Choosing a Questionnaire Measuring Connectedness to Nature for Human–Computer Interaction User Studies

Choisir un questionnaire mesurant le rapport à la nature pour

des études utilisateur en Interaction Humain-Machine

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ABSTRACT

Evaluation of human–computer interfaces that aim at shaping users' pro-environmental attitudes and behaviors should consider measuring participants' affinity with nature: analyses of user studies in this context have to discriminate a possible effect on the results. This paper proposes to guide the choice between 21 questionnaires available in the literature measuring the Connectedness to Nature (CtN) construct. We thus share a review and an analysis that we made to choose one scale questionnaire for our needs of a user study recruiting in public places and a longitudinal user study aiming to evaluate the use and impact of shape-changing interfaces at workplaces to assist pro-environmental behavior. This paper analyzes questionnaires through eight criteria for Sustainable HCI user studies, reports some meta-analyses' results, illustrates two questionnaire choices, then overviews the limitations of available questionnaires for user studies in HCI.

RÉSUMÉ

L'évaluation d'interfaces humain-machine visant à agir sur les attitudes et les comportements pro-environnementaux de leurs utilisateurs devrait tenir compte du rapport à la nature des participants : l'analyse d'études utilisateur dans ce contexte doit en effet pouvoir discriminer un possible effet sur les résultats obtenus. Cet article propose de guider le choix parmi 21 questionnaires issus de la littérature mesurant le rapport à la nature (via des échelles du construit *Connectedness to Nature*, CtN). Nous reprenons une revue et une analyse que nous avons conduites pour en choisir un répondant à nos besoins pour une étude recrutant sur l'espace public et pour étude utilisateur longitudinale visant à évaluer l'utilisation et l'impact d'interfaces à changement de forme sur des lieux de travail afin d'accompagner un comportement environnemental. Cet article analyse les questionnaires selon huit critères relatifs aux études utilisateurs en IHM pour la soutenabilité, reprend les résultats de méta-analyses et illustre deux choix de questionnaire,

puis revient sur les limitations de l'offre de questionnaires pour des études utilisateur en IHM.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; • **General and reference** → *Evaluation*; • **Social and professional topics** → *Sustainability*; • **Applied computing** → Psychology.

KEYWORDS

HCI; Sustainable HCI; Sustainability through Design; User studies; Environmental psychology; Attitudes measurement; Pro-environmental values; Questionnaire; Connectedness to Nature.

MOTS CLÉS

IHM ; IHM durable ; Soutenabilité par la conception ; Études utilisateur ; Psychologie environnementale ; Mesure des attitudes ; Valeurs pro-environnementales ; Questionnaire ; Rapport à la nature ; Connectivité à la nature.

1 INTRODUCTION

Some environmental consequences of human activities are already unavoidable. For example, the sixth IPCC's Assessment Report on climate change states in 2021: *"Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5 [The fifth Assessment Report in 2013]"* [48]. However, impactful actions are possible for a better future. User Interfaces that help users limit resource consumption are part of such strategies. Even so, approaches merely aiming to improve technological efficiency (energy consumption or production of technologies) will not be sufficient to achieve sustainability [33]. These approaches must thus be combined with sufficiency strategies [33], which aim at changing users' behavior. HCI thus has a role to play to help

users control their energy consumption and have beneficial impacts to overcome the current environmental crisis.

Sustainable HCI (SHCI) adds environmental considerations to HCI objectives. Mankoff et al. [45] distinguish two approaches in SHCI. First, Sustainability *in* Design aims to mitigate software and hardware's material effects on the environment (in line with Green IT approaches) and reduce rapid product obsolescence cycles [4]. Second, Sustainability *through* Design (SHCI-TD) aims to influence decision-making and sustainable lifestyles—this work follows this second approach. Di Salvo et al. [19] identify persuasive technology as a major genre of SHCI-TD. Fogg defines *persuasive technology* as an interactive technology that changes attitudes or behaviors [27]. In order to influence environmental behavior, SHCI-TD systems can provide information to users about their degree of sustainability (like wasting, recycling, or saving resources) or their degree of resources' consumption (e.g., water [1, 28, 41] and energy [14, 15]). Although a controversy calls into question these work because tackling small individual gestures and considering users as resource managers [8, 21, 80], the community strives to reorient systems on socially-shared practices [38, 39, 59, 65].

We consider two illustrative cases. First, some systems aim to change people's attitudes by interacting shortly in public places (e.g., StationENR [64]). Second, some systems aim to shape or assist people's behavior in the long term in semi-public spaces such as workplaces (e.g., CairnFORM [14]). Evaluating and assessing such systems' impact on what users think and how users behave should consider gauging an environmental index about participants' affinity toward nature[1]. Such an index would indeed be helpful for the needs of user studies results' interpretation and work replicability and reproducibility, when comparing efficiency between groups and between studies.

Since the 1970's—when the environmental concern started raising attention—the social and behavioral sciences' literature developed tools measuring pro-environmental attitude (e.g., New Ecological Paradigm [22]) and behavior (e.g., General Ecological Behavior [34, 35]). Some tools ask respondents about what they *think* (values, beliefs, feelings) [23, 49], what they *do* (behavior) [34, 35], or what they *are* (identity) [10] about nature. These tools aim to measure how much people relate, or not, to nature. Wilson's biophilia hypothesis [84] outlines the innate human affinity for life and lifelike processes, but numerous drivers disconnect humans from nature [85]. For example, the urban lifestyle contributes to a loss of affective and cognitive relationships with nature [2].

The extent to which each individual relates to nature is thus variable. Based on the assumption that the separation between the vision of the self (or humanity) and nature contributes to the lack of willingness to act to preserve nature, environmental psychologists developed tools to measure this affinity through the concept of Connectedness to Nature [2] (CtN). These tools

are scales measuring Connectedness to Nature constructs, using questionnaires about knowledge, beliefs (including worldviews), affect, motives, behavior, and identity. Environmental psychologists found that Connectedness to Nature is positively linked with environmental behavior [85]—what makes it a reliable measure for SHCI user studies needs.

This paper shares a review and an analysis that we made to choose a Connectedness to Nature scale for our needs of a longitudinal user study aiming at evaluating the use and impact of shape-changing interfaces to assist behavior change on semi-public spaces (e.g., displaying renewable-energy and behavior-feedback data). These interfaces will assist users at workplaces toward pro-environmental behaviors, as does CairnFORM [13, 14]: the behavioral changes that we study are about specific tasks—not about a global lifestyle change.

Choosing a Connectedness to Nature questionnaire for the needs of Sustainable HCI user studies requires HCI researchers to explore a variety of work: scales and their questionnaires are spread among several papers, are sometimes revised or adapted, and are often cited with different names and acronyms. Hence, the choice of a questionnaire could benefit from some guidance. We ask the following question: how to choose a questionnaire for evaluation needs in Sustainable HCI? This paper proposes eight criteria related to the context of SHCI-TD user studies, uses them to classify and analyze 21 scales and their questionnaires, and then summarizes experimental validations and comparisons between eight of those questionnaires. Then, we illustrate questionnaire choices for two cases. Finally, we expose our analysis of scales' limitations for SHCI needs and discuss recommendations for the HCI community.

2   RELATED WORK

The performance or success of Sustainable HCI systems designed to affect lifestyles lies in their impact on users' behavior: the question of measuring "sustainability impact" is thus addressed by the Sustainable HCI community. In 2010, Silberman and Tomlinson [77] distinguish three approaches to evaluate Sustainable HCI projects: (1) the *principles* approach checks that the project matches with some global principles for sustainability defined by experts; (2) the *heuristics* approach measures some indicators (e.g., resulting from user behaviors or device designs); (3) the *indices* approach measures composite environmental indices (e.g., ecological footprint). In 2017, Remy et al. [62] list four ways to assess impact in Sustainability *through* Design: large-scale deployments, long-term studies, participatory design, and goals redefinition with different models. In 2018, Remy et al. [61] propose a metamodel to evaluate research artifacts in HCI to provide guidance for evaluations in Sustainable HCI. Whereas pro-environmental knowledge, beliefs (including worldviews), affect, motives, activities, and identity seem a prerequisite to sustainable behavior and lifestyle [49], measuring these environmental values and identity seems absent from previous work on Sustainability *through* Design evaluation, even though they can affect systems' performance and results' interpretation.

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[1]The word "nature" refers to all the living entities other than human and non-living entities not human-made. "Nature" is a social construct: its definition is highly variable across cultures and reflects interactions and perceptions of other living entities [18].
[2]The word "connectedness" refers to connection, mutual dependence (being linked), and a sense of belonging or affinity. *Connectedness to Nature* is now established as the leading term of the measure [63]; however, several terms refer to this concept in the literature, such as *Connection to Nature, Connection with Nature, Connectedness with Nature, Nature Relatedness, Human–Nature Relationships,* or *Affinity with Nature*. A practitioner's guide is available to the interested reader [66].

3 CONNECTEDNESS TO NATURE

The Connectedness to Nature concept provides a framework to capture respondents' relationship toward the environment and nature. This concept from environmental psychology refers to the identification and relationship with nature that is personal for each one. Zylstra et al. refer to Connectedness to Nature as *"a stable state of consciousness comprising symbiotic cognitive, affective, and experiential traits that reflect, through consistent attitudes and behaviors, a sustained awareness of the interrelatedness between one's self and the rest of nature"* [85]. Thus, the Connectedness to Nature construct can be considered as the outcome of nature-related dimensions comprising [63, 85]: (1) *cognitive dimensions* (knowledge and beliefs); (2) *affective dimensions* (feelings and emotions); (3) *behavioral dimensions* (actions and experience).

The Connectedness to Nature concept encompasses numerous constructs varying according to their importance to the cognitive, affective, and behavioral dimensions. For example, the *love and care for nature* construct [57] emphasizes affective aspects, and the *disposition to connect with nature* construct [6] emphasizes affective and behavioral dimensions. We illustrate the Connectedness to Nature concept in Figure 1. We merge environmental *motives* with *affects* as the related scale asks respondents what they care about (i.e., environmental problem consequences that concerned them the most) [71]. In addition, we make *identity* a dimension of Connectedness to Nature because several scales emphasize the inclusion of nature in identity [10, 44, 72]. Committed Connectedness to Nature refers to the sustained embodiment of Connectedness to Nature as a behavioral set to serve social and ecological communities through transformative leadership [85]. This behavioral set includes pro-environmental behavior such as experimenting and improvising for self-sufficiency [85].

The level of Connectedness to Nature can be measured using evaluation tools: constructs' dimensions are measured using scales shaped as questionnaires comprising items, as illustrated in Figure 2. Scales can be composed of sub-scales or divided into categories. For example, EAATE [83] contains three categories: environmental apathy, anthropocentrism, and ecocentrism. Each sub-scale or category has specific items. Items' measurements provide values that can be computed for each sub-scale or category. The whole questionnaire provides an overall measured value of the construct. We detail these constructs and tools in the following sections.

As literature reviews reported [63, 85], several empirical studies suggest that Connectedness to Nature strongly predicts environmental behavior. Thus, users with a high connection to nature will be more likely to exhibit environmental behavior already or change their behavior to a more environmentally-friendly one. As well, the reverse relationship is possible. For example, Ernest and Theimer [26] show that performing an environmental behavior strengthens children's Connectedness to Nature.

4 CRITERIA FOR SHCI-TD STUDIES

This section presents eight criteria to select and compare tools measuring Connectedness to Nature. We choose those criteria according to the measurable characteristics of Connectedness to Nature scales and the needs of SHCI-TD user studies.
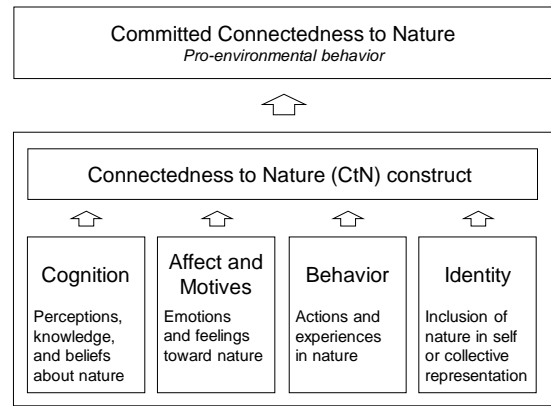

Figure 1: Illustration of the Connectedness to Nature concept and its dimensions based on Restall and Conrad [63], and Zylstra et al. 's [85] descriptions.
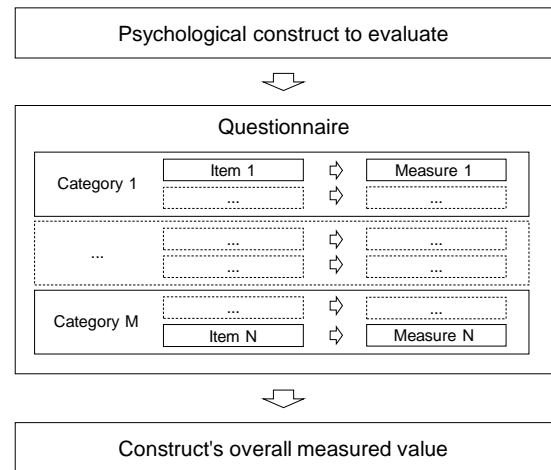

Figure 2: Illustration of scales toolchains.

4.1 Point of View

We discriminate four points of view that are used in questionnaires to place respondents' thinking when they are reading the items:

- Aggregate ('A'): Items' scope is humanity viewed by respondents. Example: *"**Humans** were meant to rule over the rest of nature"* [23]. These items are usually measured using Likert scales (i.e., from "Strongly Disagree" to "Strongly Agree");
- Individual ('I'): Items' scope is the respondent's view of himself. Example: *"When **I** think of my place on Earth, **I** consider **myself** to be a top member of a hierarchy that exists in nature"* [49]. These items are usually measured using Likert scales (i.e., from "Strongly Disagree" to "Strongly Agree"), but can also be measured using frequency scales (i.e., from "Never" to "Always"), identity scales (i.e., from "Not at all true of me" to "Completely true of me"), or Venn Diagrams (i.e., a series of pairs of circles—one representing "Me", the other one "nature"—that overlap more or less);

- Portrait ('P'): Items' scope is the respondent's view of himself relative to others. Example: *"It is important for **her** to be in unity with nature"* [5]. These items are measured using portrait scales (i.e., from "Not like me at all" to "Very much like me");
- Concept ('C'): Some concepts are described using only a few words; respondents rate their connectedness with a concept or associate some concepts together. Example: rating *"PREVENTING POLLUTION"* [79], or associating *"ANIMAL"* with *"NATURE"* or *"BUILT"* [73]. These items are rated using importance scales (from -1: "opposed to my values", to 0: "not important", to 7: "of supreme importance") [79], or measured using association response speed [73].

4.2 Construct Dimensions

Questionnaires vary according to Connectedness to Nature's measurable dimensions. Restal et al. [63] propose classifying questionnaires according to the dimensions addressed by their items: cognitive, affective, and behavioral. We propose to refine this classification into the following: knowledge ('K'), beliefs ('Bl'), affect and motives ('AM'), behavior ('Bh'), and inclusion of nature in identity ('Id'). We consider as *knowledge* all environmental facts part of a scientific consensus (e.g., human-caused global warming [12]).

4.3 Age Groups and Languages

Questionnaires are designed for specific age groups; some are later adapted to other age groups. As SHCI-TD user studies can take place in public areas where all types of public may participate, adequate questionnaire versions must be used. We therefore distinguish three age groups to classify the questionnaires' audience: adults ('A'), teenagers ('T'), and children ('C').

Evaluating SHCI-TD systems across countries by the international research community requires valid questionnaires available in local respondents' languages. We distinguish the original language of questionnaires ('o'), from validated translations ('v'), two-way back-translations ('b'), and one-way direct-translations ('d'). We thus reported questionnaires for six languages: English ('EN'), French ('FR'), Spanish ('SP'), Italian ('IT'), German ('GE'), and Portuguese ('PT')—only questionnaires whose papers provide the translated items were included.

4.4 Consistency and Measurement

When provided by their authors, we reported questionnaires' internal consistency through the Cronbach's alpha coefficient (Tau-equivalent reliability). We also reported the kind of measurement between 'Likert Scale', 'Yes/No Questions', and 'Other'. The latter kind includes other measurements such as importance scales (i.e., from -1: "opposed to my values", to 7: "of supreme importance"), identity scales (i.e., from 1: "Not at all true of me", to 4: "Neither true or untrue", to 7: "Completely true of me"), frequency scales (i.e., from "Never" to "Always"), portrait scales (i.e., from "Not like me at all" to "Very much like me"), Venn Diagrams, or words association time.

Table 1: Corpus composition from literature reviews, showing included papers' occurrence between reviews.

	Included				Rejected
Source	Once	Twice	Thrice	Total	Total
Zylstra et al. (2014) [85]	1	5	6	12	1
Restall and Conrad (2015) [63]	6	6	5	17	1
Salazar et al. (2021) [67]	0	0	6	6	2
Own literature review	3	0	0	3	0

4.5 Questionnaire Administration

Although administration time is a decision criterion when choosing a questionnaire, the average times to take tests were not measured when validating scales and are not provided for any of the scales. Connectedness to Nature's questionnaires were designed to understand a population's psychology at a large scale as the main question, not as a secondary variable at the scale of HCI user studies analyses. User studies' participants usually have to answer a variety of questions: questions about themselves (demography) and their skills (experience), and about the user interfaces or the tasks (usability), for example. Answering those questions takes time during user studies: time of the participants and time of the experimenters, involving energy of both persons. Measuring Connectedness to Nature requires adding more questions, thus increasing completion time and leading to inappropriate administration time. First, longitudinal user studies' participants may have some time planned to answer, but they will have to take some questionnaires several times and get bored with long questionnaires over time. Second, participants of user studies recruited in public places may have a short time to answer.

We examined questionnaire administration through two criteria: questionnaire items count ('#Items') and estimated their reading time ('Time') (not including the instructions provided with some questionnaires)—we consider a reading speed of 200 words/minute.

5 THE CORPUS

We collected scales from three systematic literature reviews on Connectedness to Nature [63, 67, 85] to which we added three scales from our own literature review. Inclusion criteria were self-report scales measuring Connectedness to Nature (as a whole or partially) at least for adults. The composition of the corpus is summarized in Table 1. The resulting 21 scales are listed in Table 2 (acronyms, names, and references). Although some of these scales are considered as "Attitudinal and Values-Based Scales" (EMS and LCN), or as "Paradigm-Based Scales" (NEC and NEP) by Keaulana et al. [37], and some were considered not measuring the Connectedness to Nature's construct by a workshop's participants (EAATE, PRS, EVO, NEP, CWN, and COM) [67], we included all these scales as measures of Connectedness to Nature in our corpus.

The remaining of this section depicts eight of the 21 scales: seven are among the most common [78], most useful to practitioners [67], and most frequently cited [85] scales (see Table 3): NEP, EATN, INS, EID, CNS, NRS, and LCN; one is the only computerized test of the corpus: IAT.

Table 2: Names and references of the 21 scales of the corpus (ordered by the main reference's publication year).

Scale			References			
# Acronyms		Name	Authors	Year	Main	Other
1. EAATE		Ecocentric and Anthropocentric Attitudes Toward the Environment	Thompson and Barton	1994	[83]	[74, 76]
2. PRS		Perceived Restorativeness Scale	Hartig et al.	1997	[31]	-
3. NEC		New Ecological Consciousness	Ellis et al.	1997	[25]	-
4. EVO/E-SVS		Environmental Value Orientations Scale	Stern et al.	1998	[79]	[17]
5. EATN/EAN		Emotional Affinity Toward Nature	Kals et al.	1999	[36]	[51]
6. NEP		New Ecological Paradigm	Dunlap et al.	2000	[23]	[22, 46, 68, 69]
7. EMS		Environmental Motives Scale	Schultz et al.	2001	[71]	[20, 71]
8. INS		Inclusion of Nature in the Self	Schultz et al.	2002	[72]	[43, 47]
9. EID/EIS		Environmental Identity	Clayton	2003	[10]	[11, 55, 60]
10. IAT		Modified version of the Implicit Associations Test	Schultz et al.	2004	[73]	[7]
11. CNS/CTN (CNI)		Connectedness to Nature Scale	Mayer et al.	2004	[49]	[9, 52, 55, 58]
12. HARN		Human Actions in and Reactions toward Nature	Beckers	2005	[3]	-
13. CWN/CwNS/ECS		Connectivity With Nature	Dutcher et al	2007	[24]	-
14. AID		Allo-inclusive Identity	Leary et al.	2008	[44]	-
15. COM		Commitment to the environment	Davis et al.	2009	[16]	-
16. NRS/NR		Nature Relatedness Scale	Nisbet et al.	2009	[54]	[20, 53]
17. LCN		Love and Care for Nature	Perkins et al.	2010	[57]	[50]
18. DCN		Disposition to Connect with Nature	Brügger et al.	2011	[6]	-
19. EAATSD		Ecocentric and Anthropocentric Attitudes Toward the Sustainable Development	Kopnina et al.	2013	[40]	-
20. DENS		Dispositional Empathy with Nature Scale	Tam	2013	[82]	[75]
21. E-PVQ		Environmental Portrait Value Questionnaire	Bouman et al.	2018	[5]	[20]

Note. '-' = empty.

Table 3: The seven scales qualified as the most common, most useful, and most frequently cited.

# Scale	Most common [78]	Most useful to practitioners [67]	Most frequently cited [85]
5. EATN/EAN	-	-	×
6. NEP	×	-	-
8. INS	-	×	×
9. EID/EIS	×	×	×
11. CNS/CTN (CNI)	×	×	×
16. NRS/NR	-	×	×
17. LCN	-	×	-

Note. '-' = empty.

5.1 New Ecological Paradigm Scale

The New Ecological Paradigm [23] is a revised version of the New Environmental Protocol [22]. NEP aims at measuring the endorsement of an ecological worldview. The revised version lies in adding new items both relating to the concept of "human exceptionalism", and in addressing the environmental crisis with the concepts of "balance of nature", "limits to growth", and "antianthropocentrism" (that were already included). NEP scale measures fundamental beliefs about the environment; it is a widely used scale for environmental concerns [32]. However, NEP measures cognitive beliefs rather than affective and experiential relationships to the environment [49]. As well, items describe beliefs about humans as a whole (e.g., *"Humans have the right to modify the natural environment to suit their needs"*, or *"We are approaching the limit of the number of people that Earth can support"*),

thus not considering a personal relationship with the environment. Nevertheless, NEP is one of the most common scales [78].

5.2 Emotional Affinity Toward Nature Scale

EATN [36] aims to *"measure an emotion that develops through experiences with nature during childhood"* [51]. Unlike NEP, this scale covers aspects related to love of nature, feelings of freedom in nature, security in nature, and oneness with nature. This scale is one of the most frequently cited scales [85].

5.3 Inclusion of Nature in the Self

INS [72] measures users' relationship with nature by asking to choose between seven pairs of overlapping circles that best represent respondents' relationship with nature: one circle is for the "self"; the other is for the "nature"—the more the circles overlap, the more respondents feel connected to nature. However, such a level of abstraction prevents reporting connection with nature accurately [49]. Martin and Czellar [47] developed an extended version of INS with four items and more possible answers through the size of circles and how the circles are centered between them. INS has been identified as useful to practitioners [67].

5.4 Environmental Identity Scale

EID [10] is designed to measure the sense of connection with nature that respondents feel, or *"a person's self-understanding as an integrated component of the natural environment"* [11]. Unlike the other scales presented above, EID focuses more on self-perceived identity. A revised version of EID was developed during a study involving several countries and cultures [11]. This scale is useful to practitioners [67].

5.5 Modified Implicit Associations Test

Schultz et al. [73] propose a computer-based test to measure Connectedness to Nature with automatic concept-attribute associations times—this test is based on the Implicit Association Test (IAT) [30]. The test consists in displaying a series of words: for each word, respondents have to quickly identify whether it is 'natural' or 'built', 'self' or 'other'. The test measures associations' reaction time of correct concepts' pairs. For example, if the word "ANIMAL" is displayed, the user has to choose between "NATURAL" or "BUILT". The correct answer is "NATURAL". If the word "MINE" is displayed, the user has to choose between "BUILT OR ME" or "NATURE OR NOT ME". The correct answer is "BUILT OR ME".

5.6 Connectedness to Nature Scale

CNS [49] measures respondents' affective and experiential connection to nature. Items describe place in nature and feelings of closeness with all the living entities. CNS was designed to measure affective dimensions (unlike NEP, INS, and IAT scales). An adaptation of this scale (a 14-item scale called CNI, Connection to Nature Index) is available for children [9]. This scale is widely used by researchers [85] and is useful to practitioners [67].

5.7 Nature Relatedness Scale

NRS [54] is designed similarly to CNS to measure individual levels of Connectedness to Nature. However, unlike CNS, the concept of nature relatedness includes the physical relationship aspect (physical experience and contact) in addition to the cognitive and affective relationship with nature. Nisbet et al. consider NRS as relatively stable over time [54]. A short-form version of NRS (NR-6) is composed of six items [53]. NRS is useful to practitioners [67].

5.8 Love and Care for Nature Scale

LCN [57] measures the love and care for nature concept, defined as *"deep love and caring for nature which includes a clear recognition of nature's intrinsic value as well as a personal sense of responsibility to protect it from harm"*. This scale is useful to practitioners [67].

6 CORPUS ANALYSIS

Tables 4, 5, and 6 examine the 21 corpus scales through their psychological constructs, targeted audience, and items, respectively. This section analyzes how the corpus covers the eight criteria.

6.1 Point of View

As Table 4 shows, sixteen of the 21 scales measure an individual sense of Connectedness to Nature (76%): only two scales use "aggregate" type of items (NEC and NEP); two use "concept" type of items (EVO and IAT); and one uses the "portrait" type (E-PVQ).

6.2 Construct Dimensions

Affect and motives toward nature are measured by most of the corpus scales (14 of 21, 67%). Beliefs and environmental identity are both covered by items of twelve out of 21 questionnaires (57%). Only three scales cover more than four Connectedness to Nature dimensions (14%); four scales cover only one dimension (19%). NRS' construct is the most complete in view of dimensions: it is the

only scale to cover all dimensions; it considers the behavioral dimension through physical experience and contact with nature in addition to the four other dimensions—some other scales consider the behavioral dimension but do not consider all other dimensions (e.g., EATN, EID, and LCN). IAT measures the extent to which respondents associate implicitly "self" with "nature" (knowledge, beliefs, and identity dimensions). DENS and EMS focus instead on affective relationships or motives toward the environment; HARN and DCN, environmental activities; and INS and AID, environmental identity aspects. Scales constructs' dimensions are reported in Table 4.

6.3 Age Groups and Languages

We restricted our corpus to scales usable with adults at least. However, several of these scales are also available for other age groups: because the original questionnaire was designed this way (INS, EID, NRS, LCN, and DCN), or because an adapted version was later published (EATN, NEP, IAT, and CNS). Scales' age groups are reported in Table 5.

All the scales were originally published in English. We found published translations of their questionnaires for the following four languages, but we failed to find some in Italian:

- French: NEP [68], EID [60], and CNS [52];
- Spanish: EAATE [74], EMS [20, 71], EID [11, 55], CNS [55], NRS [20], DENS [75], and E-PVQ [20];
- German: EAATE [76], NEP [69], EMS [20], NRS [20], and E-PVQ [20];
- Portuguese: CNS [58] and LCN [50].

The most available scale through languages is CNS, with four languages: English, French, Spanish, and Portuguese. Translations must, however, be used carefully: for example, Pasca et al. [56] show that CNS's Spanish version of Olivos et al. [55]—a back-translated one—is not equivalent to the original English version. Scales' available languages are reported in Table 5.

6.4 Consistency and Measurement

Questionnaires' internal consistency is provided for nearly three-quarters of the scales (15 of 21, 71%): Table 6 gives Cronbach's alpha coefficients for whole questionnaires or by items' categories. Most corpus scales were reported a good internal consistency in their original publication ($\alpha > .70$ as recommended by [42]). Exceptions are the following: EAATE ($\alpha = .67$ for anthropocentrism), EVO ($\alpha = .62$ for openness to change, $\alpha = .65$ for conservation values, $\alpha = .65$ for altruistic values, and $\alpha = .67$ for self-enhancement), and E-PVQ ($\alpha = .68$ for altruistic values).

Two-thirds of corpus scales use Likert scales (14 of 21, 67%): over half of these scales are measured on five points (8 of 14, 57%); over one-third, on seven points (5 of 14, 36%); only one uses 9-point Likert scales (1 of 14, 7%). Whereas some work suggests better data quality with 7-point scales, no effect was found on NEP scores [32]. Some work combines measurement kinds, such as CWN, which uses four Likert scales and one Venn Diagram item based on INS. Some other work, such as AID, uses only Venn Diagrams. Then, E-PVQ asks participants to position themselves according to statements (i.e., a portrait). DCN asks about behaviors using Yes/No questions and frequency scales. HARN—based on DCN—also integrates Yes/No

Table 4: Psychological constructs of the 21 scales of the corpus.

# Scale	PoV	K	Bl	AM	Bh	Id	Topic
1. EAATE	I	×	×	×	×	-	Ecocentric attitude (intrinsic values related to the appreciation of the environment), Anthropocentric attitude (extrinsic values related to comfort and survival of humans), and Environmental apathy (the lack of awareness about environmental issues).
2. PRS	I	-	-	×	×	×	Being Away, Fascination, Coherence, and Compatibility.
3. NEC	A	×	×	-	-	-	Future environmental, overpopulation, and economic crisis.
4. EVO/E-SVS	C	-	×	-	×	×	Egoistic, altruistic, and biospheric value orientations.
5. EATN/EAN	I	-	-	×	×	-	Emotional connection to his or her natural environment.
6. NEP	A	×	×	-	-	-	Endorsement of an ecological worldview.
7. EMS	I	-	-	×	-	-	Environmental motives about self (egoistic concerns), other people and future generations (altruistic concerns), and the biosphere (environment concerns).
8. INS	I	-	-	-	-	×	Feeling of connection to the environment.
9. EID/EIS	I	-	×	×	×	×	Self-understanding of being an integrated component of the natural environment.
10. IAT	C	×	×	-	-	×	Implicit association of the self and nature.
11. CNS/CTN (CNI)	I	-	×	×	-	×	Closeness with all the living entities of the environment and own place within the environment.
12. HARN	I	-	-	×	×	-	Specific behaviors that people differentially engage related to their connectedness with nature.
13. CWN/CwNS/ECS	I	-	×	×	-	×	Experiencing nature as being part of the same community.
14. AID	I	-	-	-	-	×	Connection to people, animals and inanimate objects.
15. COM	I	-	×	×	-	×	Attachment and long term orientation toward the environment.
16. NRS/NR	I	×	×	×	×	×	Connectedness with the environment (including physical contact).
17. LCN	I	-	-	×	×	×	Love and caring (responsibility) for nature.
18. DCN	I	-	-	×	×	-	Behavior and feelings toward animals and outside activities.
19. EAATSD	I	×	×	×	-	-	Ecocentric, anthropocentric attitude, and apathy toward the environment.
20. DENS	I	-	-	×	-	-	Empathy when animals suffer.
21. E-PVQ	P	-	×	-	×	×	Biospheric, altruistic, hedonic, and egoistic values.

Notes. '-' = empty; 'PoV' = Point of View: 'A' = Aggregate; 'I' = Individual; 'P' = Portrait; 'C' = Concept.
Construct Dimensions: 'K' = Knowledge; 'Bl' = Beliefs (including worldview); 'AM' = Affect (e.g., emotions, feelings) and Motives;
'Bh' = Behavior (actions, experience, or physical contact with nature); and 'Id' = Identity (inclusion of nature in self and values).

Table 5: Targeted audiences of the 21 scales of the corpus.

# Scale	Age Group			Language					
	A	T	C	EN	FR	SP	IT	GE	PT
1. EAATE	o	-	-	o	-	d	-	v	-
2. PRS	o	-	-	o	-	-	-	-	-
3. NEC	o	-	-	o	-	-	-	-	-
4. EVO/E-SVS	o	-	-	o	-	-	-	-	-
5. EATN/EAN	o	a	-	o	-	-	-	-	-
6. NEP	o	-	a	o	v	-	-	v	-
7. EMS	o	-	-	o	-	b	-	b	-
8. INS	o	o	o	o	-	-	-	-	-
9. EID/EIS	o	o	-	o	v	v	-	-	-
10. IAT	o	-	a	o	-	-	-	-	-
11. CNS/CTN (CNI)	o	o	a	o	v	b	-	-	v
12. HARN	o	-	-	o	-	-	-	-	-
13. CWN/CwNS/ECS	o	-	-	o	-	-	-	-	-
14. AID	o	-	-	o	-	-	-	-	-
15. COM	o	-	-	o	-	-	-	-	-
16. NRS/NR	o	o	o	o	-	b	-	b	-
17. LCN	o	o	-	o	-	-	-	-	d
18. DCN	o	-	o	o	-	-	-	-	-
19. EAATSD	o	-	-	o	-	-	-	-	-
20. DENS	o	-	-	o	-	v	-	-	-
21. E-PVQ	o	-	-	o	-	b	-	b	-

Notes. '-' = empty.
Age group: 'A' = Adults; 'T' = Teenagers; 'C' = Children;
o = original article; a = adapted in further article.
Language: 'EN' = English; 'FR' = French; 'SP' = Spanish; 'IT' = Italian; 'GE' = German; 'PT' = Portuguese;
o = original version; v = validated translation (listed in Table 2's references);
b = back-translation (listed in Table 2's references); d = direct-translation.

questions. Finally, IAT uses an original measure compared to other scales: word associations' response time. Scales' measurements are reported in Table 6.

6.5 Questionnaire Administration

As average times to take questionnaires were not estimated, this section examines questionnaires administration regarding the reading times and items counts that are reported in Table 6.

The average estimated reading time is 57.6 seconds (on 18 of the 21 questionnaires). The three longest scales to read are EAATE, DCN, and EAATSD (1'55, 1'45, and 1'33, respectively), making them less adequate to administer when recruiting participants in public places—where people have only a little time to spend on a user study. The fastest scale to read is EMS, taking only 6 seconds. All the items of this scale are associated to the same starting sentence: *"I am concerned about environmental problems because of the consequences for […]"*. Then, this sentence has to be achieved twelve times with each of the following words: *"Plants"*, *"Me"*, *"People in my country"*, *"Marine life"*, *"My lifestyle"*, *"All people"*, *"Birds"*, *"My health"*, *"Children"*, *"Animals"*, *"My future"*, and *"My children"*. However, each of EMS's twelve items has to be rated on a 7-point importance scale. Moreover, estimated reading time does not consider time for cognitive analysis, decision, and motoric tasks required to answer the questionnaires.

The number of items ranges from 1 to 40, with an average of 17.2 items (on 20 of the 21 questionnaires). Only INS has one item: it takes the form of Venn Diagrams. Apart from INS, the scale with

Table 6: Items and measurement of the 21 scales of the corpus.

# Scale	Normal version			Short version			Measurement		
	#Items	Time[1]	Alpha[2]	#Items	Time[1]	Alpha[2]	L.S.	Y/N	Other
1. EAATE	30	1'55"	.67, .78, .82	-	-	-	5 pts	-	-
2. PRS	26	1'08"	n.c.	-	-	-	7 pts	-	-
3. NEC	10	40"	.83	-	-	-	7 pts	-	-
4. EVO/E-SVS	16	24"	.62, .65, .65, .67, .84	-	-	-	-	-	Importance Scales (9 pts)
5. EATN/EAN	16	1'18"	.74, .80–.92, .84–.93	-	-	-	6 pts	-	-
6. NEP	15	43"	.83	-	-	-	5 pts	-	-
7. EMS	12	6"	.78, .83, .92	-	-	-	-	-	Importance Scales (7 pts)
8. INS	1	n.a.	n.a.	-	-	-	-	-	Venn Diagrams (7 pts)
9. EID/EIS	14	58"	.92	-	-	-	-	-	Identity Scales (7 pts)
10. IAT	n.a.	n.a.	n.a.	-	-	-	-	-	Association times (Words)
11. CNS/CTN (CNI)	14	1'02"	.84	-	-	-	5 pts	-	-
12. HARN	33	1'24"	.88	-	-	-	5 pts	×	Frequency Scales (5pts)
13. CWN/CwNS/ECS	5	23"	.72	-	-	-	5 pts	-	Venn Diagrams (3 pts)
14. AID	16	41"	n.c.	-	-	-	-	-	Venn Diagrams (7 pts)
15. COM	11	39"	.91	-	-	-	9 pts	-	-
16. NRS/NR	21	1'06"	.87	6	17"	.83–.86	5 pts	-	-
17. LCN	15	52"	.97	-	-	-	5 pts	-	-
18. DCN	40	1'45"	n.c.	-	-	-	-	×	Frequency Scales (3 pts)
19. EAATSD	22	1'33"	n.c.	-	-	-	5 pts	-	-
20. DENS	10	40"	>.90	-	-	-	7 pts	-	-
21. E-PVQ	17	47"	.68, .71, .78, .88	-	-	-	-	-	Portrait Scales (7 pts)

Notes. '-' = empty; 'Alpha' = Cronbach's alpha (ρ_T); 'L.S.' = Likert Scales; 'Y/N' = Yes/No Questions; n.c. = not calculated; n.a. = not applicable.

[1] Questions' reading time (not including the instructions) of the English version, estimated using an online tool with 200 words per minute rate (https://niram.org/read, accessed 2022-02-07).

[2] Several values are given when internal consistency is calculated by items' categories.

the least number of items is CWN (five items). Nevertheless, the fifth item is a series of three Venn diagrams indicating the extent to which respondents feel that they and nature are the same. The scale with the third-lowest number of items is NR-6, the short version of NRS. The three scales with the highest number of items are EAATE, HARN, and DCN (with 30, 33, and 40 items, respectively), but no short versions are provided: the only short version available for corpus scales is NR-6. Finally, IAT's consists of 70 association measures; however, IAT is a computerized test that should require concentration and quietness—to better measure response times—and may be challenging to administer in public areas.

7 EXPERIMENTAL VALIDATIONS

Beyond meta-information provided by scale characteristics and analysis through criteria, scales' experimental comparisons provide information about their validity and reliability (i.e., the predictive power of environmental beliefs and behaviors). This section reviews experimental validation and comparisons of CNS, IAT, NRS, EID, LCN, E-PVQ, EVO, NEP, and cultural cognition scales.

Several contributions show that CNS is a reliable predictor of environmentally responsible behavior (e.g., see the review of Zylstra et al. [85]). Geng et al. [29] show that IAT predicts spontaneous behaviors, whereas CNS predicts deliberate behaviors related to the environment. NRS, EID, and LCN are also shown as reliable predictors of environmental behavior [81]. When introducing E-PVQ, Bouman et al. [5] compared it to EVO. Whereas they showed the two scales are valid and reliable, the respondents slightly preferred the E-PVQ portrait scale over EVO (for ease, clarity, and comprehensibility).

Sparks et al. [78] compared NEP, CNS, EID, and cultural cognition scales—the cultural cognition scales measure people's concern for risk based on their cultural background. They found that CNS and EID are strong predictors of pro-environmental behavior. More precisely, they found a better predictive power of environmental behaviors for CNS and EID over NEP and cultural cognition. Whereas EID predicted slightly better public behaviors, CNS better predicted private behaviors.

8 MAKING A CHOICE

This section exposes our choices to measure Connectedness to Nature in future user studies. These studies will evaluate the effect of some SHCI-TD interfaces on users' behavior at workplaces, and the impact of some others on users' thinking in public places. Because participants' level of Connectedness to Nature may affect attitudinal and behavioral change observations, we want to measure this level as an independent variable of our user studies as it can influence participants' environmental behavior.

8.1 Longitudinal User Studies at Workplaces

CNS is the first choice for our user studies at the workplace. CNS captures the three dimensions of beliefs, affect and motives, and identity. Physical contact dimension is not measured but may not be relevant for the users we consider. The questionnaire asks participants to position themselves according to first-person assertions (using Likert scales). Among the corpus, only E-PVQ and IAT attempt to reduce biases related to self-representation contentiousness. However, E-PVQ is not available in French, and including a computerized association test such as IAT—among other questions—may be intrusive. CNS's authors reported a good

internal consistency of the questionnaire (α = .84). Versions of CNS can be found for all three age groups. CNS's length is only in the corpus average, but the estimated reading time of 1'02 and the 14 items to fill out can fit for longitudinal studies where time is planned. An alternative scale could be EID because of reliability (α = .92), diversity of the four measured dimensions (beliefs, affect and motives, behavior, and identity), and a medium administration time (14 items, 58-second reading time) equivalent to CNS. Finally, both CNS and EID are available through validated French versions for our user studies in France.

8.2 User Studies Recruiting in Public Places

Only three scales are available for all three age groups: INS, CNS, and NRS. The one-item INS scale is not reliable [49]. CNS's reading time (1'02) is only in the corpus average (57.6"), and no short version is available. NRS would then be the first choice for user studies in public spaces. NRS captures all the dimensions of Connectedness to Nature. Like CNS, respondents have to position themselves according to first-person affirmations. However, NRS has a validated short version: the fewer items of NR-6 may not capture all thoughts of the construct dimensions, but it does not *"significantly compromise the reliability or validity"* of the scale [53]. Both the 21-item and the 6-item versions of NRS were reported to have good internal consistencies. Versions of NRS can be found for all three age groups—such availability is convenient for user studies in public places. However, no validated translation of NRS is available in French: we could not use it for further user studies.

9 ANALYSIS OF SCALES' LIMITATIONS

Several limitations appear when choosing a questionnaire for HCI needs. This section analyses and summarizes those limitations regarding our criteria.

9.1 Construct

Although a portrait scale is slightly preferred over a concept scale for ease, clarity, and comprehensibility [5] and reduces biases related to self-representation contentiousness, three-quarter of corpus scales uses individual point of view (see Figure 3a). Furthermore, whereas some corpus constructs focus on one dimension, most focus on two or three, and only a few cover more than four (see Figure 3b). However, these constructs were not designed for HCI user study concerns: the correct dimensions to consider are unknown.

9.2 Audience

Many questionnaires focus on limited ranges of audiences and contexts [67]. For example, only three scales of the corpus are available for all three age groups (INS, CNS, and NRS), and over half are available for one age group only (see Figure 3c). Adapting or designing more scales covering all audiences would be valuable for HCI user studies.

The corpus questionnaires' availability is very low through the six languages we examine (English, French, Spanish, Italian, German, and Portuguese): all are originally published in English; not enough are translated in other languages (e.g., none is available in Italian). Only one scale is available in up to four languages (CNS);

six in three languages; two in two languages; and over half were not translated (see Figure 3d). Moreover, only half of those translations are validated ones (8 of 17, 47%), even though the back-translation procedure can result in questionnaires nonequivalent to the original one [56] and direct translations receive no verification at all.

9.3 Measurement

Getting overall measures of Connectedness to Nature is useful as ANOVA's variables and as scores to gauge groups between studies. However, no corpus scale explicitly provides a calculation formula—neither for an overall value nor by items' categories. Though the calculation is trivial for homogeneous scales using only Likert scales, importance scales, frequency scales, or portrait scales, getting meaningful values is less evident for heterogeneous scales combining several measurements' kind or unalike numbers of points. Items' measurement ranges from Likert scales to identity scales, sets diagrams, portrait scales, Venn diagrams, frequency scales, word associations, importance scales, and Yes/No questions. Ensuring standard scale calculation would be valuable to compare results between user studies.

9.4 Administration Time

Questionnaires' administration time can be approximated from information such as items' count, measurement's kind, and questions' reading time. We estimated that the longest questions' reading time (nearly 120 seconds) is ten times the shortest ones (a dozen seconds): reading time ranges from less than 30 seconds (3 scales) to nearly 120 seconds (3 scales beyond 1'30), and over half of questionnaires takes from 30" to 1'30 reading time (11 scales). Scales' distribution by reading time ranges is showed in Figure 3e. Knowing average administration times to take tests would be valuable criteria when designing user studies: those times should be measured for the corpus scales and new scales when published.

A way to decrease administration time is to decrease items count by removing some items: only five scales comprise less than ten items (see scales distribution by items count range in Figure 3f). For example, one scale of the corpus (NRS) proposes a validated short version that decreases the number of items by 71% and reading time by 74%. Some work shortened scales for their needs by combining subsets of items, but items' choice and count vary [32], thus preventing comparisons between studies. Developing and validating more short versions would be valuable for HCI user studies, especially when high administration time.

10 DISCUSSION

Environmental psychologists designed many Connectedness to Nature scales for social sciences concerns to better understand humans' relationship with the environment. However, the number of possible questionnaires is relatively low once filtered through criteria for SHCI user studies analysis needs, preventing driving the final choice according to the psychological construct, the internal validity, and the predictive power.

Connectedness to Nature's scales should be available in languages that allow researchers and practitioners to conduct user studies in their cities and countries. Having more translations with cultural validation is necessary to get questionnaires covering, at
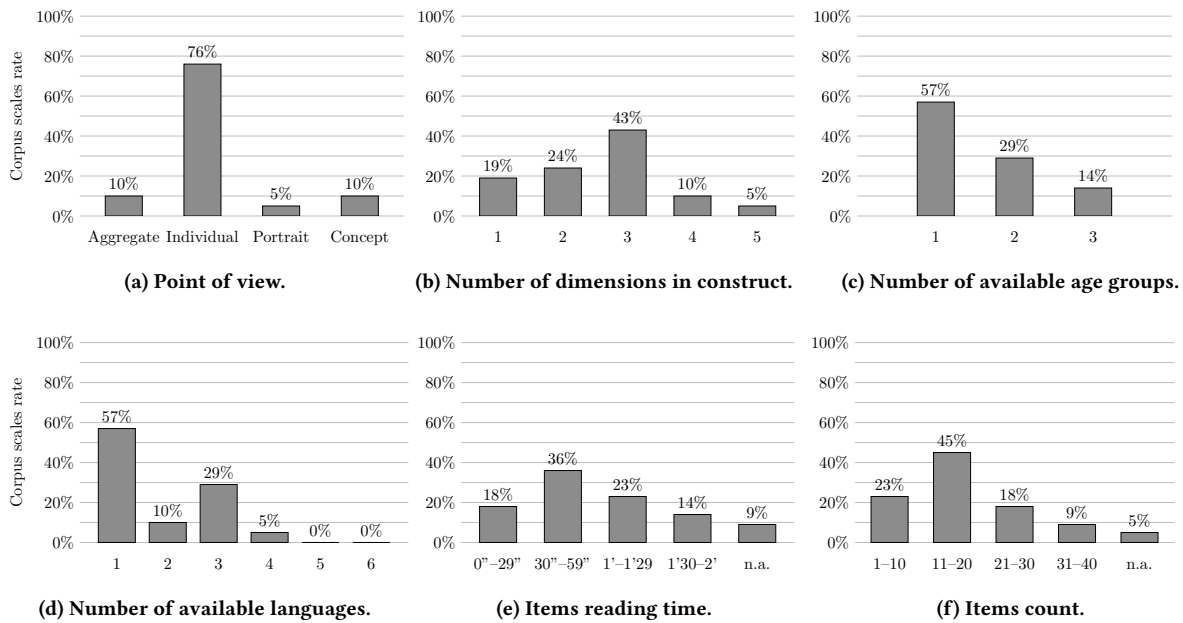
Figure 3: Corpus scales' distribution through six of our eight criteria.

Note. n.a. = not applicable.

least, countries with high greenhouse gases (GHG) emissions. As Sustainable HCI systems can target users of any age group, adapting or designing more scales that cover all audiences would be valuable for user studies, especially in public places.

Evaluating Sustainable HCI systems requires asking questions beyond Connectedness to Nature, such as usability and user experience. Hence, developing and validating short versions would be valuable for HCI user studies, especially when questionnaires' administration time is high. Moreover, knowing the average administration times to take tests would be valuable information to researchers and practitioners when designing user studies; according to the context of the study, users can have little time to spend or become bored by the repetition of long questionnaires.

Furthermore, the evaluation of Sustainable HCI systems through longitudinal user studies, in several countries, by several researchers and practitioners, may result in several studies across time. Comparing these studies' results is possible only if groups' Connectedness to Nature is known. Therefore, ensuring that researchers and practitioners use scores calculated the same way is necessary for result comparisons between user studies.

SHCI user studies need at least one questionnaire measuring Connectedness to Nature available through languages and age groups, requiring short administration time, providing good internal consistency, good predictive power, and a calculation formula guaranteeing a standard overall measure. Researchers and practitioners could then all use it across countries, thus allowing results comparison between user studies. An inspiring example from HCI should be the User Experience Questionnaire 8-item short version, UEQ-S [70], that measures two qualities normalized in the -3 pts to 3 pts range and is available in more than 30 languages[3].

11 CONCLUSION

Sustainable HCI *through* Design (SHCI-TD) can benefit from standardized Connectedness to Nature (CtN) measures for user study analyses. This paper attempts to make Connectedness to Nature measures accessible for SHCI-TD user studies: we hope it will help other HCI researchers select tools for their user studies. First, we present a corpus of 21 self-report tools selected from previous systematic literature reviews and our own literature review. Next, we examine these tools through eight criteria based on questionnaires' characteristics and Sustainable HCI *through* Design user studies needs. Finally, we illustrate with questionnaire choices for two cases: CNS or EID for longitudinal user studies at workplaces; NRS's 6-item version for user studies recruiting in public places. Our future work will integrate one questionnaire in a longitudinal user study on using shape-changing interfaces as eco-feedback displays at the workplace. These interfaces will display renewable energy production peaks to enable participants to modify their use of electric appliances during work hours. This study will focus on studying behaviors' alignment with renewable energy production in collaboration with an autonomous shape-changing system. Environmental psychologists designed Connectedness to Nature scales first for social sciences concerns to better understand humans' relationship with the environment. A potential future work for research communities is to adapt these tools to HCI domain needs (e.g., validated translations, standardized overall values, estimated administration time, and short versions). Such tools would also help—beyond the development phase's user studies—to create profiles that serve parametrizing and customizing systems' content and objectives according to users' Connectedness to Nature level.

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