Brain Disorders & Therapy
ISSN: 2168-975X

Heim and Keil, Brain Disord Ther 2016, 5:2
DOI: 10.4172/2168-975X.1000210

Commentary Open Access

Predicting Real-Life Cognitive Performance from Laboratory Data: A Case for Developmental Studies Using the Attentional Blink

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Commentary

In an increasingly digital world, complex cognitive skills such as executive control and working memory capacity are crucial for adaptive behavior. In children and adolescents, methods are therefore needed for assessing and predicting strengths and weaknesses in these capacities, opening avenues for intervention and training regimes. This commentary argues that laboratory tasks in combination with suitable brain measures have the potential to address this need, having the potential to quantify and predict specific aspects of cognitive skills in the real world. The so-called attentional blink paradigm and its developmental trajectories are discussed as an example for such an approach.

The prediction of future cognitive performance has been a key question in many areas of Psychology and the Cognitive Sciences. Progress in these fields has resulted in the realization that cognitive performance is not a monolithic concept, but is based on a multitude of specific skills, capabilities, and processes that contribute to performing well in a given area of achievement. Although this view is in line with common sense intuition, surprisingly little research has been devoted to relating experimentally well-defined processes – behavioral or neurophysiological – to future outcome in real-world cognitive tasks.

In a growing body of work, we and others have established that experimentally defined building blocks of cognition differentially predict specific elements of academic and real-world cognitive performance. Particularly productive have been developmental studies in children and young adults, examining the ability to regulate and control attention over time when information is presented densely and rapidly. Several independent processes contribute to this ability, and they can be quantified on the behavioral and neurophysiological level. Of interest, different facets of attention control over time such as (1) the ability to identify and recall a particular stimulus in a rapid stream, (2) maintaining attention over time, or (3) ignoring salient distractors, are reliably related to aptitude in specific areas of academic achievement such as reading and decoding, spelling, and computer skills. This existing body of research consists of developmental as well as experimental studies in which prediction of future performance is on short time scales (minutes to hours). A major obstacle of progress in this field has been the lack of robust neural measures, capturing attention control dynamics in time and space along with a rigorous test of their predictive value, in large samples of children and adolescents.

Research designs are now available that tap into complex aspects of attention selection, such as sharing limited resources among multiple attended objects or the temporal competition among targets and distractor items [1]. One important approach to study the temporal dynamics of attention control has been the rapid serial visual presentation (RSVP) paradigm. In RSVP studies, stimuli (digits, symbols, words etc.) are presented sequentially at a high rate, for instance 10 items per second [2]. Participants are invited to search the stimulus stream for target items identified by a specific feature, for instance a certain shape or color. A frequently used variant of the RSVP design involves its implementation as a dual task, requiring the participant to work on two distinct task demands in rapid succession. A typical trial in a dual task RSVP paradigm, as illustrated in Figure 1A, invites the report of two highlighted target stimuli occurring amidst a series of distractors. The number of distractors between the first and second targets (T1 and T2, respectively) is varied to yield different lag times. Given a 10-item per second stimulation rate, zero intervening distractors result in a temporal separation of 100 ms, while six intervening exemplars lead to a lag of 700 ms. An observer's performance profile often follows a hook-shaped path, with lowest report accuracy when T1 and T2 are separated by at least one distractor and about 150-200 ms of time (Figure 1B). This performance decrement is referred to as the attentional blink (AB). Most views of the AB attribute the impairment for T2 stimuli to decreased availability of cognitive resources [3,4] or attentional capacity [5] to process T2, which is assumed to occur as a consequence of encoding/selecting the T1 item or the subsequent distractors.

Neuroscience studies of the AB have consistently shown that trials with missed T2s are characterized by greater neural response amplitudes to T1 and smaller amplitudes to T2, compared to trials with correct T2 [6,7] suggesting sensitivity to temporal trade-off phenomena, illustrating and quantifying the limitations of the human attention system when putting under time pressure. Thus, a variety of factors affecting attention control and stimulus processing can be studied using AB-RSVP paradigms. Given the fundamental importance of attention control for higher-order cognition, the AB is also a strong candidate for use as a predictor for cognitive skill learning. This is particularly evident in developmental studies with children. For example, 10-to-13-year-old students exhibited a hook-shaped AB performance pattern typically found in adults [8]. Second target identification was highest at the longest T1-T2 lag, decreased linearly toward the critical blink interval (232 ms), and showed a relative gain when T1 and T2 occurred within 116 ms, in direct sequence (Figure 1C, blue line). Here different aspects of temporal attention control were linked to different aspects of cognitive functioning in the real world: The relative gain for subsequent targets was specifically linked to automatized language processing, including reading/spelling of familiar words (Figure 1D). In contrast, the performance decrease after one intermittent distractor was primarily related to superior performance in controlled language

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Received February 20, 2016; **Accepted** March 01, 2016; **Published** March 04, 2016

Citation: Heim S, Keil A (2016) Predicting Real-Life Cognitive Performance from Laboratory Data: A Case for Developmental Studies Using the Attentional Blink. Brain Disord Ther 5: 210. doi:10.4172/2168-975X.1000210

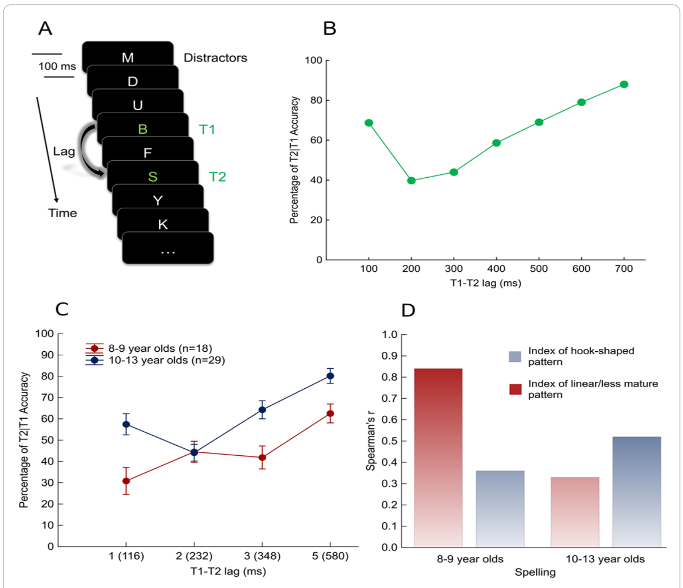

Figure 1: Panel A represents an illustration of the AB design to be used as a predictor task. Panel B displays a prototypical, hook-shaped, behavioral response pattern as seen in many studies with adults (Note: T2|T1 = conditional T2 accuracy, taking into account only trials with correct T1 report; T1-T2 lag denotes inter-target interval). The AB design elicits a strong diagnostic signal in the visual cortex that can be measured with scalp electroencephalography. Panel C shows behavioral response profiles in groups of younger (8-9 years) and older (10-13 years) children as a function of inter-target interval (Note: means ± standard error of the mean are shown) [9]. Increasingly mature profiles (hook-shaped as opposed to linear patterns) are associated with age and class level as well as better performance in specific linguistic tasks, as exemplified for spelling in Panel D [8,9].

production tasks, such as rule-based decoding of pseudowords (i.e. pronounceable nonsense words which conform to the orthographic structure in a given language).

When translating the same analysis approach to a younger group of children, who worked on an AB task and various achievement tests, a more linear profile was observed, as illustrated in Figure 1C, red line [9]. This overall less mature AB profile of 8-to-9-year-olds showed pronounced inter-individual variability, in which the maturity of the AB profile co-varied with language skills: Both reading/spelling of age-appropriate words and arbitrary pseudowords showed relatively heightened performance in those with more mature (hook-shaped) profiles (Figure 1D). Thus, less proficient (younger) literates seem to benefit from more mature temporal attention management irrespective of whether the material to be read is new or more familiar. Interestingly, measures taxing nonverbal intellectual functions, such as visuo-spatial and abstract reasoning skills, did not systematically relate to AB parameters across the age groups examined [8-10]. The findings in younger and older school students suggest that (i) specific sub-processes of selective attention may be linked to different types of academic skills, and (ii) their developmental trajectories may interact with different stages of academic competency.

We believe that the systematic exploration of links between controlled laboratory tasks measuring specific cognitive processes and real-world cognition holds significant promise: It enables the development of training and education programs that aid the development of those elements of attentional control that are relevant for successfully dealing with the demands imposed by both academic and non-academic environments. This line of research also enables efforts to augment our understanding of specific limitations and dysfunctions of temporal attention, as well as how to assess them, and thus to contribute to current efforts to improve the diagnostic assessment of cognitive disorders in children. In particular, objective neuroscience and behavioral measures can complement subjective, clinician-based indices used in diagnosis, judgments of prognosis, and outcome research.

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