interesting, since the decades and units of two-digit number words follow opposite structures in German (i.e. unit-decade) and French (decade-unit). In a series of experiments pupils from grades 7, 8, 10, 11, and adults made magnitude comparisons and additions that were presented in different formats: Arabic digits and number words. Both tasks were performed in separate German and French testing sessions and we recorded correct responses rates and response times. The results obtained during magnitude comparison show that orally presented comparisons are performed differently by the same participants according to task language (i.e. different compatibility effects in German vs. French). For additions it appears that the level of language proficiency is crucial for the computation of complex additions, even in adults. In contrast, adults tend to retrieve simple additions equally well in both languages. Taken together, these results support the view of a strong language influence on numerical representations and computations.

Language differences in basic numerical tasks

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Connections between knowledge of language and knowledge of number have been suggested on theoretical and empirical grounds. Chomsky (1986) noted that both the sentences of a language and the numbers in a counting sequence have the property of discrete infinity, and he suggested that the same recursive device underlies both (Bloom 1994 and Hurford 1987). Numerical researchers have therefore begun to examine the influences of linguistic properties.

In this internet study, we explored adults from various countries in some basic numerical tasks consist of symbolic and non-symbolic magnitude comparison and parity judgment, and recorded responses to find the error rate and reaction time. The results suggest that not only distinct languages influence these kinds of tasks differentially, but that the other cultural and individual factors play an important role in numerical cognition.

Cognitive components of the mathematical processing network in primary school children: linguistic and language independent contributions

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We have tested the cognitive components of mathematical skill in more than one hundred 9 year old primary school children. We aimed to separate the contributions of language related and language independent skills. We used 18 cognitive tests and 9 custom experiments. We identified phonological decoding efficiency and verbal intelligence as important contributors to mathematical performance (measured by standardized tests). In addition, spatial ability, visual short term and working memory were also strong predictors of arithmetic performance. Further, children with pure developmental dyscalculia only showed impaired visuo-spatial processing but no impairment in verbal and language function. The results can shed light on the differing role of language and visual function in arithmetic and on co-morbidity of language and arithmetic disorders.

It does exist! A SNARC effect amongst native Hebrew speakers is masked by the MARC effect

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The SNARC effect has been found mainly with participants who speak Germanic languages. The effect in these studies implies that mental number line spreads from left-to-right. Therefore, it was suggested that the effect derives from the experience of writing from left-to-right. Commonly, studies of spatial-numerical associations in Hebrew speakers report a null SNARC effect when the standard designs in which the participants are asked to perform parity task twice, each time with a different parity-to-hand mapping. It has been argued that this is due to different reading directions of words and numbers. Hebrew is written from right-to-left while numbers are written by Hebrew writers from left-to-right as in Germanic languages. In this paper, we show that a SNARC effect in native Hebrew speakers does exists when the design minimizes the MARC effect. Furthermore even Hebrew is written from right-to-left the mental number line as estimated by the SNARC effect spreads from left-to-right as in Germanic languages. These findings challenge the assumption that direction of reading is the main source of the direction of spatial-numerical association.

MODELING OF COGNITIVE ASPECTS OF MOBILE INTERACTION

Convenors: *Nele Russwinkel, Sabine Prezenski, Stefan Lindner*
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Interacting with mobile devices is gaining more and more importance in our daily life. Using those devices provides huge comfort, but nevertheless entails specific challenges. In contrast to the classical home computer setting, mobile device usage is more prone to disruptions, more influenced by time pressure and more likely to be affected by earlier interaction experiences. An important issue in this context consists in interfaces fitting best for the users' cognitive abilities. These abilities display a high variety between different groups of users. How can developers and designers adapt an interface to meet the users' skills and preferences? For these purposes, cognitive modeling provides an appealing opportunity to gain insights into the users' skills and cognitive processes. It offers a theoretical framework as well as a computational platform for testing theories and deriving predictions.

The scope of this symposium lies in introducing selected approaches to user modeling and showing their application to the domain of mobile interaction. In this context we are particularly interested in criteria like learnability and efficiency from a cognitive as well as a technical point of view. Moreover, research concerning individual differences, interruption and expectancy is presented. Overall, we aim to show that the mobile interaction scenario offers an interesting research area to test model approaches in real life applications, but also discuss cognitive processes that are relevant within those tasks. We will look upon those different cognitive aspects of mobile interaction and the role of modeling to improve cognitive appropriate applications.

Creating cognitive user models on the basis of abstract user interface models

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The recent explosion of mobile appliances creates new challenges not only for application developers and content creators, but also for usability professionals. Conducting a classical usability study of a mobile user interface (UI) on an exhaustive number of devices is more or less impossible. One approach to tackle the engineering side of the problem is *model-based user interface* development, where an abstract UI model is adapted to the target device at runtime (Calvary et al. 2003). When this method is applied, the application flow is modeled first and user controls are abstractly identified by their roles therein (e.g. command, choice, output). The elements of the final UI as presented to the users (e.g. buttons, switches, labels) are all representations of those, enriched by physical properties like position, size, and textual content.

While knowing the sizes and positions of the UI elements already allows predictions of completion times for previously specified tasks, e.g. by creating simple cognitive models using CogTool (John et al. 2004), the additional information encoded into the abstract UI model allows to go much further. It contains machine readable knowledge about the application logic and the UI elements that are to be visited to attain a specified goal, which creates a significant opportunity for machine translation into more precise cognitive models (Quade et al. 2014). In this talk, I will show how completion time predictions can be improved based on abstract UI model information. Data from two empirical studies with a kitchen assistance application is presented to illustrate the method and quantify the gain in prediction accuracy.

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Expectations during smartphone application use

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Expectations serve a multitude of purposes and play a large role in the adoption and use of new technological devices. I will briefly discuss a classification of expectations, implementation ideas in ACT-R and their role during smartphone app use.

In a general sense, expectations coordinate our goals and desires with the current and the future state of the environment. They are necessary for any kind of intentions, help in action preparation (Umbach et al. 2012), and play a prominent role in action-perception feedback loops (Friston, Kiebel 2009).

Experience-based expectations are expectations that result from the individual learning history. Both the utility and activation mechanisms of ACT-R can be interpreted as reflecting experience-based expectations about our environment. One possible way to model the formation of experience-based expectations from past experiences using the partial matching and blending algorithms of ACT-R is described in Kurup et al. (2012). Other implementations are possible (Lindner, Russwinkel 2013). *Universal expectations* are expectations that result from the universally inherited pre-structuring of the environment. In ACT-R universal expectations are in part already reflected in the modeler's decisions regarding the content of the model environment, memory items and production elements.

Both types of expectations play a dynamic role during the adaptation and use of a technical device. Using a new smartphone app users will first rely on general expectations derived from past use of other smart phone apps or computer programs. Universal expectations, especially in the form of assumed form-function contingencies, play an important role in this phase as well. With time, however, users will increasingly rely on expectations that are in line with specific knowledge acquired during use.

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Evaluating the usability of a smartphone application with ACT-R

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The potentials of using ACT-R (Anderson 2007) based cognitive models for evaluating different aspects of usability are demonstrated using a shopping list application for an Android application.

Smartphone applications are part of our everyday life. A successful application should meet the standard of usability as defined in EN ISO-924-110 (2008) and EN ISO-924-111 (1999). In general, usability testing is capacious and requires vast resources. In this work, we demonstrate how cognitive models can answer important questions concerning efficiency, learnability and experience in a less demanding and rather effective way. Further we outline how cognitive models provide explanations about underlying cognitive mechanisms which effect usability.

Two different versions of a shopping list application (Russwinkel and Prezenski 2014) are evaluated. The versions have a similar appearance but differ in menu-depth. User tests were conducted and an ACT-R model, able to interact with the application, was designed. The task of the user respectively the model consists in selecting products for a shopping list. In order to discover potential learning effects, repetition of the task was required.

User data show, that for both versions time on task decreases as user experience increases. The version with more menu-depth is less efficient for novice users. The influence of menu-depth decreases as user experience increases. Learning transfers from different versions are also found. Time on task for different conditions is approximately the same for real users and the model. Furthermore, our model is able to explain the effects displayed in the data. The learning effect is explained through the building of application-specific knowledge chunks in the model's declarative memory. These application-specific knowledge chunks further resolve why expertise is more important than menu-depth.

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Simulating interaction effects of incongruous mental models

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Traditional usability evaluations involving older adults are difficult to conduct (Dickinson et al. 2007) and the results may also be misleading, as often only the cognitively and physically fittest seniors participate (Hawthorn 2000). In addition to this, older adults often lack experience in using modern devices (Hanson 2011). Furthermore, it is reasonable to assume that older adults often have problems operating new devices, if they inappropriately transfer prior experience using other devices (Arning, Ziefle 2007). Such an inappropriately transfer would result in an increase of wrong or redundant interaction steps, which in turn may lead to unintended actions being recognized by the system (Bradley et al. 2011).

To simulate the effects of incongruous mental models or the inappropriate transfer of prior experience using other devices, an existing tool for automatic usability evaluation—the MeMo workbench—was extended. The goal of the enhancement was to simulate interaction of users with a smartphone including mistakes and slips; According to Reason (Reason 1990, p 12 ff.), Mistakes, Lapses, and Slips are the primary error types which can be used to classify errors in human computer interaction. To simulate mistakes—errors which result from incongruous mental models or inappropriately transferring prior experience—a new processing module was added. This processing module uses 4 generalized linear models (GLMs) to compute what kind of interaction the user model intends to apply to the touchscreen. To simulate slips we added a new execution module which computes the probability that the user model interaction is not executed as intended (e.g. missing a button when trying to hit it).

Our results show that it is possible to simulate interaction errors (slips and mistakes) and describe interaction parameters for younger and older adults operating a touchscreen by using the improved MeMo workbench.

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"Special offer! Wanna buy a trout?"—Modeling user interruption and resumption strategies with ACT-R

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Interruption is a frequently appearing phenomenon users have to deal with in interactions with technical systems. Especially when using mobile applications on Smartphones they are confronted with a variety of distractors, induced by the system itself (e.g., product advertisement, system crash) or resulting from the mobile context (e.g., motion, road traffic). Such interruptions might be critical especially in periods of already enhanced demands on working memory, resulting in increased experienced workload. Based on a time course model of interruption and resumption to a main task, developed by Altmann and colleagues (e.g., Altmann, Trafton 2004), this research explores an interruption scenario due to product advertisement while using a simple shopping app Product advertisement is an omnipresent and at the same time cognitively demanding kind of interruption, as it forces a decision for or against the offered product.

We developed an ACT-R model, able to perform an interrupted product selection task under alternating workload conditions, resuming by either cognitively or visually tying in with the product selection. In brief, the task consists of searching and selecting a set of predefined products in several runs, and meanwhile being interrupted by product advertisement at certain times. Different levels of workload are induced by shopping for one vs. three people. Model validation is performed experimentally with a sample of human participants, assessing workload by collecting pupil dilation data.

Our main focus of analysis consists in how execution and resumption performance differ in case of workload, and what strategies users apply in this terms to react to interruptions. In detail, we expect an impaired task performance and extended resumption times with increasing workload. Moreover, strategies while resuming to the product selection might differ in terms of varying workload levels. Important results concerning the assumed effects will be addressed within this talk.

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