# Development of the (adaptive) Computer Literacy Scale (CLS)

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The paper describes the development of the computer literacy scale (CLS), an objective knowledge test estimating the ability to understand ICT related symbols, functional elements and interaction patterns as an essential aspect of computer literacy that reliably predicts successful ICT interaction. The original version (CLS-ST) was developed as a paper & pencil questionnaire and has been used in a variety of studies including older participants. The second version (CLA-IA) allows for the assessment of procedural knowledge in online work samples. The third version (CLS+) adds more difficult items to extend the measurement range to more proficient users. For the fourth version (CLS adaptive), still more items were added and those items that fit the Rasch model were selected for the item bank used in the adaptive version of the CLS, which reduces testing time to under five minutes while maintaining high reliability.

**Practitioner Summary:** The paper describes the development of the computer literacy scale (CLS), a short objective test estimating basic ICT interaction knowledge that reliably predicts successful ICT interaction. The obtained CLS-score can be used as control variable in research involving participants using ICT and as a measure of universal usability in design projects. CLS can be obtained from www.computer-literacy.net and used for free.

**Keywords:** computer literacy, measurement, test, questionnaire development

## 1. Introduction

The demographic change underscores the public interest currently invested in the issue of aging as an important challenge for society, effecting the entire world. Concurrently, the rapid development of ICT (Moore's Law, Moore, 2006, 1965) has made ICT virtually ubiquitous, creating wonderful new opportunities as well as tremendous challenges for its users. Mark Weiser, one of the pioneers in the field who coined the term "ubiquitous computing", envisioned that one day "machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods" (Weiser, 1991, p. 104). However, many older users still experience ICT very differently. Even if computers are integrated in everyday life like water is for the fish, computers are still often alien to them and a source of frustration and avoidance. Yet, older adults are increasingly confronted with ICT, not just in public access systems. And they could benefit from using it, perhaps as much as or even more than younger adults. Aging and technology could be friends, not foes, as Nehmer et al. (2010) put it, yet that requires deliberate action from designers of such systems to accomodate their needs and capabilities. Thus, knowing about these needs, capabilities and limitations can help in creating truly universally usable products and services.
Any successful use of ICT requires domain knowledge and interaction knowledge and one of the capabilities that is central to successful use of ICT is computer literacy, which can be conceptualized as the basic interaction knowledge required for successful use of computers and other ICT, even though there is no generally agreed upon definition of computer literacy (Turner et al., 2000; Mason & Morrow, 2006). Not surprisingly, there is also little agreement on how to measure it. Even though there is a variety of computer literacy and related measures available, none was found to be short, objective and age specific for older adults, which led to the development of the computer literacy scale (Sengpiel & Dittberner, 2008)

The CLS is an objective knowledge test of ICT-related symbols and terms commonly used in the graphical user interface (GUI) of information and communication technology (ICT). It has been designed specifically for older adults or people with little computer knowledge and is based on the idea that knowing common symbols and terms is as necessary for using computers, as it is for reading and writing letters and books. This paper describes the further development of the computer literacy scale (CLS) introduced by Sengpiel & Dittberner (2008) that has been extended with 1) iteractive items to measure procedural knowledge, 2) more difficult items to measure novices and experts and 3) an adaptive online version to increase test efficiency in a research period spanning 7 years.

## 2. Method

The CLS focuses on a small but essential aspect of computer literacy and uses it as indicator for the broader construct: "If literacy can be considered the ability to read symbols and use them, then computer literacy could be considered the ability to understand and use computer related symbols, functional elements and interaction patterns" (Sengpiel & Dittberner, 2008, p. 8). Using the CLS, this ability can be tested in an objective knowledge test with 26 items (21 symbols and 5 terms) in a matching task, taking about 15 minutes to complete, depending on literacy level. It is not the goal of the CLS to differentiate people with high computer literacy from those with very high computer literacy (e.g. web designers from programmers), but rather to differentiate people with low to medium computer literacy and to detect a lack of basic interaction knowledge needed to successfully interact with ICT. Just like research participants should be able to read, if instructions or responses are to be given in written form, they should know about basic ICT operation, if studies are to be conducted using ICT and their computer literacy level could have an impact on results obtained with ICT.

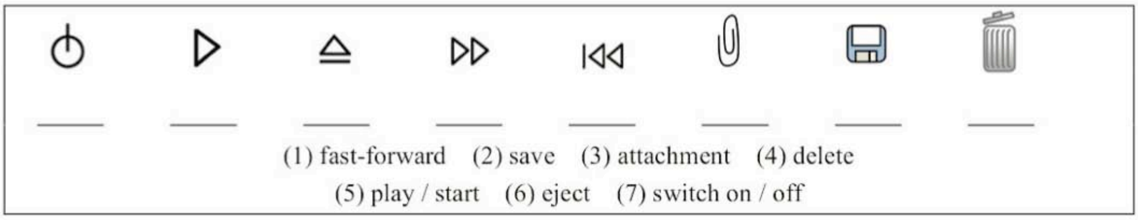


Figure 1. Sample items in the matching task of the CLS-ST, seven targets and one distractor in one thematic block.

To clearly differentiate this "original" CLS from the following versions, it can be called CLS-ST (for symbols and terms). Figure 1 shows sample items in the matching task. The CLS-ST can be downloaded for free as printable pdf. It is available in English, German and Spanish and has been used to measure computer literacy as control variable in a variety of studies, showing high reliability and good predictive validity (Sengpiel & Jochems, in press). For example, in a study with 124 participants, CLS-ST showed high internal consistency with a Cronbach's alpha between .93 and .96, and a discrimination power ranging from $r = .22$ to $r = .84$. Item difficulty was low for young participants, but reasonably broad for the old group, ranging from $P = .13$ to .87. Kolmogorov-Smirnov-Tests revealed that the CLS-ST scores were normally distributed for older but not for younger participants, for whom most items were too easy (Sengpiel, in press). Also, some participants claimed that they would know how to use the computer even if they did not know exactly what the symbols and terms meant - and we had to admit to a lack of assessment for procedural knowledge in the CLS-ST. This shortcoming has also been seen by Boot et al. (2013), who developed the "Computer Proficiency Questionnaire" (CPQ) to assess the computer proficiency of seniors, arguing that the CLS had been designed for older adults, but focused largely on declarative knowledge rather than the ability to perform computer tasks.

Thus, three challenges became apparent: First, "interactive" items were designed to complement the assessment of declarative knowledge with the assessment of procedural knowledge. Second, more difficult items had to be found and validated to add to the CLS, so it would be suitable to differentiate people with higher levels of computer literacy as well. Third, many researchers told us that they were convinced they should measure computer literacy as control variable in their studies and that they would use the CLS - if it were only shorter. Thus, still more items were gathered and analyzed to provide a sound basis for a computerized adaptive test (CAT), that should shorten testing time to < 5 min, while maintaining high reliability.

### *CLS-IA (interactive)*

The CLS-ST has been complemented with an interactive version (CLS-IA for interactive) to assess procedural knowledge in work samples. For that purpose, a web based diagnostic platform was realized as a database-driven web application that presents users with tasks that require computer literacy (Zeissig, 2009). Thus the design goal was not optimal usability but incorporation of diverse GUI widgets, most of which can be classified as input widgets according to the W3C WAI-ARIA widget taxonomy, such as: select, option, range, textbox, menuitem, checkbox. These widgets were combined and used in four different interaction scenarios: In the first scenario (see Fig. 2 left), the user was presented with different GUI methods to select objects with mouse and keyboard and tasks such as „Please select all folders at once!“. In the second scenario (see Fig. 2 right), the user was presented with different GUI methods to copy, paste, and delete folders and tasks such as „Please copy folders…“. The third scenario was more complex, asking participants to book a flight for three people to a congress in Vienna on a specified date with a simplified GUI incorporating a listbox to choose the destination, a textbox with calendar call out to enter the date, a textbox to enter the name, radio buttons to choose economy/business/first class, and a range widget (1-5) to enter the number of travelers (see fig. 3 left). The fourth and final scenario resembled a simplified GUI to mix and buy paint from the cheapest retailer, incorporating tabs to switch between 1) paint buckets, shown in a carousel and providing on mouse over tooltips 2) selection of color and amount with two range widgets and 3) retailer and shipment shown in a scrollable table with sortable headers and editable size (see fig. 3 right). Tasks were divided in steps and points were awarded for accomplished steps to measure participants' procedural interaction knowledge (Zeissig, 2009).

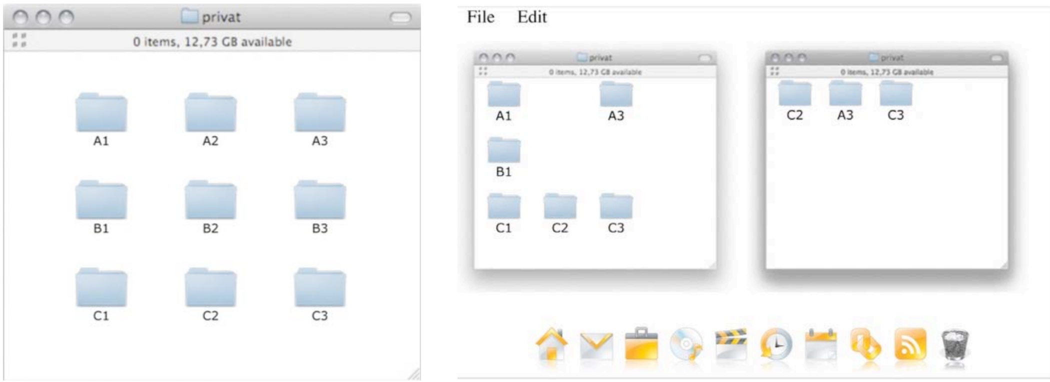


Figure 2. Sample items in the CLS-IA (interactive), with simple scenarios to select folders (left) and copy, paste, delete folders (right).

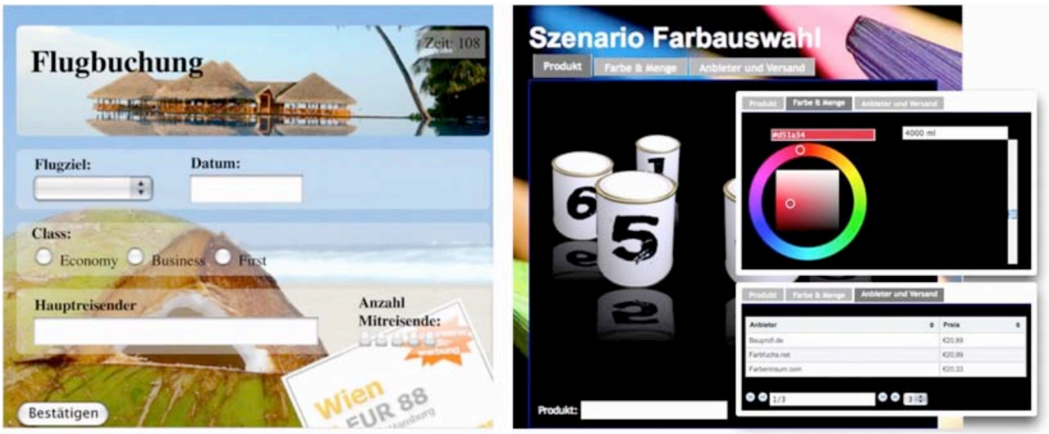


Figure 3. Sample items in the CLS-IA (interactive), with scenarios to book a flight (left) and to mix and buy paint (right).

### *CLS+ (more difficult items)*

A third version added more difficult items to extend the measurement range to more proficient users. Spiering (2010) gathered 58 new items that are commonly used with diverse electronic devices. These items were added maintaining the format of the CLS-ST with matching tasks in 8 thematic blocks. Five of these blocks each contain eight items with two blocks showing icons (i.e. for Bluetooth, Ethernet, Firewire etc.), one block showing widgets (i.e. Radio buttons, drop-down-menus etc.), one block showing keyboard command letters (i.e. C/copy, V/paste, S/save etc.) and one block showing file extensions (i.e. .csv, .iso, .rar, etc.). Three of these blocks each contain six items showing computer terms (i.e. thumbnail, tooltip, cache etc.). Figure 4 shows 16 of these CLS+ items.

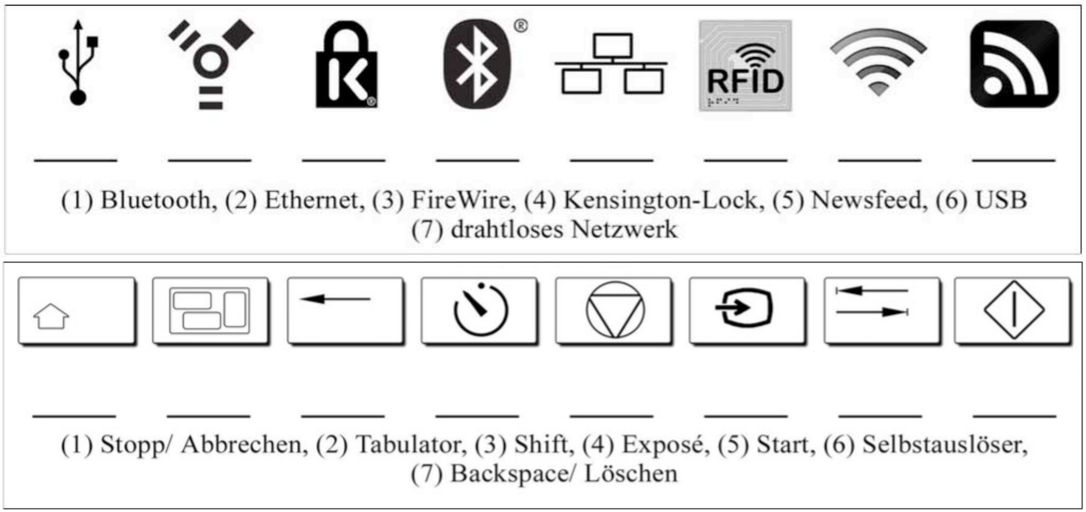


Figure 4. Sample items in the CLS+, with two blocks showing eight icons each, seven targets and one distractor.

70 participants, 41 female and 29 male, with a mean age of 28 (SD=9) were recruited to fill out the CLS+ questionnaire online, mainly through social networks and the participant server of the institute of psychology at the Humboldt University Berlin. 52 of them reported to have a high school degree of higher. Their computer experience (CLS part A) was comparable to the young group in Sengpiel & Dittberner (2008), with an average duration of use of 13 years (with a range between 5 and 15 years), an intensity of M=31 hours per week (with a range of 4 to 100 hours per week) and a diversity of use of 62%, the most popular applications being email (99%) and surfing the Internet (97%), and the least popular programming (22%). Table 1 shows a comparison of the mean values in both studies. Their average CLS-score was 42 of 58 possible points (SD = 10), which equals 72% of the maximum score and is a substantially lower than the 92% the younger group achieved in Sengpiel & Dittberner (2008), indicating that adding the new items to the CLS has indeed resulted in a more difficult test. Figure 5 shows the distribution of item difficulty for all 58 items. Overall, CLS+ showed high internal consistency (Cronbach's alpha = .91) and good dispersion of item difficulty ranging between .23 and .99 with a mean of .72, as well as good discriminatory power with mean $r_{pbis}$ = .41, ranging from $r_{pbis}$ = −.02 to .68. Items were selected to yield high discrimination power and a broad range of item difficulty, with a preference to keep difficult items over easy items. The goal was to select the best 30 out of the 58 items, the same number as in the original CLS-ST, containing 26 target items and 4 distractors (Spiering, 2010).

Table 1. Mean values for computer experience (duration, intensity and diversity) and computer literacy (CLS-score) in the studies of Sengpiel & Dittberner (2008) and Spiering (2010).

| Computer experience (Means in) | Duration | Intensity | Diversity | CLS-score |
|---|---|---|---|---|
| Sengpiel & Dittberner 2008 | 10 years | 27 hours per week | 61%* | 92%* |
| Spiering 2010 | 13 years | 31 hours per week | 62% | 72% |

Note: * young group values are reported for comparison.

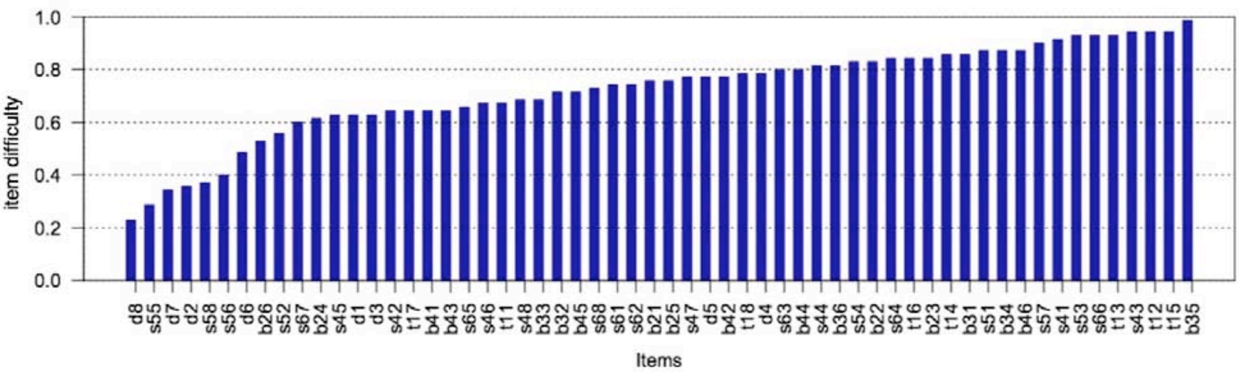


Figure 5. Distribution of item difficulty for the 58 items of the CLS+.

***CLS adaptive (CAT)***

Finally, a fourth version was developed as an adaptive test to further reduce test duration while maintaining high reliability. To reach that goal, the item pool was extended once more and conformity to the Rasch model was verified in two steps with N=169 to 100 items (Arsenyeva, 2012) and with N=150 to 121 items (adding 21 items typical for mobile devices, Götzinger, 2014), as follows. Arsenyeva (2012) added more items to the CLS, reaching a total of 116 items (100 target items and 16 distractors) and recruited 169 participants aged between 9 and 73 years (M=28, SD=17, 57% female) who had diverse computer experience in daily life (senior citizens, students, programmers, etc.). Notably, 82 of the participants were students who filled out the questionnaire while the teacher was present. Items were presented on 4 pages A4 paper in 16 blocks with 6 or 8 items each in a matching task (blocks were created according to content and expected difficulty of items). Time to fill out the questionnaire was not restricted but participants were asked to respond quickly. The written instructions proved to be self-explanatory across all participant groups, including the youngest. Incomplete questionnaires were excluded from analysis. In the item analysis and selection process, 76 of the 116 items were chosen that fit the Rasch model and can provide a basis for the adaptive test.

Götzinger (2014) further extended the item pool and participant sample. She added 21 items used for mobile devices to the 100 items used by Arsenyeva (2012) and presented them online to 150 participants (47% female), in fixed order with increasing difficulty (based on the measured difficulty from Arsenyeva (2012) and on prima facie estimates for the 21 new items). Figure 5 shows screenshots of the online CLS used. In the item analysis and selection process, 112 items were chosen that fit the Rasch model and can provide a basis for the adaptive test of computer literacy called “CLS adaptive”. These items range in their difficulty parameter between $eta_{min}$= -3.19 and $eta_{max}$= 3.46 with a mean of 0.018 (SD = 0,267) and a normal distribution across the scale. Figure 6 shows the distribution of items across the ability spectrum and their Item Characteristic Curve (ICC) plot. Thus, the resulting item bank meets the requirements for an adaptive version of the CLS, which resembles the CLS online seen in the screenshots of fig. 5, but presents only a selection of suitable items in the testing process.

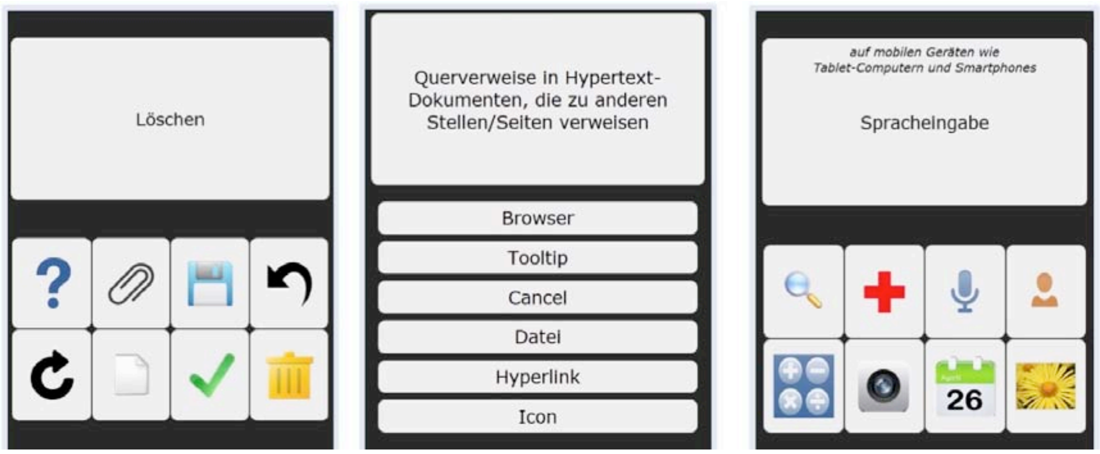


Figure 5. Screenshots of the CLS online questionnaire used by Götzinger (2014), the German translates as “delete” (left), “Cross reference in hypertext documents leading to other sources/pages” (middle) and “Speech input” (right).

## 3. Results

The CLS has been used in a variety of studies and predictive validity has been shown with different ICT applications. It shows strong correlations to control beliefs regarding technology use, attitude toward technology, computer anxiety and fluid intelligence (eg. measured with scales from WAIS & LPS 50+). Among these ICT-related control variables, CLS proved to be the best predictor of successful ICT interaction, if fluid intelligence was controlled for (Sengpiel, in press). The CLS can be accessed online and printed from a pdf - it is currently downloaded about 40 times per week. The CLS can be conducted on paper in 10 to 15 minutes, depending on literacy level. The new adaptive CLS can reduce testing time to less than 5 minutes and can be accessed on mobile devices as well (tested with iOS, Android, Windows, Linux and MacOS).

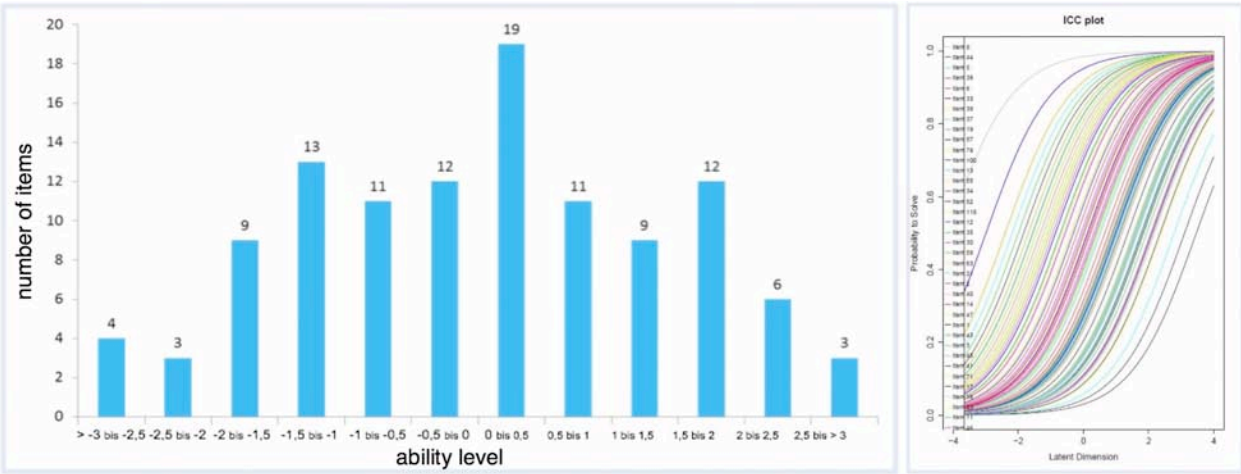


Figure 6. Distribution of CLS items across the ability spectrum (left) and their Item Characteristic Curve (ICC) plot (right).

## 4. Discussion

It is argued that ultimately, computer literacy could have an impact on any ICT-interaction and thus it should be measured as control variable in any study using ICT. Also, the degree to which ICT can be used independently of age or age related user characteristics such as computer literacy can be considered a measure of universal usability, making CLS an interesting testing tool for designers of universally usable systems. Fortunately, universal usability is an extensively researched and well documented craft, with a growing body of research specializing in issues involving "designing for older adults" (Fisk et al., 2009). To learn more about age and age related user characteristics and how to accomodate them through design is a constant challenge for researchers and designers, much like it is a constant challenge for older adults to keep up with technological advances. These technological advances constantly change the face of computer literacy, demanding constant adaptation of the CLS. Thus, the CLS will never be finished and anyone using the CLS not only gets results (CLS score) immediately, but helps to improve the CLS over time. All researchers interested in measuring computer literacy as control variable are invited to use it for free. CLS is available from www.computer-literacy.net.

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