Assessing Individual differences in Basic Computer Skills: Psychometric characteristics of an interactive performance measure

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Abstract

A definition of Basic Computer Skills (BCS) is proposed and the psychometric properties of a newly developed BCS scale are investigated. BCS is defined as the ability and speed of performing basic actions in graphical user interfaces of computers to access, collect, and provide information. BCS is thus considered one basic component skill of the much broader construct of ICT literacy. Data from the German PISA 2009 field trial was used to determine the BCS scale's factor structure, and convergent and discriminant validity. The latent factor structure underlying the BCS scale was investigated by modelling response times and responses in confirmatory factor analysis (CFA) models. CFA results suggest that there is one dimension of BCS speed and BCS ability, respectively. Pointing to convergent validity, practical computer knowledge and skill in digital reading had strong associations with BCS speed and ability. Pointing to discriminant validity, only moderate associations were found with lower level reading skills, and self-reported computer skills. Differences between BCS speed and ability and further developments of the BCS scale are discussed.

Key words: basic computer skills; interactive performance scale; ability; speed; convergent and discriminant validity

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## 1 Introduction

In this paper, we describe the development and validation of a scale assessing basic computer skills. Given the increasing importance of Information and Communication Technology (ICT) in peoples' everyday lives, computer-related skills have become a significant research topic from an individual differences and assessment perspective (e.g., Kim, Jung, & Lee, 2008; Lennon, Kirsch, Von Davier, Wagner, & Yamamoto, 2003; Poynton, 2005; Russell, Goldberg, & O'Connor, 2003). Many conceptualizations of ICT literacy are available, differing in the extent to which they focus on technological, informational and motivational aspects. Tsai (2002) defines computer literacy in a broad sense as "the basic knowledge, skills, and attitudes needed by all citizens to be able to deal with computer technology in their daily life" (p. 69). In the present study, ICT literacy is conceptualized as a competence (cf. Klieme, Hartig, & Rauch, 2008), i.e., as a context-specific cognitive disposition including knowledge, skills, and routines that are acquired by learning and that are required to deal successfully with informational tasks in ICT contexts. In this sense, the International ICT Literacy Panel (2002) presents a definition of ICT literacy, which does not take attitudes into account but focuses on cognitive and technological aspects. The Panel suggests five information-related competencies constituting ICT literacy: "ICT literacy is using digital technology, communications tools, and/or networks to access, manage, integrate, evaluate and create information in order to function in a knowledge society" (p. 16).

This article presents a newly developed scale for the assessment of basic ICT skills utilizing interactive simulations. Basic ICT skills are not to be confounded with ICT literacy, but can be seen as the lower level part of ICT literacy. Models of computer related information processing like the IPS-I model (Information Problem Solving on the Internet, Brand-Gruwel, Wopereis & Walraven, 2009) distinguish between three layers of component skills and processes. The lowest level is made up by basic skills, like basic reading and computer skills. These skills are required for cognitive actions of searching, processing, and integration information to be performed on the second layer. Finally, on the third layer, information processing is being governed by metacognitive regulation processes, such as monitoring, and evaluating. It is important to note that the scale described in this work addresses the first layer only, and here only basic computer-related skills.

Consider, for example, a student required to find information for an essay on genetically engineered foods. This student might engage in an internet search to this end, e.g. by using a search engine, requiring to access, read, evaluate and integrate multiple digital documents to solve the information problem. To carry out such a complex ICT-based information search, a number of basic component skills are required. Obviously, it is required to read, but also basic knowledge and related perceptual and motor skills on using the computer interface are required. For instance, the box in the search engine has to be identified, knowledge about the correct keys or buttons to send the search request must be at hand, knowledge about how to operate hyperlinks and a browser interface must be available, etc. In addition, using the technical interface should happen as quick and automatic as possible, to free cognitive capacity on higher layers, e.g. evaluating source credibility when integrating information from various sources. Throughout this article, when we refer to basic computer skills, we refer to lower-level skills only that will be highly automatic and be represented usually as procedural, rather than declarative knowledge (cf. Anderson, 1982).

We relate our conceptualization of basic computer skills (BCS) to other existing frameworks and argue for a performance based measure of basic ICT skills that takes into account not only accuracy, but also the response times in performing basic ICT tasks. Then, we explicate and test our hypotheses about the psychometric properties of the BCS scale and its validity, i.e., we focus on the dimensionality of BCS speed and BCS ability as well as their covariance structure. Here, we follow the approach of confirmatory measurement models and conceive speed and ability as latent variables that are measured by actual response times, and response accuracy, respectively (see e.g., van der Linden, 2009). Finally, we investigate how BCS are related to other cognitive and demographic variables, to determine the BCS scale's convergent and discriminant validity.

## 1.1 Definition of Basic Computer Skills

We propose to conceptualize the construct of Basic Computer Skills (BCS) as *the fundamental ability and speed of performing basic actions in graphical user interfaces of computers to access, collect, and provide information.*

The definition refers to *fundamental* skills which can be considered as core technical skills enabling to perform simple actions being common to many software applications, e.g., handling the file management function (cf. Markauskaite, 2007). Such actions can be completed in few steps and are usually encountered regardless of the current purpose of using a particular software, e.g., operating the copy-and-paste functionality of a word processor may be used when writing a letter but also when creating a timetable.

Basically, *ability* and *speed* represent major aspects of human performance in cognitive tasks (for a review see Carroll, 1993). From a measurement perspective, ability and speed are hypothesized person parameters to explain individual differences in response behavior above and beyond the influence of task characteristics, i.e., speed differences account for response time differences and ability differences explain differences in accuracy (cf. van der Linden, 2009, for an example see Goldhammer, & Klein Entink, 2011). Considering both speed and ability, which together indicate efficiency, seems most appropriate when focusing on basic skills reflected by relatively easy tasks (cf. the approach by Sandene, Bennett, Braswell, and Oranje, 2005, measuring both input speed and input accuracy as components of computer skills). The definition centers on *information*, i.e., ICT is considered as a tool applicable to dealing with information for solving daily life tasks. The term *computer* is used in a general sense; it covers the operation of desktop computers, which may be connected to networks, but also communication devices. The human-computer interface is assumed to be *graphical* given the importance of visual perception in human information processing (e.g., Anderson, Matessa, & Lebiere, 1997). To represent programs and commands graphically, the user-interface includes windows, icons and menus which can be manipulated by a mouse and keyboard. *Accessing* information involves basic technical skills for making information available for acquisition and further processing, e.g. using links in a web environment, navigation buttons of a web browser, menus, and search functions. *Collecting* information is related to basic ways of gathering information to maintain accessibility, e.g. file management, creating bookmarks and connections, typing, as well as copying and pasting. Finally, *providing* information means information is made accessible for others, using basic technical functions for sharing information, e.g. by sending or forwarding email messages in an email client.

The relevance of the construct of BCS and a valid measure of BCS is given in several respects. First, BCS itself is a highly relevant competence construct in that individuals lacking sufficient basic ICT skills will clearly be left behind both in educational as well as in professional contexts (cf. Leu, Kinzer, Coiro, & Cammack, 2004). Related research requires measures of ICT literacy to assess it cross-sectionally or longitudinally, e.g. to study the effect of instructional interventions aiming at the improvement of ICT literacy or to investigate the development of ICT literacy across the live-span (e.g., Weinert et al., 2011). Second, the BCS construct has become an important control variable because numerous assessments increasingly rely on computer-based assessment procedures. If the individual level of prior computer experience affects the test score above and beyond the to-be-assessed cognitive disposition, the test score's validity is threatened (e.g., Parshall, Spray, Kalohn, & Davey, 2002; Russell et al., 2003; Sandene, Bennett, Braswell, & Oranje, 2005). Thus, when developing computer based assessments of cognitive dispositions, in methodological terms, it is crucial to minimize the influence of individual differences in computer-related skills or control it by assessing them as covariate. Third, the computer itself has become an important means of instruction, and to-be-learned materials are being delivered through the computer as hypertext, hypermedia, or simulations. In research on learning with the computer, in general, ICT skills are an important covariate to be measured (e.g. Wecker, Kohnle, & Fischer, 2007).

## 1.2 Assessment of Basic Computer Skills

Self-ratings of ICT skills have often been used in their assessment (e.g. the ICT self-efficacy scale, Markauskaite, 2007). Although self-ratings provide some insight into actual skills (e.g. Ballantine, Larres, & Oyerle, 2007), they also reveal some shortcomings. For example, students tend to overrate their actual skill in some ICT domains, such as adequately judging the reliability of information found on the internet (Metzger, Flanagin, & Zwarun, 2003). Furthermore, some evidence points to this effect being more pronounced for boys than for girls (Hakkarainen et al., 2000), possibly causing an over-estimation of boys' advantages over girls in ICT-related skills.

In another approach to the measurement of ICT literacy, paper-and-pencil based tests including multiple choice questions were used. For example, in their 'Internet skills for school' test, Kuhlmeier and Hemker (2007) used screenshots depicting a task, and asked students what best to do in that situation. A similar approach was taken by Potosky (2007) with the 'Internet

Knowledge' (iKnow) measure. Similarly, in their 'Computer Literacy Inventory' (INCOBI), Richter, Naumann, and Horz (2010) used verbal scenarios of everyday computer tasks, together with four response options, only one of which was correct.

Although paper-and-pencil tests of computer knowledge are more objective, and better than self-reports in the prediction of actual performance, they also have limitations. Most important, unlike computer simulations, paper-and-pencil tests cannot provide an authentic interactive task. This is a major drawback if computer-related skills need to be assessed. Moreover, paper-and-pencil tests usually do not provide information about the test takers' response times. However, in the case of basic, and, therefore, easy computer skills tasks, individual differences might be even greater in speed of task completion than in response accuracy. Following this reasoning, the present study aimed at the development of an interactive and objective performance measure to assess ability and speed in interacting with a simulated computer environment. Although this strategy seems to be most adequate for assessing ICT literacy conceptualized as an interactive competence, only a few performance-oriented measures are available, e.g., the Information and Communication Technology Literacy Test (iSkills) by ETS (2008; see also Katz & Macklin, 2007).

The goal of the present work was to develop a BCS scale for the national extension of the Programme for International Student Assessment (PISA) 2009 study targeting German fifteen-year-old secondary school students. We designed tasks that simulate typical computer environments, and require responses within these environments using mouse and/or keyboard.

### 1.3 Hypotheses

The first hypothesis addresses the psychometric properties of the newly developed BCS scale: (1) Since BCS enable to deal with task requirements that are common to many software applications and purposes, we assume unidimensionality in both BCS speed and BCS ability. The unidimensional model is contrasted with a plausible alternative, less restricted measurement model assuming environment-specific dimensions, i.e., ability and speed dimensions being specific to text editor, web browser and email client. The two constructs are expected to be positively related dimensions, i.e., more able participants tend to complete basic ICT tasks faster.

The following hypotheses refer to the convergent and discriminant validity of the BCS scale. The construct validity of the BCS scale is addressed by investigating how well covariates that are assumed to underlie BCS actually predict BCS (2.1), by clarifying the relation of the objective BCS scale to a subjective scale assessing computer skills (2.2), by replicating gender associations with computer-related skills (2.3), and by investigating the predictive validity of BCS as an underlying component of electronic reading ability (2.4).

(2.1a) Domain knowledge is assumed to be a necessary condition for literate behavior in that competence acquisition is considered as a learning process that includes gaining and applying knowledge (cf. Mayer, 2003). For BCS, we assume that in particular *practical* computer knowledge, i.e., the knowledge about how to solve everyday computer problems, facilitates the development of BCS. The relation of BCS and computer knowledge however is probably bi-directional: While good knowledge helps in developing good BCS, also good BCS help in operating the computer without being under cognitive strain and thus help in acquiring new knowledge of procedures (see e.g. Keith & Frese, 2005; Keith, Richter & Naumann, 2010)

As a consequence, we assume that practical computer knowledge has strong associations with BCS ability and BCS speed, respectively.

(2.1b) While it is largely undisputed that ICT literacy in general has reading skills as a basis, amongst others, this is less clear for BCS. However, BCS tasks also usually include detecting and reading simple verbal labels of, e.g., buttons, menu items. Thus, higher level components of reading skill, such as integrating text contents with prior knowledge in forming a mental model (see e.g. Kintsch, 1998) are assumed to be distinct from BCS. However, lower level decoding skills, as measured through tasks like lexical decision, are required. We thus assume that ability and speed in word recognition are also associated with BCS performance.

(2.1c) When taking both practical computer knowledge and word recognition into account, we assume effect sizes found for word recognition to be smaller than those for practical computer knowledge, because basic reading abilities are necessary, but not a sufficient condition for the successful completion of BCS tasks.

(2.2) BCS ability and speed are assumed to be positively related to self-reported computer skills (see e.g., Ballantine, Larres, & Oyelere, 2007). Given that the assessment of BCS and computer skills involve two different types of measures (i.e., objective test vs. subjective self-report) and do not measure exactly the same construct (i.e., computer skills refer to more complex ICT activities than BCS, and reflect not only skills, but also self-efficacy), the correlations between BCS ability and speed are assumed to be moderate, that is, at most about .30. This magnitude is usually found when self-report measures are compared to performance measures of the same ability construct (cf. Mabe & West, 1982).

(2.3) A number of recent studies indicated that male students have (slightly) better ICT skills than females (e.g., Ilomäki & Rantanen, 2007; Imhof, Vollmeyer, & Beierlein, 2007; Kuhlemeier & Hemker, 2007). As the development of ICT skills depends on learning and opportunities to learn, we do not assume that males are in principal superior to females. However, males tend to use the computer more often and more intensively than females (e.g. Colley & Comber, 2003; Schumacher & Mohran-Martin, 2001; Vekiri & Chronaki, 2008), giving them more practice which in turn might produce faster and more accurate responses especially in lower level tasks. Based on this assumption, a valid BCS measure should be able to reveal the slight advantage of males. Therefore, we assume that male participants show higher mean levels of BCS ability and speed than females.

(2.4) Finally, we assume BCS ability and speed to be predictors of electronic reading ability. Compared to traditional reading literacy, reading electronic texts presumably affords additional and specific processing requirements because printed and electronic texts differ in their structure. Most important, electronic reading requires people to deal with the computer interface, and therefore BCS are needed, for instance to navigate in a web browser (cf. Leuet al., 2004; OECD, 2011).

# 2 Material and methods

## 2.1 Participants

A total of 320 secondary school students were included in the study. They participated in the German field trial of the PISA 2009 study, the target population consisting of fifteen-year-old students. Five participants with very high missing rates in BCS data (i.e., they completed less than one third of the 15 BCS tasks) were excluded from data analysis, resulting in a sample size of 315. The sample included 50.5% females and 42.5% males (7% unknown), aged 15.42 to 16.33 years ($M$=15.87, $SD$ =.28).

## 2.2 Measured variables

### 2.2.1 Basic Computer Skills

The Basic Computer Skills Test comprised 15 tasks (cf. Table 1), designed to cover the construct of BCS as defined above. Seven tasks basically require students to access information (tasks 1, 2, 5, 6, 9, 10, 11), six tasks require them to collect information (tasks 3, 4, 7, 8, 12, 14), and two tasks focus on providing information (13, 15). Each task starts with a brief instruction explaining the BCS task embedded in an informational context. Then the stimulus including a simulated graphical user interface of a computer environment is presented (see examples in Figure 1). The tasks refer to either a web environment (nine tasks), a text editor environment (four tasks), or an e-mail client environment (two tasks) (see Table 1). The focus is on web environments as browsing the Internet can be considered a major computer-related activity in the targeted age group (e.g., OECD, 2005, 2011). The simulated environments were abstracted from real software and operating systems. However, they can be assumed to share general characteristics of interaction functions with real computer environments (e.g., clicking onto a menu opens a list of menu items, clicking onto blue underlined text in a web browser links to another page etc.). All tasks are supposed to be solved by using the mouse, except for tasks 4 (Typing) and 10 (Finding a string), which require use of the keyboard for entering text. Nine tasks can be solved by one single interaction with the environment, while five tasks require two steps for completion, and one task requires three steps (see Table 1, column required interactions to solve the task).

Test takers are asked to complete the tasks as quickly and accurately as possible. They navigate between tasks by clicking a “next” button to the left of the stimulus area. This is practiced in a tutorial at the beginning of the test. We took care for the BCS tasks to be delivered in a secure testing environment allowing for logging of user interactions, including time stamps to compute response times. For each task, the individual log-transformed response time (RT) and the response (R) were collected.

### 2.2.2 Practical Computer Knowledge

Computer knowledge was assessed with the scale *practical computer knowledge* (PRACOWI) from a German inventory for the assessment of computer literacy, computer related attitudes and computer anxiety (*Revised Computer Literacy Inventory* INCOBI-R, Richter, Naumann, & Horz, 2010; see also Naumann, Richter, & Groeben, 2001). The scale PRACOWI presents 20 everyday computer problems in the form of written scenarios. For each problem, four possible solutions are presented, one of which is correct.

The scale successfully captures the degree of practical knowledge necessary to deal with everyday computer tasks and problems. It correlates substantially with measures of computer use, such as number of desktop or www applications used (Naumann, Richter, & Groeben, 2001, Richter, Naumann, & Groeben, 2001; Richter et al., 2010), it differentiates between computer experts and novices (Naumann et al., 2001), and it predicts performance in everyday computer tasks. The items of the PRACOWI have been shown to be unidimensional (Richter et al., 2010).

*Sample Item:* “You want to prevent other persons from following your navigation behavior on the internet. What do you do? (a) In my computer system settings, I delete my computer’s IP address. (b) In my computer system settings, I set the security settings so that my computer is invisible for others on the internet. (c) I delete all existing Cookies and set the settings of my web browser to not accept new ones. (d) I delete my computer’s MAC address and set the settings of my computer not to retrieve a new one.”

### 2.2.3 Word recognition

Students’ efficiency, i.e., speed and accuracy of word recognition (WR) were assessed with a Lexical Decision Task (see e.g. Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004). Students judged 30 words and 30 non-words that appeared successively on a computer screen. Participants were asked to work as quickly as possible, while avoiding errors. Each 10 of the words were nouns, verbs in the infinitive form, and adjectives. They varied in length between four and eight letters and between one and three syllables. To cover a wide variety of difficulty levels, orthographic regularity and number of orthographic neighbours were varied across items. Non-words were constructed by finding for each word another word that was equivalent in word type, length, frequency, regularity and number of orthographic neighbours. From this second word, a non-word was constructed by switching letters. Individual differences in word recognition are reflected by both response accuracy and (log-transformed) response time.

*Sample Item (Word):* “spielen” (German word for to play). *Sample Item (Non-word):* “tuckel”.

### 2.2.4 Self-reported computer skills

The *self-report on computer skills* included 12 items using a four-point scale from ‘do well by myself’ to ‘don’t know’ to indicate the confidence in doing ICT tasks. The statements referred to topics such as E-mailing, using the internet, multimedia, computer viruses, databases and file management (for details see OECD, 2011, chapter 5).

*Sample Item:* “To what extent are you able to do each of the following tasks on a computer?

Use a spreadsheet to plot a graph. (a) Do well by myself. (b) Do with help. (c) Know but can’t do. (d) Don’t know.”

### 2.2.5 Electronic reading

Electronic reading ability was assessed by means of 67 text comprehension tasks in 13 short hypertexts. The tasks included simulated hypertext environments with text materials that are typical for electronic reading (e.g. blogs, e-mails, websites, online learning environments). They required the participants to use various navigation tools, e.g., clickable images or menus with links, to access textual information that was needed to answer the comprehension questions (see OECD, 2009, Annex A2; OECD, 2011, chapters 2 and 3). Released units from the Electronic reading Field Trial and Main Study can be viewed at http://erasq.acer.edu.au/, using “public” and “access” as username and password (10/28/2011).

*Sample Item:* Philosophers' Café - Question: "You are at the Philosophers' Café Homepage. Click on the link for Confucius. What did Confucius mean by 'Ren? (a) Peace and prosperity. (b) Living in chaos and war. (c) The behaviour of rulers. (d) Kindness to other people. (e) Living in harmony."

## 2.3 Procedure

The administered instruments were part of the PISA 2009 field test, and a German national extension thereof. Students were tested in groups of 5-10 in computer labs at schools. First, the PISA study was introduced as an investigation of what 15 year old students know. All participants were asked to complete the computer-based performance measure and then the questionnaire. The overall completion time was about 120 minutes.

## 2.4 Data Analysis

Psychometric properties of the BCS scale were analyzed using Confirmatory Factor Analysis (CFA) (e.g., Bollen, 1989) and, by considering coefficients related to classical test theory (CTT). CFAs were conducted to test the hypothesized unidimensional measurement models for BCS ability (measured by item response indicators), and for BCS speed (measured by item response time indicators). Moreover, CFAs were used to assess the indicators' properties, and, finally, to explore the covariance structure assumed to exist between BCS ability and speed. Model parameters were estimated by means of the Mplus software (Muthén & Muthén, 1998–2010). For CFAs including continuous RT indicators the MLR estimator being robust to non-normality was used; to conduct CFAs including also categorical response indicators, the WLSMV estimator was used (see e.g., Forero & Maydeu-Olivares, 2009). A model was considered to show a good overall model fit if the following criteria were met (note, values in parentheses indicate a still acceptable fit): nonsignificant $\chi^2$ value, ratio of the $\chi^2$ value and degrees of freedom below 2 (3), root mean square error of approximation (RMSEA) below .05 (.08), standardized root mean square residual (SRMR) below .05 (.10); Weighted Root Mean Square Residual (WRMR) below .90; comparative fit index (CFI) and nonnormed fit index (NNFI) above .97 (.95) (Schermelleh-Engel, Moosbrugger, & Müller, 2003, Schweizer, 2010; for WRMR see Muthén, 1998-2004). Also, local areas of misfit were assessed by checking for patterns in the correlation residual matrix (Bollen, 1989).

CTT-related item coefficients and Cronbach's $\alpha$ were estimated using statistical packages of the R environment (R Development Core Team, 2009). For investigating the validity of the BCS scale, Mplus was used to estimate regression and correlation coefficients. As participants were sampled from schools, the estimation was configured to take non-independence of observations into account and thereby to provide correct standard errors (Mplus option TYPE=COMPLEX).

# 3 Results

## 3.1 CFA modelling of the BCS tasks

To test the unidimensionality of BCS speed and ability as claimed in Hypothesis 1, measurement models were tested. First, unidimensional CFAs were conducted separately for responses and response times, and then jointly to explore the covariance structure of BCS ability and speed. Item 2 was dropped from the beginning because it did not show any variance in responses.

Results for the initial RT-CFA model showed that item 4 did not load significantly on the latent speed factor (standardized solution: $\lambda_{4\text{Speed}}$=.08, $z$=1.12, $p$=.27); however, it was not dropped as it may measure BCS ability well. Following the model fit criteria as described above, the fit of the model was very good. This unidimensional model was compared to a three-dimensional model assuming environment-specific speed factors. As expected, the obtained fit for the less restricted model was also very good. Most importantly, however, the unidimensional model did not fit the data worse than the three-dimensional model as indicated by the Wald test, $\chi^2(3, N=315)=.87$, $p=.83$, suggesting retention of the more parsimonious unidimensional model.

The firstly tested R-CFA model including all items except for item 2 did not fit the data well, $\chi^2(77, N=315)=127.83$, $p<.01$, RMSEA=.046, WRMR=1.22, CFI=.61, NNFI=.54). The inspection of residuals revealed that residuals were greatest for item 3. By excluding item 3, the model fit became acceptable. Again, the final unidimensional model was compared with a model assuming three environment-specific ability factors. The fit for the less restricted model was also acceptable. Once again, however, the unidimensional model did not fit the data worse than the three-dimensional model as indicated by the Wald test, $\chi^2(3, N=315)=.81$, $p=.85$.

Based on these results supporting the hypothesis of unidimensionality of both BCS speed and ability, a joint RT-R-CFA model was tested including all but the dropped items 2 and 3. The overall fit of the model was not entirely acceptable, $\chi^2(298, N=315)= 377.65$, p<.01, RMSEA=.029, WRMR=1.03, CFI=.84, NNFI=.83. Modification indices suggested to free the item-specific residual correlations between response and response time indicator of item 4 and item 7, respectively. The fit of the modified model was acceptable. Results showed that the variances of both BCS speed and ability were significant, *Var*(Speed)=.08 ($z=3.79$, $p<.01$), and *Var*(Ability)=.36 ($z=2.04$, $p=.04$), as well as their correlation of *Cor*(Speed, Ability)=.56 ($z=6.95$, $p<.01$). The first result indicates systematic variance between individuals in their BCS speed and ability. The latter result indicates that, as expected, participants with higher levels of ability also tend to work at a higher speed.

Table 2 shows the estimated CFA model parameters of the final joint measurement model including items 1, and 4 to 15. Most of the thresholds are negative indicating that the tasks are easy, as it can be expected for tasks measuring basic ICT skills. In the RT model, the intercept parameter reflects the required time corresponding to the average RT; the factor loading indicates how well an item distinguishes between participants' speed levels. Although items 4 and 9 showed low factor loadings on BCS speed and BCS ability, respectively, they were not dropped because of good measurement properties related to BCS ability and BCS speed, respectively. Table 2 also presents item coefficients related to CTT, i.e., for response data, item difficulty *M*(R) and discrimination $Cor(R_i,R_t)$, and similarly for response time data the RT-related discrimination $Cor(RT_i,RT_t)$. Reliability analysis revealed Cronbach's $\alpha$ values of .84 for BCS speed and of .70 for BCS ability.

In sum, the part of Hypothesis 1 proposing unidimensionality of speed and ability was supported for the revised scale. This means the data support the notion that for test takers' accuracy in completing the BCS tasks one latent variable is sufficient to explain individual differences in accuracy. Thus, as regards the materials used in the present study, there appears to be one BCS ability, rather than multiple abilities relating to multiple environments. The same claim can be made for the observed response times: Individual differences are again best explained by the assumption that there is one speed of BCS task completion rather than multiple that are distinguished along the lines of different environments.

BCS ability and BCS speed were also substantially related to one another, sharing about one fourth of their variance. This indicated that test takers with higher levels of ability also work at a higher level of speed. However, the correlation of BCS speed and ability was far less than one. This means that while BCS speed and ability are related, they are by no means the same, providing evidence for the notion that it is necessary to measure them both. In other words:

Measuring BCS speed gives information about a test taker that is not available if only BCS ability is measured, and vice versa.

## 3.2 Evidence for the convergent and discriminant validity of the BCS scale

As a preparatory step of the following validation, CFAs were conducted for scales assessing practical computer knowledge, word recognition (WR, both WR speed and ability), self-reported computer skills, and Electronic reading ability. CFAs served to test the assumed unidimensionality of these scales, and to estimate factor scores. Table 3 shows distribution parameters, reliability coefficients, and Pearson correlations for factor scores of all measures. As the Electronic reading items were delivered in a booklet design, Cronbach's α could not be computed; therefore, we present the IRT-based reliability (cf. Wu, Adams, Wilson, & Haldane, 2007).

### 3.2.1 Results on Hypothesis 2.1: Predictive validity of practical computer knowledge and word recognition

(2.1a) The regressions of BCS speed and BCS ability on practical computer knowledge revealed, as hypothesized, significant (standardized) regression coefficients of $b$=.47 ($z$=9.61, $p$<.01) for BCS speed and of $b$=.60 ($z$=17.15, $p$<.01) for BCS ability.

(2.1b) Also when regressing BCS speed on WR speed and BCS ability on WR ability, significant regression coefficients of $b$=.36 ($z$=4.01, $p$<.01) for BCS speed and of $b$=.32 ($z$=5.05, $p$<.01) for BCS ability could be shown, which, however, were smaller than those found for practical computer knowledge.

(2.1c) Multiple regression of BCS speed on practical computer knowledge and WR revealed significant associations of BCS speed with both practical computer knowledge of $b$=.40 ($z$=8.32, $p$<.01), and with WR speed of $b$=.30 ($z$=3.71, $p$<.01) when accounting for the respective other predictor. The proportion of explained variance was $R^2$=.29 (for practical computer knowledge $\Delta R^2$=.16, for WR speed $\Delta R^2$=.07). When BCS ability was regressed on practical computer knowledge and WR ability, again significant associations were obtained for both practical computer knowledge of *b*=.55 (*z*=12.66, *p*<.01), and for WR ability of *b*=.18 (*z*=3.14, *p*<.01). For BCS ability the amount of explained variance of $R^2$=.38 was even greater than for BCS speed (for practical computer knowledge $\Delta R^2$=.28, for WR ability $\Delta R^2$=.02). The fact that associations of practical computer knowledge and BCS remained after including WR as a predictor in the model indicated that the prediction of BCS ability and speed from practical computer knowledge is not an artefact driven by the fact that reading is involved in solving both BCS tasks and practical computer knowledge tasks. It also indicated that rapid access to the meaning of words is predictive of task success in digital environments requiring the decoding of verbal information, e.g. as displayed on buttons. This is in line with the theoretical notion that at least basic decoding skills are required to successfully cope with even low level computer tasks.

### 3.2.2 Results on Hypothesis 2.2: Relation to self-reported computer skills

As expected, the correlation between self-reported computer skills and BCS speed of *r*=.18 was significant (*z*=2.03, *p*=.04), but small. Similarly, the obtained correlation of self-reported computer skills with BCS ability of *r*=.26 was moderate and significant (*z*=4.19, *p*<.01). This indicated that students' perceptions of their ICT skills were related to their actual skills as measured by BCS speed and ability, but these relations were weaker than the relationships of an objective test of practical computer knowledge with BCS speed and ability.

### 3.2.3 Results on Hypothesis 2.3: Relation to gender

When BCS speed was regressed on gender, a significant regression coefficient of *b*=.21 (*z*=4.11, *p*<.01) was found. When BCS ability was regressed on gender, a similar regression coefficient of *b*=.24 (*z*=5.94, *p*<.01) was obtained. The proportions of explained variance for

BCS speed was $R^2$=.04, and for BCS ability it was $R^2$=.06. As expected, the positive regression coefficients indicated a better performance of males in BCS tasks than females; however, the amount of explained variance by gender was only small.

#### 3.2.4 Results on Hypothesis 2.4: Prediction of electronic reading ability.

Finally, the predictive validity of BCS with electronic reading was investigated. As expected, electronic reading was predicted by BCS ability, $b$=.45 ($z$=5.23, $p$<.01), and BCS speed, $b$=.21 ($z$=2.18, $p$=.03). The regression coefficients indicate that BCS ability and speed independently predict electronic reading. The proportion of variance in electronic reading skill explained by BCS ability and speed was $R^2$=.38. This result indicates that Electronic reading, that in itself constitutes an important aspect of computer use in information society, is predicted to a substantial degree by BCS speed and ability. This is in line also with current models of problem solving in the context of ICT assuming basic computer skills are a prerequisite of higher order problem solving activities (Brand-Gruwel et al., 2009).

Taken together, the hypotheses pertaining to the internal structure of BCS, and its association with other cognitive as well as demographic variables were confirmed. As expected, BCS ability and speed proved to be unidimensional and separable dimensions of BCS. Regarding their assumed cognitive basis, BCS ability and speed had substantial correlations and partial correlations with practical computer knowledge, as well as word recognition. There were lower but significant correlations with self-assessed computer skills. Also, as suggested by previous findings, males had slightly higher levels of BCS ability and speed than females. Finally, as hypothesized, BCS ability and speed were shown to be underlying components of electronic reading ability.

## 4 Discussion and Conclusions

The aim of the present study was to develop a BCS scale that allows for an assessment of the participant's ability, as well as speed in completing basic computer tasks. The task design was based on a definition that conceptualizes BCS as ability and speed of accessing, collecting, and providing information by performing basic actions in computers' graphical user interfaces. A computer-based assessment approach was selected to obtain a more valid measurement by means of interactive and simulation-based task types, and to collect also response time data for measurement models taking both responses and response times into account. For validation, we considered various constructs related to computer skills and measurement approaches.

Empirically, unidimensionality in both BCS speed and BCS ability could be assumed after dropping two ill-fitting tasks. It is important to note that the present results need to be replicated in independent samples in future studies. If this result holds up, it would confirm the theoretical assumption that BCS represent generic skills which are not specific to particular environments but refer to task demands that are common to different software applications.

BCS speed and BCS ability were substantially related, indicating that participants being accurate also tend to be fast. However, the amount of unique variance suggests that both person parameters carry specific information, i.e., in a group of participants with a given ability level, there will still be variability in the level of speed, and vice versa. The empirical separability of BCS ability and speed supports the theoretical notion that both ability and speed are specific constituents of BCS. Practically, this implies that assessing and reporting of BCS should take both speed and ability into account (e.g., Sandene et al., 2005).

The scale as it stands appears to provide a valid measure of BCS, according to a number of relations to other measures, both in terms of convergent, and discriminant validity. First, both BCS speed and ability show strong correlations with knowledge on the solution of higher order

ICT tasks (Practical Computer Knowledge). This is in line with models such as the IPS-I model of problem solving on the Internet, where basic computer skills are deemed a requirement for the solution of higher-order tasks. Second, relations with basic reading skills are in line with the fact that decoding of small text segments was required for the basic ICT tasks appearing on the test, starting with reading the task, and ending with e.g. pressing a particular button with a textual label. Indeed, while models like the IPS-I assume reading skills to be a basic requirement of problem solving on the internet, we would claim that at least basic reading is also a prerequisite for solving basic ICT tasks. However, while there were correlations of BCS and basic reading, these were significantly lower than the association of BCS with practical computer knowledge. Finally, BCS speed and ability were found to predict performance on a measure of an essential 21st century skill, comprehension of on line text, including the selection and integration of various text segments from a complex information space. As expected, these associations were again stronger than the association with pure word decoding skill. All in all, the pattern of associations of BCS with other measures warrant the conclusion that the scale proposed here provides a valid measure of a person's skill in carrying out basic operations in using the computer to access, collect, and provide information.

Hypotheses on validity were put forward for both BCS speed and ability. The most noticeable empirical difference was that practical computer knowledge (and also electronic reading ability) showed stronger associations with BCS ability than with BCS speed. One explanation would be that ability-related measures (here: BCS ability) in general show higher commonalities with other ability-related measures (here: practical computer knowledge) than with speed-related measures (here: BCS speed) due to a general underlying cognitive ability component (cf. Carroll, 1993). However, the low correlation of .32 between BCS ability and WR ability as another ability parameter suggests that the strong association of BCS ability with practical computer knowledge cannot be explained solely by an unspecified underlying cognitive ability. Rather, according to Hypothesis 2.1, practical computer knowledge seems to be a domain specific condition for BCS.

Taken altogether, the obtained results suggest that the BCS scale is a reliable and valid means of assessing a person's basic computer skills, both in educational and research contexts. Possible applications of the scale in applied settings might include the tailoring of computer-based instruction providing students with more study time who - e.g. because of limited access to computers - already struggle with very basic operations of computer-based information access. In research settings, the scale described in this article provides researchers with a covariate for e.g. disentangling different sources of variance in performance of more complex ICT tasks. For instance, as shown by results from PISA 2009, around the world, in a number of countries, large proportions of students have problems with accessing information in hypertext environments, and as a consequence, receive only poor scores on a digital reading test (see OECD, 2011, ch. 3). Including a measure of basic ICT skills in such a study might help determining whether students lack BCS, or whether it is more e.g. metacognitive strategies of evaluating the contents of a document that prevent them from gathering the information they need.

For the further development of the BCS scale, some extensions and modifications of the present version need to be considered. First, to obtain a more systematic construct representation, the BCS scale should be balanced with respect to simulated environments and information skills, i.e., tasks should be added that simulate email client, text editor or processor, and file manager, and some more tasks should require participants to collect information and to provide it to others. Items 3, 4 and 9 should be replaced as they showed item misfit or low discrimination with respect to BCS speed and BCS ability, respectively. A limitation of the present scale is the restricted range of item difficulties. All items are of low and medium difficulty, i.e., participants with high levels of BCS ability cannot be discriminated. To increase the benefit from the BCS ability parameter, some more difficult tasks should be added to the scale by increasing task complexity, thereby, however, maintaining the scale capturing basic skills of accessing, collecting and sharing computer-based information. Future studies should also aim at supplementing the present findings with the investigation of how BCS ability and speed are related to other ICT literacy competencies or performance in other ICT tasks such as creating information using word processors or graphics programs, or managing information using, e.g., data bases.

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Table 1

*Items of the BCS scale.*

| ID | Item | Simulated environment | Task description (instruction) | Required interactions solve the task |
|---|---|---|---|---|
| 1 | Clicking search button | Web browser | The term „New York“ was typed in the search machine Global Search. Use the mouse to get the search results. | 1. click button "Global - Search" |
| 2 | Scrolling | Web browser | You are at a website of the public transportation service, which has a link to the Black Forrest. Find the link and click on it to enter the corresponding website. | 1. scroll down<br>2. click link |
| 3 | Formatting | Text editor | You want to format a part of your text document in bold letters. The text part you want to format is already marked. Use the mouse to format the text part in bold letters. | 1. click menu item |
| 4 | Typing | Text editor | You are shown a text, which you should typewrite error-free in the input box below. Click ok when you are done. | 1. type a text of 239 characters |
| 5 | Clicking home button | Web browser | You are on a website about butterflies and you want to go back to the start page of your browser. Use the mouse to go back to the start page. | 1. click button "Home" |
| 6 | Clicking menu item | Web browser | You are on a website that shows train connections. Find the fastest train connection using the sorting function. | 1. click on menu "Choose"<br>2. click on menu item "Duration" |
| 7 | Copy & paste | Web browser | You are shown a latin text. Use the mouse to copy the text into the input box below, then click ok. | 1. highlight text<br>2. copy<br>3. paste |

| | | | | |
|---|---|---|---|---|
| 8 | Saving as new file | Text editor | You have just updated a document and want to save it while keeping the old version. Use the mouse to save your updated text version without losing the old one. | 1. click on menu "File"<br>2. click on menu item "Save as" |
| 9 | Searching images | Web browser | You want to search for pictures with the search engine Global Search. Use the mouse to start the picture search. | 1. click button "Images" |
| 10 | Finding a string | Web browser | You are on a website of the city Münster. Use the search function to find out if the website contains information about an architect named Schlaun. | 1. type the word "Schlaun"<br>2. click button "Search" |
| 11 | Clicking back button | Web browser | You are on a website about butterflies and you want to go back to the website that you have visited before. Use the mouse to go back to the website you have visited before. | 1. click button "Back" |
| 12 | Saving file | Text editor | You want to save your text document. Use the mouse to save the text. | 1. click menu item |
| 13 | Clicking reply button | Email client | You have received an email and want to reply to it. Use the mouse to start creating a reply. | 1. click button "Reply" |
| 14 | Clicking bookmark | Web browser | You are on a website and now want to switch to a website called www.Nachrichten.de, for which a bookmark exists. Use the bookmark function to open the website www.Nachrichten.de. | 1. click button "Bookmark"<br>2. click on "Nachrichten.de" |
| 15 | Clicking forward button | Email client | You have received an email, which you want to forward to another person. Use the mouse to send the email to someone else. | 1. click button "Forward" |

Table 2

*Model parameters of the final CFA model for responses and response times in BCS items and corresponding CTT item coefficients (items 2 and 3 were not included in the final CFA model).*

| | | CFA model parameters | | | | CTT item coefficients | | |
|---|---|---|---|---|---|---|---|---|
| | | Response model | | Response time model | | Response data | | Response time data[a] |
| ID | Item | Threshold | Loading (standardized) | Intercept | Loading (standardized) | *M*(R) Difficulty | *Cor*($R_i$,$R_t$) Discrimination | *Cor*($RT_i$,$RT_t$) Time-related discrimination |
| 1 | Clicking search button | -1.87 | .60 | 8.74 | .48 | .97 | .27 | .53 |
| 2 | Scrolling | - | - | - | - | - | - | - |
| 3 | Formatting | - | - | - | - | - | - | - |
| 4 | Typing | 1.09 | .43 | 11.92 | .12 | .14 | .50 | .24 |
| 5 | Clicking home button | -0.03 | .30 | 8.90 | .62 | .51 | .43 | .62 |
| 6 | Clicking menu item | -1.18 | .41 | 10.13 | .60 | .88 | .33 | .59 |
| 7 | Copy & paste | .48 | .34 | 10.13 | .57 | .32 | .52 | .62 |
| 8 | Saving as new file | .58 | .33 | 9.48 | .60 | .28 | .57 | .64 |
| 9 | Searching images | -1.52 | .14 | 8.57 | .69 | .94 | .03 | .68 |
| 10 | Finding a string | .75 | .49 | 9.43 | .29 | .23 | .47 | .41 |
| 11 | Clicking back button | -1.05 | .44 | 8.38 | .63 | .85 | .25 | .66 |
| 12 | Saving file | -1.25 | .45 | 8.80 | .60 | .89 | .25 | .65 |
| 13 | Clicking reply button | -1.52 | .24 | 8.78 | .54 | .94 | .26 | .59 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 14 | Clicking bookmark | -.99 | .61 | 9.63 | .65 | .84 | .38 | .66 |
| 15 | Clicking forward button | -1.84 | .72 | 8.69 | .55 | .97 | .11 | .58 |

*Note*. R=response, RT=log-transformed response time, *Cor*($R_i$,$R_t$) =point biserial correlation between item score and total score, *Cor*($RT_i$,$RT_t$)=Pearson correlation between item response time and total response time. [a]The values for *M*($RT_i$) per item are not presented as they correspond to the intercepts of the response time CFA model (expected value of $RT_i$).

Table 3

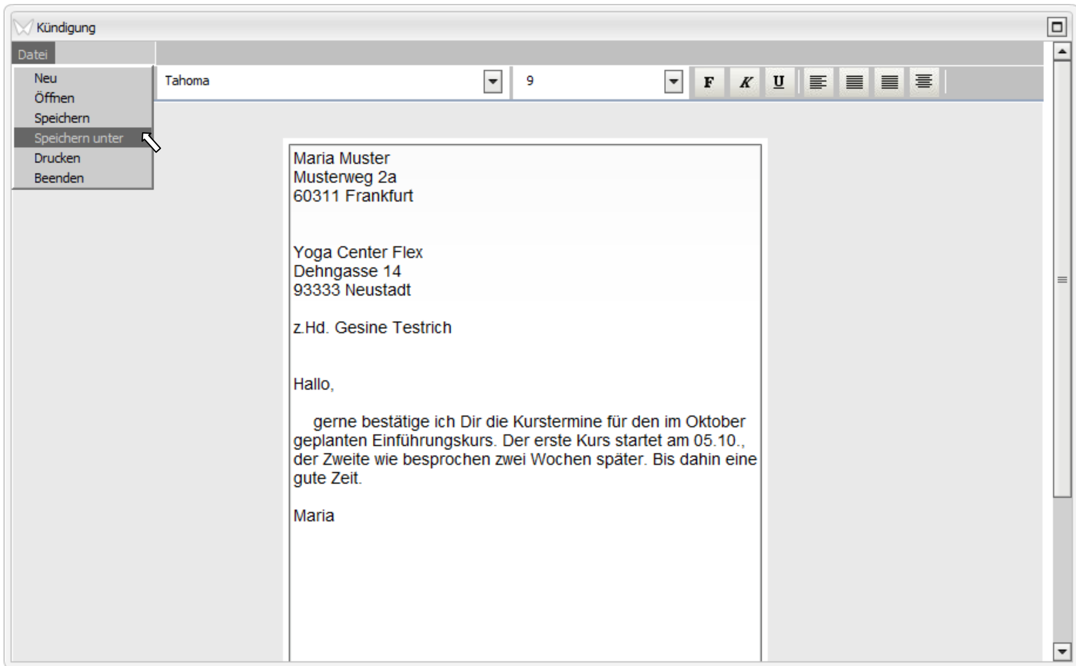
*Distribution parameters, scale reliability, and Pearson correlations of Basic Computers Skills (BCS), Practical Computer Knowledge, Word Recognition (WR), Self-reported Computers Skills, and Electronic Reading.*

| Measure | | *M* | *SD* | Skewness | Kurtosis | Cronbach's α | Pearson Correlation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | BCS - Ability | -.03 | .46 | -.26 | -.24 | .70 | | | | | | |
| 2 | BCS – Speed[a] | .01 | .26 | .32 | .12 | .81 | .74 | | | | | |
| 3 | Practical Computer Knowledge | .01 | .45 | .36 | -.05 | .81 | .60 | .47 | | | | |
| 4 | WR - Ability | .00 | .12 | -1.89 | 3.48 | .91 | .32 | .23 | .24 | | | |
| 5 | WR – Speed[a] | .00 | .23 | .18 | .54 | .96 | .29 | .36 | .16 | -.03 | | |
| 6 | Self-reported Computers Skills | -.03 | .57 | -.41 | .59 | .86 | .26 | .18 | .35 | .04 | .13 | |
| 7 | Electronic Reading | .04 | 1.70 | -.27 | -.56 | .71[b] | .60 | .54 | .54 | .44 | .30 | .16 |

*Note*. [a]Factor scores from CFA actually reflect slowness; for the computation of correlations, factor scores were multiplied by (−1) so that all measures have a positive orientation. [b]IRT-based Reliability.

Figure Caption

*Figure 1.* Two sample screenshots of BCS tasks: The upper screenshot shows the stimulus of Task 8 ‘Saving as new file’. To complete it correctly, the test taker clicks on menu “File” (in German: “Datei”) and selects menu item “Save as” (in German: “Speichern unter”). The lower screenshot shows the stimulus of Task 15 ‘Clicking forward button’. To complete it correctly, a click on the button “Forward” (in German: “Weiterleiten”) is required.


Kündigung
Datei
Neu
Öffnen
Speichern
Speichern unter
Drucken
Beenden
Tahoma
9
F
K
U
Maria Muster
Musterweg 2a
60311 Frankfurt
Yoga Center Flex
Dehngasse 14
93333 Neustadt
z.Hd. Gesine Testrich
Hallo,
gerne bestätige ich Dir die Kurstermine für den im Oktober geplanten Einführungskurs. Der erste Kurs startet am 05.10., der Zweite wie besprochen zwei Wochen später. Bis dahin eine gute Zeit.
Maria


email
Back
Forward
Home
Adresse
https://webmail.internet.org
email
Antworten
Weiterleiten
Drucken
Speichern
Löschen
Neu
Von: martin.schmidt@wmx.de
An: elena.r@wmx.de
CC: Klaus.k@webs.de
Betreff: Referat nächste Woche
Hi Elena,
ich schaffe es heute nicht mehr, noch was für unser Referat vorzubereiten. Kannst Du vielleicht schon mal anfangen, die wichtigsten Infos zusammen-zuschreiben? Kannst sie ja auf Deinen Blog stellen.
Hab bereits im Internet gesucht und ein paar interessante Links gefunden. Einfach hier gucken:
http://globalsearch/search?hl=de&q=gesunde+Ern%C3%A4hrung&btnG=Globalsearch Suche&meta=
Danke, ich kümmere mich dann mit Klaus um die Ausarbeitung!
Bis morgen!
Martin
> ----Ursprüngliche Nachricht-----