All items had at least 0.4 factor loading and explained at least 50% of the variance (< 69.75%), thus emphasizing the reliability of the factor analysis results (Streiner, 1994). The Cronbach's α were all acceptable, meaning that the subscales were all internally consistent (Taber, 2018): Eudaimonic Interaction Inventory (EII, 12 items): α = 0.90; Meaning (EII-M, 3 items): α = 0.73; Excellence (EII-E, 3 items): α = 0.82; Growth (EII-G, 3 items): α = 0.88; and Authenticity (EII-A, 3 items): α = 0.70. The final set of items can be found in Table 1. All items of the EII-A are reversed items, meaning that each score was reversed accordingly (7 = 1 on the 7-point Likert scale). Theoretical model fit variables, such as the Tucker-Lewis Index (TLI) (= 0.94), Comparative Fit Index (CFI) (= 0.95), and Root Mean Square Error of Approximation (RMSEA) (= 0.06), were in the acceptable range as determined in prior research (Fabrigar et al., 1999; Byrne & Byrne, 2013). For all combinations, the 4-factor solution was calculated in a nested comparison model compared to all variants, and, except for one case, which was weakly significant, it was always significantly improved. In the case of the weakly significant model improvement, the RMSEA was lower, which we also considered as a fit indicator, so that, ultimately, based on this dataset, the 4-factor solution appeared to be optimal. The following confirmatory factor analysis (CFA) was performed to strengthen the existing inventory.

Table 1: The four dimensions of the EII (meaning, excellence, growth and authenticity), each with three items

No.	Item	Factor I	Factor II	Factor III	Factor IV	$h2$
	EII-M (Meaning)					
1	I don't feel passive in the interaction with [the system].	-0.111	-0.003	**0.485**	0.116	0.261
2	I feel involved in the process of the result with [the system].	0.060	0.056	**0.855**	0.025	0.739
3	I am largely responsible for the quality of the actions with [the system].	-0.065	-0.061	**0.738**	-0.032	0.554
	EII-E (Excellence)					
4	[The system] lets me concentrate on my task.	-0.033	**0.975**	-0.046	0.006	0.955
5	I can be concentrated when I use [the system].	0.170	**0.541**	0.147	0.010	0.343
6	[The system] lets me focus my attention.	0.070	**0.642**	0.143	0.027	0.438
	EII-G (Growth)					
7	I feel inspired by using [the system].	**0.767**	0.011	0.0556	-0.114	0.604
8	[The system] awakens my curiosity for things.	**0.712**	-0.106	-0.075	0.134	0.542
9	[The system] makes it fun to learn.	**0.756**	0.111	0.009	0.033	0.584
	EII-A (Authenticity)					
10	I use [the system] to please others, but not me. (-)	0.071	-0.008	-0.108	**0.537**	0.305
11	I feel controlled and restricted by the interface of [the system]. (-)	0.028	-0.026	0.028	**0.836**	0.702
12	[The system] prevents me from freely deciding how I want to interact. (-)	-0.087	0.114	0.058	**0.625**	0.415

Note: The items with high factor loadings on the respective factors. This results in four clear factors. The communalities (h2, explained variance by the item) can be taken from the last column. The factor loadings are rounded to three decimal places. (-) means that the item is to be calculated as reversed.

Confirmatory Factor Analysis

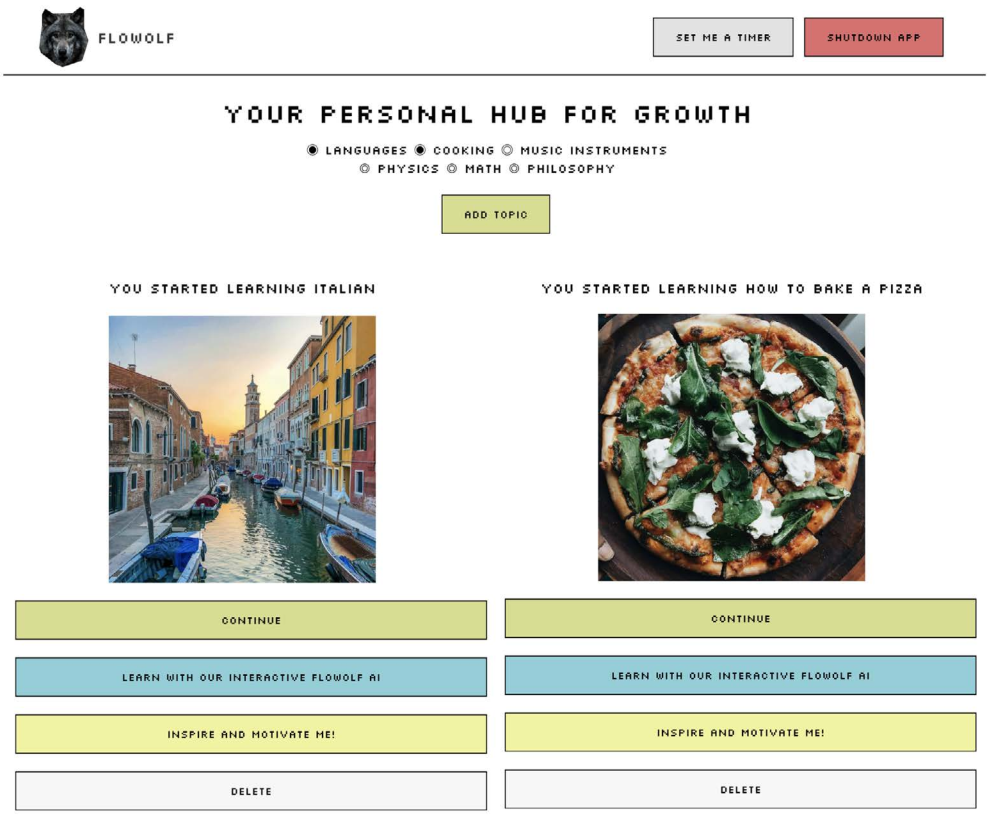
To validate the items as consistent measurement instruments for dimensions of eudaimonic virtues in interaction with technology, a new, independent sample must, first, confirm the relevance of the items and, second, demonstrate good model fit indices (Boateng et al., 2018). Thus, to test the selected factor structure, it is common to perform a CFA, which is used to test dimensionality (Boateng et al., 2018). A CFA is applied to evaluate the identical shape of items, factors, and functional relationships across two independent samples. Known model fit indices have been used for this: RMSEA, TLI, and CFI. As the fourth step (see Figure 1), we conducted a CFA. In the second distinct setting of our study, an interactive wrapper was developed using concepts of eudaimonic-oriented activities and design heuristics to promote psychological well-being in interaction with technology (Pace, 2004; Peters, 2023; Peters et al., 2018; Finneran & Zhang, 2005; Burnell et al., 2023). The system recommends activities for the user's personal growth and inspiration, such as selected content of altruism, universalism, and contributions to a bigger picture. We thought of the palindrome flow (a word that is the same backward or forms another valid word (flow = wolf)), resulting in the name *Flowolf* for the prototype. In the survey, participants were able to view finished screenshots of the demo and use it interactively via a web link. Figure 2 shows a part of the demo that was available to the user both as screenshots in the questionnaire system and interactively via a link. The participants had to evaluate the interactivity with the wrapper using the new items. A total of 292 participants took part in the second survey. None of those from the first study took part in the second (prevented by an exclusion list via Prolific). The average submission time was 2:55 minutes. When providing demographic data, a small number of participants refused to provide such data and were thus anonymized. The age range was 18–69 (stated by 290 participants), including 143 women (49.65%) and 145 men (50.35%) (stated by 288 participants). In terms of ethnicity, 184 people described themselves as White (63.89%) and 67 as Black (23.26%). Lastly, 37 participants were subsumed under "Others," as in the first study. A total of 43 nationalities were involved in the study. Students represented 32% of the participants. The Cronbach's α were acceptable (Shi et al., 2012; Taber, 2018): EII: $\alpha = 0.87$; EII-M: $\alpha = 0.61$; EII-E: $\alpha = 0.92$; EII-G: $\alpha = 0.88$; and EII-A: $\alpha = 0.77$. The loading of item no. 3 ("I don't feel passive in the interaction with Flowolf") was, while acceptable (0.70–0.72, i.e., > 0.3; Hair, 2009), lower (0.39) than the other items. In this constellation with four factors, 75.77% of the variance could be explained. We used the *semopy* (https://semopy.com/index.html) package to generate the structural equation model using a maximum likelihood estimator (Wishart log-likelihood). The chi-square value of the model (see Figure 3) was not significant ($\chi2 = 54.43$, $p = 0.23$), leading us to assume a good model of fit (Alavi et al., 2020). The fit indices show an even better model fit than in the first study (CFI = 0.996, TLI = 0.995, RMSEA = 0.021), as expected. The scale could therefore be confirmed in this second study.

3.5 Differentiation

The fifth step involved validating that the scale could differentiate between the perception of a system harmonizing eudaimonic virtues and an alternative system. Otherwise, we would not be able to identify systems that may fulfill less of the experience of eudaimonic virtues in interaction with technology. To reach the differentiation validity, a second demo, *LazyDuck*, was developed in addition to *Flowolf*, which was intended to promote feelings of relaxation, pleasure, and comfort in the interaction, and thus represent a hedonic-oriented system design. The *LazyDuck* system offers the user entertaining or relaxing videos without much customization. Users can click on these videos that are randomly extracted from a manually created list. We generated thumbnails for videos on *LazyDuck* with Crayon, a free AI image generator (https://www.craiyon.com/). In addition, the same page layout as *Flowolf* was used to prevent other effects on the EII's evaluation. Figure 4 shows the system design of *LazyDuck*. For the setting of our final study, participants from the first and second studies were again technically excluded. Participants were randomly assigned to a group (*Flowolf* or *LazyDuck*). An attention check was used in which they were asked to specifically tick "strongly disagree." After interacting with the demo, they were asked to rate the interaction using the EII. For a normal distribution of the data, a t-test was performed to determine whether the EII responses were significantly different. For a non-normal distribution, the Mann-Whitney *U* test was used (MacFarland & Yates, 2016).

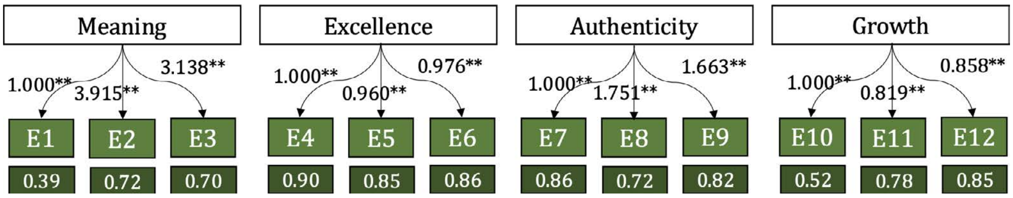
For the third study, 86 valid submissions were used for the evaluation. The manual review revealed contradictory entries, which we marked as not serious submissions (n = 12, 12.24% of all submissions (n = 98)). Among them, someone accidentally entered their name in a text field for entering the anonymized Prolific ID to provide payment, leading us to remove this non-anonymized submission. The age range was 18–71. Regarding gender, 41 women (47.67%) and 45 men (52.23%) participated in the study. Moreover, 63 participants identified as White and 10 as Black, and 13 as Others. In total, 22 nationalities took part, and 33% of the participants were students. The average completion time was 07:35 minutes. In preparation for the following validation step, we collected additional scale scores, which explains the increase in completion time. The Cronbach's α were also acceptable (Shi et al., 2012; Taber, 2018): EII (all items): $\alpha = 0.85$; EII-M: $\alpha = 0.69$; EII-E: $\alpha = 0.90$; EII-G: $\alpha = 0.79$; and EII-A: $\alpha = 0.90$. The Shapiro-Wilk test (Shapiro & Wilk, 1965) showed no normal distribution of the data ($W = 31.48$, $p < 0.000$), so the Mann-Whitney U test was used (Mann & Whitney, 1947). For all subscales, the test statistic U was significant ($\alpha = 0.05 > p$): $U = 69365.6$, $p < 0.000$*** (EII); $U = 6371.5$, $p < 0.000$*** (EII-M); $U = 7057.0$, $p < 0.05$* (EII-E); $U = 4786.0$, $p < 0.000$*** (EII-G); and $U = 6622.5$, $p < 0.01$** (EII-A). The differences in central tendencies in the groups were significantly different from zero, meaning that the scale showed different values for different technology types (eudaimonic- or hedonic-oriented technology). In other words, participants in the *Flowolf* group gave statistically significantly higher scores than their counterparts in the *LazyDuck* group. The scale could thus be said to make a valid distinction between experience with eudaimonic- and hedonic-oriented activity-focused platforms. The final stage of our validation required correlations with other related scales. With the help of the third study, further scale data were collected, which were used for the subsequent convergent validity to show the correlation of the EII with existing scales and also the discriminant validity to indicate a low correlation with conceptually unrelated concepts, such as the extrinsic motivation to use technology.

Figure 2: Screenshot of the first web-based demo of Flowolf.
Source: https://tech.joersi.com/flowolf/



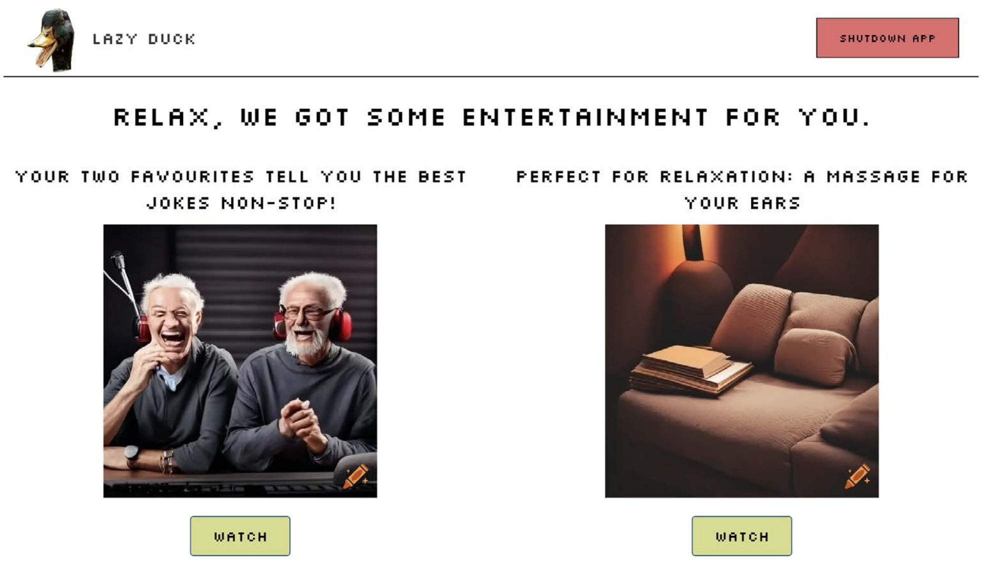
Note: Flowolf is a system for promoting personal growth through learning interaction and the discovery of new content. Extensive filter options and possibilities are designed to give the user a sense of autonomy in direct interaction.

Figure 3: A graphical representation of the beta estimator values of the three items of the four dimensions (meaning, excellence, authenticity and growth) of the Confirmatory Factory Analysis (CFA)



Note: Model fit of the second study with 292 participants: The direction arrows show the estimators of the model for the respective item. All p-values show significant estimators in the model ($p < 0.01$**). The factor loadings for each item are noted in the dark green boxes.

Figure 4: Screenshot of the first web-based demo of Lazyduck. With LazyDuck, random entertainment videos can be consumed on the web using a predefined video repertoire. Source: https://tech.joersi.com/lazyduck/



Note: The page layout and font are identical to Flowolf.

3.6 Convergent & Discriminant Validity

The sixth and final validation step relates to convergent and discriminant validity, where we seek to showcase that the EII leads to similar results to related scales and does not correlate with non-related scales. If, for example, there were a lower correlation with the intrinsic motives of technology interaction (Brühlmann et al., 2018) or comparative scales, such as the ETES (Woźniak et al., 2023), then the scale could not be validated in this respect. Therefore, the Pearson correlation coefficients were calculated with already validated scales, as recommended in the guidelines for demonstrating convergent and discriminant validity (Boateng et al., 2018). The following scales and subscales were used for validation:

User Motivation Inventory (UMI): The UMI (Brühlmann et al., 2018) contains various motivations when using technology, such as a continuum of motivation to use technology (from extrinsic to intrinsic) originating from self-determination theory (Ryan & Deci, 2000). Following the instructions for using the UMI, we calculated average values for both groups (intrinsic and extrinsic) and formed a correlation with our scale. In Table 2, these scales have been abbreviated as "UMI-Intr." and "UMI-Extr." A high correlation of EII with intrinsic motivation is expected.

Technology-based Experience of Need Satisfaction Scales (TENS): The TENS subscales have three aspects of investigation (autonomy, competence, relatedness) and are divided into four spheres each (life, behavior, task, and interface) and two subscales that are intended to measure support or frustration for the respective aspects of investigation (Burnell et al., 2023). For example, the scale can help analyze differences between perceptions of autonomy and competence in direct contact with technology (interface sphere) and perceptions at higher levels, such as the execution of tasks (task sphere), behavior (behavior sphere), or even in the life of the user (life sphere). In Table 2, the subscales have been abbreviated for enhanced readability. It seems reasonable that the EII correlates positively with the scales for autonomy and competence in the interface and behavior sphere.

Eudaimonic Technology Experience Scale (ETES): As a final check, the EII should correlate with the ETES (Woźniak et al., 2023), so that the harmonization of eudaimonic virtues and experiences measured by both respective scales correlate. The ETES has two subscales: Eudaimonic goals (ETES-EG) and Self-knowledge (ETES-SK). The items of the subscale ETES-EG ask for the experience of aspiration or goal pursuit, while the ETES-SK contains items relating to the experience of one's deepest feelings or the connection to a true self.

Except for the UMI subscale for extrinsic motivation, which (as expected) negatively correlated with the EII (–0.27) as expected, the EII correlated positively with all other scales, at least moderately (> 0.4) (Schober et al., 2018). All correlations tested in relation to the EII were significant ($p < 0.05$). Accordingly, convergent validity could be said to have been achieved. Furthermore, we derived the discriminant validity from the negative correlations with UMI scales for extrinsic motivation. All results of the correlation analysis can be seen in detail in Table 2.

Table 2: Correlation data of the EII with other contextually related scales (ETES, UMI, TENS), as part of the convergent or discriminant validity analysis ETES).

	EII	EII-M	EII-E	EII-A	EII-G	UMI-Intr.	UMI-Extr.	TENS-B.-A.[1]	TENS-T.-C.[1]	TENS-I.-A.[1]	TENS-I.-C.[1]	ETES	ETES-SK	ETES-EG
EII	1													
EII-M	0.77**	1												
EII-E	0.67**	0.4**	1											
EII-A	0.60**	0.29**	0.14	1										
EII-G	0.82**	0.58**	0.48**	0.25*	1									
UMI-Intr.	0.74**	0.57**	0.37**	0.34**	0.80**	1								
UMI-Extr.	-0.27*	-0.18	-0.26*	-0.27*	-0.08	-0.11	1							
TENS-B.-A.	0.64**	0.54**	0.39**	0.21	0.69**	0.77**	-0.18	1						
TENS-B.-C.	0.59**	0.44**	0.40**	0.25*	0.59**	0.39**	-0.10	0.65**	1					
TENS-I.-A. (S)	0.66**	0.53**	0.28**	0.36**	0.67**	0.77**	-0.12	0.73**	0.64**	1				
TENS-I.-C. (S)	0.43**	0.27**	0.49**	0.23*	0.28**	0.72**	-0.29**	0.43**	0.59**	0.39**	1			
ETES	0.68**	0.49**	0.37**	0.29**	0.77**	0.73**	-0.02	0.52**	0.60**	0.68**	0.28**	1		
ETES-SK	0.55**	0.41**	0.33**	0.19	0.63**	0.60**	0.10	0.41**	0.49**	0.61**	0.26*	0.92**	1	
ETES-EG	0.71**	0.49**	0.36**	0.35**	0.78**	0.74**	-0.14	0.54**	0.61**	0.64**	0.25*	0.92**	0.70**	1

Note: All correlations (no threshold) with the subscales used (UMI, TENS, and ETES). The subscale of the UMI on extrinsic motivation shows no or weak negative correlation with other scales including EII ($p < 0.05$*, $p < 0.01$**). Correlations with the support items; for reasons of readability, the frustration items were not shown. They can be found in the supplementary material.

3.7 Usage & Application

After conducting three studies, the four-dimensioned EII can be used for future research. A total of 12 items, of which 3 each relate to one of the 4 dimensions (authenticity, excellence, meaning, and growth), are to be assessed using a 7-point Likert scale. The following instruction can be chosen for the use of the EII in the course of a study: *"Please rate the following statements about the interaction with [the system] on a scale from 1 (strongly disagree) to 7 (strongly agree)."* The EII appears as particularly generically applicable for all types of technology and groups of participants for two reasons: First, each study featured a highly diverse group of users (nationalities, genders, place of residence), for which the EII was validated across all demographic groups in all steps. Secondly, in the first study, all items referred to a freely selectable technology, so that the factor loadings for the respective items proved to be consistent across multiple technology types. However, the scale was primarily verified via web-based applications and, specifically during the EFA, with desktop-based applications (e.g., Microsoft Word). However, it should be used while bearing in mind that virtual reality applications were not tested, so that the scale application is primarily limited to screen or web-based applications (*Flowolf* is also a web-based desktop application) and mainly as a means for design research purposes instead of changing orientations or directly influencing the eudaimonic well-being of the user.

4 Discussion

The aim of this contribution was the conceptualization, development, and validation of a measurement instrument for the experience with technology in terms of the four eudaimonic virtues based on a review of the literature on eudaimonic well-being. In three separate studies, the results showed that the EII is an adequate instrument for measuring the experience of these virtues during an interaction with technology. The low cross-loadings show a reliable measurement of the respective dimensions (authenticity, meaning, excellence, and growth). The detailed description of statistical parameters, factor loadings, and evaluation steps is intended to ensure transparency in the development of the scale. The correlations with other scales (e.g., UMI, TENS, and ETES) indicate a consistent development from the theoretical background. In the following, the most important findings in scale development are discussed and placed in the canon of existing literature.

4.1 Different Meaning of Technology for Eudaimonia

Overall, the results show that the four categories of eudaimonic orientations as experienced virtues (authenticity, excellence, meaning, and growth) were a solid basis for the development of the EII, and thus accord with the existing philosophical-psychological research. For example, our items for meaning indicate that this orientation is addressed by perceptions of involvement in the development of the outcome, responsibility for the actions, and abstinence from passivity in the interaction. The loading items support the theoretical foundations (Csikszentmihalyi, 1999; Finneran & Zhang, 2005; Pace, 2004). However, one finding of the analysis was the solely acceptable internal consistency of the meaning subscale across all studies. This inconsistency was caused to a greater extent by the question about passivity in interaction (Item 1). This item was formulated mainly due to the importance of intense involvement for eudaimonic-oriented individuals in their activities (Waterman et al., 2010). However, a certain group of eudaimonic-oriented individuals seems to position themselves differently in terms of technology use. As shown by Mekler and Hornbæk (2016), these individuals regard technology as more of a pragmatic tool. For example, when tuning a guitar, an app may provide pragmatic support in tuning it correctly. The eudaimonic-oriented individual may initially be passive before pursuing personal growth in a practice process with the tuned guitar. In this case, the tuner is merely an enabler of their eudaimonic activities. This may explain the somewhat lower significance of non-passivity during the interaction with technology. However, it is limited to a smaller subset of participants, but it is certainly a relevant research object to distinguish these usage intentions. This assumption is in line with the theory of multiple forms of meaning in HCI (Mekler & Hornbæk, 2019): Technology can be used very pragmatically, and thus holds meaning as a tool. Otherwise, an attempt can be made to enable eudaimonic-oriented individuals to interact within the technical environment, such as through games generating eudaimonic experiences. Consequently, this technology itself is the origin of a eudaimonic experience.

4.2 The Importance of Authenticity and Excellence

After the item generation, three reversed items remained in the assessment of authenticity during the interaction. In line with Tuch and Hornbæk (2015), our results show that technology cannot lead to “more authentic” perceptions of the individual, but it seems that it must fulfill a minimum level. Our items appear to be similar to those of the UMI (Brühlmann et al., 2018), emphasizing that the interaction with technology should be intrinsically accepted and not extrinsically nudged. This rejection of externalization comes close to the critical view of quantified-self technologies (Gerdenitsch et al., 2023), which states that the development of such technologies must be designed with profound design considerations, as they can have negative effects on the individual. In a recent contribution to modern software engineering, Doyuran (2024) also showed concern that this instrumentalization of activities can be a problematic shift in motivation. The results show that the construct of excellence can be considered close to an experience of concentration in interaction with technology. Our literature study has confirmed this perspective on excellence (Orlick & Partington, 1988; Csikszentmihalyi, 1999; Pace, 2004; Huta, 2015).

This is also a structural nuance of the EII that we can position in relation to the ETES: We were able to claim a form of convergent validity between the EII and ETES. However, the validity was mostly based on the two subscales of meaning and, especially, growth (strongest correlation). In its two-dimensionality, the ETES with questions on an experience of learning and goal fulfillment primarily addresses the orientation toward personal growth. This can also be explained by the fact that the ETES's subscale for eudaimonic goals correlates strongly with the EII's subscale for growth based on the correlation evaluation defined by Schober et al. (2018). However, there are weak values (< 0.4) for the dimensions of authenticity and excellence (evaluation is also based on Schober et al. (2018)), so that the correlation can mainly be explained by the dimension of personal growth (the experience of learning). It appears that the ETES primarily addresses this virtue of growth. The EII can be used to examine the experience of other virtues, such as authenticity and excellence, thus speaking to its structural strength.

4.3 Emphasizing Personal Growth

Finally, regarding differentiation validity, the assumption that eudaimonic-specific orientations may exist (Huta, 2020), and these orientations can be experienced during a system interaction, can be supported. We showed that the hedonic-based platform *Lazyduck* is significantly less "satisfactory" in terms of eudaimonic virtues for the participants. For eudaimonic-oriented individuals, learning as an activity is an important reason for technology use in general (Mekler & Hornbæk, 2016). Our results show that the awakening of curiosity and inspiration, and the facilitation of learning processes are particularly important during an interaction. For example, Item 7 (*I feel inspired by using [the system]*) indicates the stimulation of inspiration leading to elevating experiences, and thus an experience of a eudaimonic emotion (Landmann, 2021).

4.4 Relevance for Future Research

The application of the EII seems particularly important in an educational context, and the analysis of more proactive technologies (e.g., AI). Ensuring eudaimonic well-being in work and life is of no small importance. If the interpretations of Robbins (1995) are valid, the increasing involvement of technology in (creative) work is a shift of decision-making to technology that makes a demand for serious human-centered approaches doubtful. The scale primarily serves to measure the experience of these four eudaimonic dimensions of action in interaction with technology. Longitudinal studies – realized through the help of the EII – are a promising approach to evaluate the long-term effects of a eudaimonic experience in interactions with technology. Thus, one possible purpose may be to determine that a technology interaction has led to a long-term shift in participants through value-change measurements (e.g., the value survey of Schwartz, 1992) or using self-reflective follow-ups. In this way, possible correlations from the technology interaction can be examined for long-term effects on the eudaimonic well-being of the participant.

4.5 Limitations

Finally, this study's limitations are here outlined. The EII is limited to the four determined dimensions that have emerged based on the work of Huta (2016). In particular, other relevant aspects of eudaimonic functioning, such as the influence on positive relationships with others and thus the social context in general, were not considered. Especially for the analysis of social technologies, the measurement of profound developments of social contacts may be important, which has yet to be mapped within the EII. Furthermore, a very strict selection strategy in identifying comprehensible and relevant items was applied, so that only 24.34% of the original items (152 items reduced to 37) remained. This is merely intended to express the limitation that other relevant aspects may have been removed or failed to be formulated comprehensibly. An improved formulation might have allowed further aspects to be taken into account. Nevertheless, the items were discussed with the reviewers, so that we essentially always checked whether larger misinterpretations had occurred. Moreover, the scale was validated exclusively via an online survey. We cannot completely rule out the possibility that the survey was not processed with full seriousness and can only make assumptions using standard statistical methods (e.g., in the event of signs of abnormal behavior). Nevertheless, a variety of attention checks were used to mitigate this limitation to the robustness of the results. The EII was also only validated with web applications, meaning that alternative forms of input (e.g., virtual headsets or haptic input devices) were not taken into account.

Finally, the absence of a further validation step should be mentioned: the temporal component of the inventory (also called test-retest validity). The results of the previous tests should be validated again at a later date with a further sample to ensure the EII's stability over time. Overall, however, the structured approach to the development of the inventory – and, in particular, the number of participants – gives us the assumption that the necessary precautions have been taken to prevent incorrect behavior and ensure the consistency of the selected items.

5 Conclusion

This paper has presented the Eudaimonic Interaction Inventory, a scale for eudaimonic technology interaction that focuses on eudaimonic virtues during an interaction with technology, emphasizing the four eudaimonic dimensions: authenticity, meaning, excellence, and growth. This was based on a literature review of past eudaimonic research, including empirical work, theoretical models, validated scales, and related theory developments. The derived items were validated according to scale development guidelines. The EII is intended to complement existing scale uses in the future to address the need for multiple measurement tools for eudaimonic technology interaction.

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