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Torkel Klingberg

Nominated by Henrik Edgren

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Professor Torkel Klingberg
Nominee to the Brock International Prize in Education 2020

Nominated by Henrik Edgren, PhD,
Head of the Department of Education, Uppsala University

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Summary

Torkel Klingberg is professor in cognitive neuroscience at the Karolinska Institute in Stockholm, Sweden. For more than 20 years, he has conducted neuroscientific studies about the human brain and its cognitive functions.

His research is groundbreaking and innovative, especially concerning his findings on how it is possible to enhance the performance of the working memory via practice. The implications – from his research – for learning and school achievements are enormous. In fact, Klingberg has proved that thought-out and not very expensive learning tools – installed in tablets or computers – dramatically improve working memory, attention and mathematical skills of young children, no matter where they live geographically or what their social and economic backgrounds are.

Klingberg's teaching tool – Vektor – has been distributed free of charge to more than 300 000 children in different countries all over the world. The use of Vektor has yielded amazingly impressive learning results; e.g. 14 hours of dedicated training with Vektor corresponded to the outcome of approximately one year's ordinary mathematic teaching.

Professor Klingberg strives to build bridges between different academic disciplines such as neuroscience, psychology, information technology and pedagogy. He is involved in projects worldwide where neuroscience meets pedagogy in schools and classrooms. He has also initiated several collaboration projects with Swedish teacher education programs.

Further, Professor Klingberg regularly gives public lectures on the liaisons between the capacities of the working memory, concentration abilities and school achievement. He has written a number of books where he pedagogically explains the main features of the brain and its cognitive functions. On a regular basis, he also takes part in the public debate, where he often – with convincing arguments based on his research – criticizes how dominating pedagogical learning theories often very badly match cognitive functions of the brain.

Presentation of professor Torkel Klingberg

Introduction

As my candidate for the Brock Prize, I nominate Torkel Klingberg, professor in cognitive neuroscience at the Karolinska Institute, Stockholm, Sweden. Professor Klingberg meets the criteria of the prize in all aspects. His research on the plasticity of cognitive functions is innovative and groundbreaking. His findings have resulted in successful teaching methods utilized worldwide, and accordingly they have had an important societal impact since they give new perspectives on how teaching and learning should be adjusted to the functions of the brain.

Professor Klingberg is currently the leader of the Klingberg Lab at the Karolinska Institute. The aim of the Klingberg Lab is to create a better understanding of the neural basis for cognitive development and brain plasticity during childhood. His research group is focusing on working memory, attention and reasoning, as well as on academic abilities such as mathematics and reading. The research methods include a wide range of neuroimaging techniques. Focus is on the function and structure of the brain. A unique aspect of the Klingberg lab is that it develops computerized methods for evaluating and training working memory and mathematical abilities.

For more than 20 years, Professor Klingberg has conducted neuroscientific studies about the human brain and its cognitive functions. Teaching applications based on his research have been – often free of charge – distributed to more than 300 000 children in around 30 countries. Klingberg was one of the first researchers who proved that it is possible to improve the working memory capacity with adapted training models.[1] Researchers were previously convinced that working memory capacity was static. However, Klingberg has shown that there is a close relation between the working memory and attention, and that an improvement of the working memory enhances attention. Presently, millions of children with attention deficits get medicine in order to improve their attention, but training of the working memory is now the most validated non-pharmacological way to amend the attention of children.

Besides being a successful researcher – with an impressive number of articles and citations in scientific journals such as *Nature Neuroscience* and *Science*[2] – Klingberg has put a lot of effort in disseminating his findings beyond the academic context, particularly to schools and teachers. In this pursuit, he has, among other things, created digital learning and teaching applications that are applied in classrooms worldwide and that have shown impressive positive effects on the working memory and mathematical skills. He has collaborated with teachers and researchers in Sweden and other countries to fulfil his comprehensive research objective: to create teaching methods for young children, methods that are fully adapted to the capabilities of the brain.

Traditionally, not at least in the Scandinavian context, collaboration between academic disciplines such as neuroscience, psychology, information technology and pedagogy is quite rare. The fatal consequence of this lack of collaboration is that many teachers and teacher education students do not get adequate knowledge about the importance of neuroscience and psychology for teaching and learning. Klingberg often underlines the significance of more interaction between relevant academic disciplines in the field of education. Consequently, he strives hard to bridge the gap between neuroscience and pedagogy in both research and teaching projects, where schools, teachers and teacher education departments are participating.

Klingberg also regularly gives public lectures on the liaisons between the capacities of the working memory, concentration abilities and school achievement. He has written a number of books where he pedagogically explains the main features of the brain and its cognitive functions.[3] On a regular basis he also takes part in public debates, where he often – with arguments from his research – criticizes how badly the dominating pedagogical learning theories match the cognitive functions of the brain.[4]

Klingberg has received several prestigious awards for his research in neuroscience. In 2002, the International Neuropsychological Society awarded him with the "The Butter's Award". In the same year, he received "The Swedish Dyslexia Foundation Reward for Outstanding Research". In 2006, he got the "Philips Nordic Prize" and in 2009, he got the "Axel Hirsch Prize" from the Faculty of Research at Karolinska Institute. In 2011, Klingberg received the prestigious *Göran Gustafsson Prize* in medicine "for his distinguished research on neuronal plasticity, which shows that exercise can affect the capacity of working memory". Furthermore, the fact that Professor Kling is a member of the Nobel Assembly that every year selects the recipients of the Nobel Prize in Medicine or Physiology can be seen as an acknowledgement of his excellence as a researcher and scholar in neuroscience.

Innovative research

Early in his research career, Professor Torkel Klingberg became involved in the development of a new academic discipline, cognitive neuroscience, which is a combination of neuroscience and cognitive psychology. Klingberg's contribution to cognitive neuroscience is, in a way, a reflection of his bachelor and doctoral studies, since he got his bachelor degree in psychology from Uppsala University and his doctoral degree in medicine from the Karolinska Institute in Stockholm. Already in his doctoral thesis, Klingberg started to investigate the functions of the working memory and the interconnections to specific brain areas, e.g. in the intraparietal cortex.[5]

The working memory and mathematics

The working memory and the cognitive capacities of the child's brain have thenceforth been his main research subject. He has conducted studies both in Sweden (the Karolinska Institute) and in the United States (e.g. Stanford University). His main research questions concern why some children manage to learn new things, e.g. mathematics or reading, very quickly, while others have to struggle harder and for a longer time. Klingberg has concluded that we can find the most constructive answers to these questions in the brain's working memory.

Regarding our learning there are two cognitive brain functions that are especially important: the long time memory and the working memory. With the long time memory – stored in the cortex and mainly managed by the brain's hippocampus – we remember episodes, rules, names and facts. It interconnects our days and our lives. Accordingly, long time memory is important for traditional school learning, but it needs assistance from the working memory, since the working memory – mainly placed in the prefrontal cortex and the parietal lobe – is decisive when we want to keep information in our mind for a brief time span and when we solve intellectual problems. The capability of "step-by-step thinking" is thus indispensable when we do mathematics or when we read, since the working memory assists us to remember relevant information without losing our focus or our attentiveness. The brain networks for the working memory are also largely identical to those networks we use in order to voluntarily direct our attention, since we need to remember what to focus on.

As mentioned above, it was presumed for a long time that it was impossible to improve the working memory via practice. One of Klingberg's first important research results proved that this assumption was wrong. Klingberg and his colleagues showed that it was possible to improve the working memory and concentration abilities by means of a computerized training program focused on transparent objectives, demanding exercises and immediate feedback.[6] Several follow-up studies confirmed these findings. It was evident that working memory practice transmitted positive effects between different working memory tasks and other functions requiring top-down attention, e.g. attention guided by intentional plans and current goals as well as prior knowledge, as opposed to bottom-up attention which is driven by external stimulus. Klingberg also demonstrated that an improved working memory decreased symptoms of concentration disorders and inattentiveness among children with ADHD. Five randomized and controlled trials by independent research groups have confirmed these results. Children who regularly exercise their working memory also improve their classroom behavior, e.g. their capacity to focus on relevant teaching instructions, as well as their concentration ability.[7]

In various studies, Klingberg and his colleagues have proved that there is a relationship between the improvement of the working memory and ameliorated capabilities in mathematics.[8] A trial from the *Educational Endowment Foundation*, including more than 1400 children, concluded that working memory training enhanced children's mathematical performance around .3 standard deviations. In more recent studies, e.g. in a survey of 288 children, Klingberg's research group showed how the baseline working memory capacity predicts to what extent exercises for the working memory boost mathematical learning.[9]

In other studies, Klingberg and his colleagues have proved that children with a working memory capacity above average benefit more – regarding their skills in mathematics – from exercising their working memory, than from specific training in mathematics. In some studies, the improvement rate was as high as 20%.[10] The benefit level decreased gradually with lower working memory capacity. The positive relationship between baseline working memory capacity and benefits from working memory training was also seen in a study where 3 500 children carried out a combination of mathematical and working memory assignments.[11]

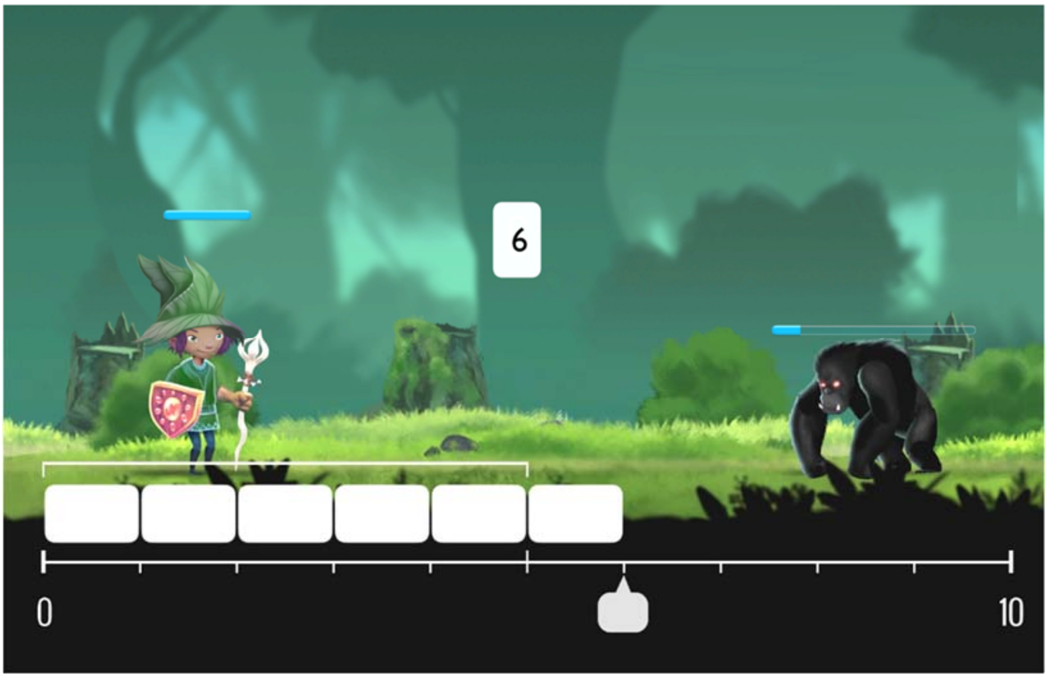
The main implication of these results is that the dose of required cognitive training differs significantly between children. Children with a low working memory capacity might need two to three times more training time compared to children with higher working memory capacities. It is also likely that other cognitive tasks might be important for mathematical learning and that there are disparities in what kind of cognitive training that benefits the individual mostly. Accordingly, individualization – e.g. via digitalized teaching tools – is one of the cornerstones in Klingberg's vision of how to organize education in the future. To decide and understand each individual's need of working memory training is presently one of the most intriguing research questions in this field of neuroscience and pedagogy.

The learning application Vektor

A good example of an individualized and digitalized teaching tool for the working memory is the non-verbal mathematical training program Vektor, constructed by Professor Klingberg, Professor Ola Helenius from Gothenburg University in Sweden and Professor Pekka Räsänen from Jyväskylä University in Finland. The main purpose of Vektor is to practice the ability to keep information in the working memory and to remember important instructions. The basis of Vektor is the number line which helps us to connect numbers with space and distance.

There are many research studies on the importance of the number line, but not so many on specific teaching methods to help children enhance their understanding of the number line.[14] Klingberg and other researchers, e.g. Professor Stanislas Dehaene, have concluded that the same area in the brain that is decisive for the working memory, the parietal lobe, also is crucial for skills such as analyzing quantity, length, spatial circumstances, and especially understanding the number line. Consequently, to exercise the number line is a good starting point for developing further and more advanced mathematical concepts. The brain is "programmed" to apprehend numbers as they are placed on a number line. This phenomenon is called "Spatial-Numerical Association of Response Code".[12]

Accordingly, Vektor's pedagogy emanates from the finding that there is a crucial link between spatial representations and the understanding of numbers.[15] Vektor is designed as a "classical" video game with heroes, monsters and treasures (see picture below). The targeted pupil group is between six and eight years old and the training is very intensive. The game challenges the pupils on an adapted level of difficulty. The quantity of training is 30 minutes a day – five days a week – during at least eight weeks. From the beginning, Vektor uses the number line and in one of its first tasks, the child interprets a symbol, in this case a digit. By dragging a finger along the number line, the child should be able to find the right place for the digit. This simple task, executed without a text or without letters, combines different aspects of what a number is: a symbol, a place on the number line, a length and a set of 1-unit items that the child is able to count.



An image of an exercise in Vektor

The results from training with Vektor have been amazingly impressive. 14 hours of dedicated training with Vektor corresponded to the outcome of approximately one year's ordinary mathematics teaching, when combining mathematical and cognitive training.[16] One important conclusion from the studies of Vektor is that there are major inter-individual differences in the responses to cognitive training. Children with learning difficulties in mathematics have good opportunities to improve their skills if they get qualified and individually adapted training, in this case with Vektor.[17]

White matter and reading

Klingberg has also investigated differences in brain activity for children with and without dyslexia. He was the first researcher to prove the association between reading ability and connections in white matter of the brain. These connections carry signals between different areas of the brain, which are important for language comprehension. The connections in white matter are therefore crucial for children both with and without reading disorders.

In achieving these pioneering results, Klingberg was one of the first researchers who used an MR technique called diffusion tensor imaging as a means to estimate brain maturation of white matter.[18] Klingberg was also a pioneer in combining diffusion tensor imaging with behavioral measurement, and thus describing the disturbances of white matter tracts for children with dyslexia.[19]

Many other researchers have thereafter confirmed Klingberg's findings of the importance of white matter, regarding reading and writing skills for both children and grown-ups, in the rear left cerebral hemisphere. The most significant implication of Klingberg's research on reading and writing abilities, as well as on mathematical capabilities, is that even if our genes very much decide the abilities of the brain, there are good opportunities to enhance our brain capacities via effective and individualized training methods.[20]

The prominence of grit

Even if Klingberg's, and others', brain research has emphasized that learning mathematics, reading and writing not only is a question about biological heritage and the function of our genes but also very much is a matter of individual efforts and training (environment), the question remains why some children learn faster than others. Why do some children decide to work harder while other children give up or put less effort in their training and learning? Accordingly, motivation is a key issue and the amount of research on motivation is enormous, but it has mostly proved what is *not* decisive for the improvement of intellectual performances, e.g. external factors such as money and fame, or internal ones as emancipation or self-realization.[21] There is a lack of research concerning motivation factors decisive *for* intellectual improvements.

To investigate the meaning of motivation, Klingberg has collaborated with the American psychologist Professor Angela Duckworth from Philadelphia. Regarding interconnections between motivation and study, Professor Duckworth has, for a long time, used the concept "grit". Grit approximately means dedication, endurance and a capacity to keep on working with long time objectives without quitting when you meet resistance. An individual with grit is seen as perseverant, conscientious, structured and dedicated. Duckworth has shown that the amount of grit better predicts future school and university achievements than IQ[22], and Klingberg wanted to study if grit also was decisive for cognitive training and the improvement of skills in mathematics. In his investigation, a group of six-year-olds worked individually, for 30 minutes a day during eight weeks, with tablets and exercises where they trained their working memory and mathematical abilities (the Vektor program). The teachers estimated the level of grit of each child and the researchers compared the results from the tablet training to the grit level estimated by the teachers. The children also answered questions on how fun they thought the training was (a measure of intrinsic motivation). Before and after the six weeks training, the children performed three tests of mathematics and three tests of working memory. Moreover, the parents informed the researchers about their children's ability to concentrate and pay attention.[23]

The findings of the study were profoundly interesting, since the level of grit obviously correlated to how much the children improved in working memory ability and mathematical competence. Klingberg and his colleagues had found a scientifically credible explanation to why some children decide to work harder while other children give up or put less effort in their training and learning. These results were even more palpable when the researchers expanded the study to 300 participating children.[24]

The conclusions of Klingberg's grit study provide crucial knowledge for teachers and parents in their efforts to motivate children to learn more and to work harder, even if it sometimes is strenuous and boring. In times of disappointments and setbacks, it is decisive to underline that children´s efforts of learning have a higher purpose and that it is possible to improve a lot via dedicated training. Teaching and learning are not always joyful and the children are fully capable to understand that hard efforts sometimes are necessary. In addition, Klingberg's study on grit underlines that training will only be successful when the teachers demand full attention and concentration from the child; when they give continuous and explicit feedback; when they work regularly with rehearsal, reflection and perfection. Teachers who demand hard – but reasonable – efforts will doubtlessly have better results from their pupils than teachers who do not give their pupils articulated and challenging assignments.[25]

The societal impact of Klingberg's research

Klingberg's findings have substantially increased the international interest in the significance of the plasticity of working memory and other cognitive brain functions for school achievements. Researchers all over the world, e.g. in United States, United Kingdom, Switzerland, Netherlands, Finland, Norway and Canada, deploy his methods and create new knowledge on the interconnections between the working brain and school results in different subjects. The dissemination of Klingberg's research is perhaps most evident in the statistics concerning citations. His scientific articles have almost 20,000 citations and his twelve most cited articles have been cited in more than 500 publications, respectively.

Concerning his research, Klingberg has not only published his findings in scientific reviews and journals. As stated above, he has written three popular science books in English and Swedish where he very pedagogically explains and discusses e.g. neuroscience, cognitive training and working memory. In the book *The Learning Brain* (Oxford University Press, 2012) he focuses on the main features of the child's memory and development, the importance of the working memory and the relationship to mathematics, brain functions, reading and dyslexia. Regularly, Klingberg gives public lectures on all these themes, and adjacent subjects, where teachers and school leaders are curious listeners. He participates regularly in public debates about pedagogy and learning theories, especially in discussions concerning advantages and disadvantages regarding digital teaching materials. On August 20, 2019, one of the biggest (concerning edition size) and most prominent Swedish newspapers, *Dagens Nyheter*, published a long interview – in two pages – with Klingberg where he discussed possibilities and risks with digital teaching applications in Swedish schools.

As described above, Professor Torkel Klingberg is an excellent and successful researcher who has contributed very much to new findings that are significant for academic disciplines such as psychology, neuroscience and pedagogy. However, Klingberg's research has also had a major impact on every day teaching in mathematics and reading in classrooms worldwide. His research is, as stated above, thoroughly trialed with many participants in different countries and in different teaching contexts. The foundation *Cognition Matters,* with

Klingberg as the CEO, hands out Vektor free of charge to countries all over the world. In Sweden, already 30% of all 6-year olds use the application. It has demonstrated its potential and utility in other countries as well, such as Mexico, Argentina, Uruguay, Australia, Russia, India and United States. The methods developed by Klingberg are not only adaptable to school environments; ADHD clinics in Sweden, the Netherlands, Japan, Australia and the United States use his methods regularly.

Professor Klingberg's research is unique in the sense that he is pursuing to create new learning theories and new teaching tools based on how our brain functions. He really wants to bridge the gap between pedagogy and neuroscience. If we want to give all children good and fair prerequisites to fulfil their dreams and potential skills, it is necessary to create more collaboration between neuroscience, psychology and pedagogy. As Klingberg has emphasized many times, this means that cognitive neuroscience together with pedagogy could give us a much better understanding and predictability of what kind of individual training that is necessary for each individual child to avoid forthcoming cognitive problems such as mathematical and reading disorders. The individual and societal gains would be enormous, even on a global scale.

Klingberg has shown that thought-out and not very expensive learning applications installed in tablets or computers dramatically improve mathematical skills for young children, no matter where they live geographically or what their social and economic backgrounds are. This does, however, not imply that Klingberg devaluates the role of the teacher and the importance of social or cultural training in the classrooms. He often stresses that no computer program in the world can replace a good and dedicated teacher who leads a critical discussion, explains subject syllabus comprehensively and constantly motivates the pupils to work harder and learn more. His main point is that elaborative individualized and computerized learning applications will give teachers and pupils better opportunities to fulfil all teaching objectives. Klingberg has proved that this is conceivable in mathematics teaching all over the world. This is an achievement that – in my opinion – makes him a well-deserved Brock Prize Laureate.

Henrik Edgren – Member of the Brock Prize Jury 2020

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[25] Klingberg (2016), p. 161-164.

Curriculum Vitae

Torkel Klingberg

CURRENT POSITION

Professor in Cognitive Neuroscience at Karolinska Institutet

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ACADEMIC HISTORY

1997 Ph.D., Karolinska Institutet. Dissertation title: "The Neurophysiology of Working Memory - functional mapping of the human brain with positron emission tomography". Prof. Per E Roland as supervisor.
1998 M.D. from Karolinska Institutet and Hospital (January 1998).
1998 Post-doc at the departments of Psychology (with Prof. John Gabrieli) and Radiology (with Michael Moseley) at Stanford University, California, USA.
2001 Post-doc position at Karolinska Institute.
2002 Assistant professor ("forskarassistent tjänst"), Swedish Research Council (VR).
2004 Associate Professor ("docent") in Neuroscience at Karolinska Institutet.
2005 Research position financed by the Royal Academy of Sciences (KVA).
2006 Professor in Cognitive Neuroscience at Karolinska Institutet.

CITATIONS

>17000 citations. H-factor=50. 11 articles cited more than 500 times. 4 articles cited more than 1000 times. Field normalized citation factor (Cf) **3.98**. Global mean is 1.0.

AWARDS

- Butter's award 'for outstanding contribution.' From the International Neuropsychological Society, 2002
- Swedish Dyslexia Foundation reward for outstanding research, 2002.
- "**Research Leader of the Future**"- award from Strategic Research Foundation, 2004, a 6-year, 10 MSEK grant and a career development program given to 17 junior professors in Sweden every 4 years.
- PhD student Pernille Olesen got the Chorafa prize for best thesis at the Karolinska Institute, 2005, and prize from "Child medicin" 2007.
- **Philips Nordic Prize, 2006**.
- **Axel Hirsch Prize, 2009**, (awarded by KI faculty of research).
- **Göran Gustafsson Prize in Medicine, 2011,** (awarded by Swedish Royal Society of Science to one person in life science or medicine each year).
- Member of the **Nobel Assembly**, deciding on the Nobel Prize in Medicine or Physiology.

GRANTS AND HONOURS

Brain Foundation's (Hjärnfonden) Post-doc Stipend 2000; Wenner-Gren Post-doc Stipend 1998 and 1999; Sven Jerrings Foundation, 2000; Dyslexia Foundation, 2000
Stiftelsen Barnavård, grant, 2000; Jeansson Stiftelse stipendiat, 2000, 2001
RBU, grant 2000; Linnéa och Josef Carlsson Stifelse, grant 2000; KI "Young promising researcher" grant, 2001; Medical Research Council (MFR/VR) 1999, 2000, 2001, 2002, 2003, 2004; Wallenberg Global Learning Network (Principal applicant, in collaboration with Stanford University) 2002-2003, 2005-2006. Elected member of the Rodin Remediation Academy, 2002. Future Research Leader grant (6 years 10 MSEK) from Foundation for Strategic Research. 2004-2010; Elected member of the Swedish Dyslexia Foundation, 2006; Riksbanken Jubileumsfond Grant: "Learning and memory in children and young adults", 3 year, 16 MSEK, 2006.

PROFIT AND NON-PROFIT ORGANISATION ENGAGEMENTS

Founder of the company Cogmed. Left the company 2013.

CEO and head of research for CognitionMatters since 2015. This is a non-profit organisation providing cognitive and mathematical training to children (www.cognitionmatters.org)

EDITORIAL AND OTHER ASSIGNMENTS

Associate editor for Journal of Cognitive Neuroscience 2011-15; Associate editor of Developmental Cognitive Neuroscience

Ad-hoc reviewer for journals: Science, Nature Neuroscience, PNAS, Trends in Cognitive Sciences, Journal of Neuroscience, Brain, Archives of General Psychiatry, Cerebral Cortex, Cognitive Brain Research, Human Brain Mapping, NeuroImage, NeuroReport, Neuroscience Letters, Neuropsychology, J Clinical and Experimental Neuropsychology, Quartely Journal of Experimental Psychology, Developmental Science, J Affective and Behavioral Neuroscience.
Reviewer for: Medical Research Council UK; European Research Council

SUPERVISION OF PHD STUDENTS AND POST DOCS

Main supervisor of graduate students
Helena Westerberg (dissertation, May 2004);Pernille Olesen (dissertation Nov 2005)
Julian Macoveanu (dissertation Sep 2006); Sissela Bergman (dissertation, Apr 2011)
Stina Söderqvist (dissertation, June 2012); Fahimeh Darki (dissertation, Nov 2014)
Henrik Ullman (dissertation, Jun 2016); Annie Möller (registered Sep 2015); Nicholas Judd (registered jan 2018).

Supervision of post-docs
Fabien Schneider (2005 - 2006); Lisa Thorell (2005); Fiona McNab (Aug 2005 -2009); Gaëlle Leroux (2006-2007); Henrik Larsson (Jan 2007-2008); Deepak Dash (2008 - 2010); Iroise Dumontheil (2010-2011); Chantal Roggeman (2009-12)
Tim Ziermans (2010-2013); Megan Spencer-Smith (2011-2013)
Charlotte Nymberg (2013-15); Federico Nemmi (2014-); Margot Schel (2014-2016), Fahimeh Darki (2015-), George Zacharopolous (2016-), Douglas Sjöwall (2017-), Dawei Zhang (Dec 2018 -)

PUBLISHED ARTICLES

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Interviews

Martin Karlberg, Senior Lecturer
https://www.youtube.com/embed/3u7W6TNyEP8?rel=0&autoplay=1?rel=0

Torkel Klingberg, Professor
https://www.youtube.com/embed/Iztza0qog18?rel=0&autoplay=1?rel=0

Jessica Randquist Swedish Elementary School Teacher
https://www.youtube.com/embed/hZe9bJ7NSqw?rel=0&autoplay=1?rel=0

Interview production: Erik Åstrand, Uppsala University

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August the 27th, 2019

Letter of Recommendation regarding the Brock Prize

I am pleased and honored to write this letter of recommendation on behalf of professor Torkel Klingberg, nominated for the Brock International Prize in Education.

For 25 years, I have been working with education, first as a teacher in elementary school, and later as a teacher educator and a researcher in educational psychology and classroom management. When I studied to become a teacher, a lot of focus was on sociocultural theory and pragmatism. These two theories were considered to answer all the important questions about teaching, learning, and education. When I later on worked as a teacher, these theories were dominant, and it was obvious that other theories were regarded with suspicion. Even during my postgraduate education and in the work as a teacher educator, pragmatism theory and socio-cultural theory were dominant. During all these years, three things troubled me: (1) The lack of curiosity about new or alternative explanatory models for the challenges the teachers and students were (and still are) facing and the hegemony of pragmatist and socio- cultural theories. (2) The lack of interest and knowledge about the brain, its possibilities and limitations, and the importance of adapting the teaching in relation to the brain. (3) The lack of ambition (among researchers, teacher educators, and teachers) to build bridges between different academic disciplines, relevant to the field of education.

Professor Klingberg addresses all these questions. For more than two decades, he has strived to create a deeper understanding of how the brain's possibilities and limitations affect concentration, mathematical ability as well as reading and writing capacity. Not only has Klingberg's curiosity been a driving force in his research, he has also succeeded in spreading this curiosity to others – both teachers and researchers – in the field of education. Klingberg has undoubtedly been a front figure and a driving force in opening up the field of education to new explanatory models.

When professor Klingberg began to study the brain, teachers, teacher educators and researchers were surprisingly uninterested in the importance of the brain for academic achievement. During the last decade, professor Klingberg has tirelessly asked and answered research questions relevant to the educational field. He has presented the results of his research, both in respected academic journals and in books addressed to the broader public. All these years, Klingberg has generously shared his knowledge. With his humble appearance and deep knowledge, Klingberg has created an understanding of the importance of the brain, how it is possible to modify the brain by practicing, and how teachers can adapt their teaching based on knowledge about the brain. This has truly been a groundbreaking and important work, influencing teaching and special education, not only in Sweden, but in countries all over the world.

Nowadays, when I meet educational researchers, I notice an increased ambition to collaborate with researchers in other academic disciplines. The gap between researchers in education and researchers in e.g. psychology, medicine, public health and prevention is narrowing. Without doubt, Klingberg has been a pioneer and central figure in this development.

In 2007, when I first read Klingberg's book, *The overflowing brain: information overload and the limits of working memory* I realized I had read something important. In the book, Klingberg presented groundbreaking research in a way that I could understand. For the first time in my career as a teacher and teacher educator, I got a theoretical framework for what I had concepts and a deeper understanding for how learning occurs, and cognitive functions both promoting and hindering learning. Truly, this was a crucial moment in my development as a teacher, researcher and teacher educator. A decade later, I am happy to notice that tens of thousands of researchers, teacher educators, students and teachers have had the opportunity to develop their teaching in accordance with cutting-edge research by professor Klingberg.

A couple of years ago, students left the teacher education program without proper knowledge about the brain. Now, the teacher educators have begun to teach not only about the importance of brain functions, but also about how different brain functions, such as the working memory, is plastic. Now teachers are able to teach in accordance with the function of the brain. It is no exaggeration to say that there has been a paradigm shift, from a resistance to cognitive science to a necessary interest and knowledge of the importance of working memory for attention, learning, development and academic achievement, as well as knowledge on how to adapt teaching in accordance to the function of the brain.

With impressive knowledge, perseverance and humility, Klingberg has created bridges between cutting-edge research and the activities in the classroom, between the brain and teaching, and between academic disciplines that previously viewed each other with great skepticism. Undoubtedly, Klingberg's research has been highly relevant to teachers and students. The demand for Klingberg's research and the development of digital tools implies that professor Klingberg's research has already received widespread dissemination and impact. His research is cutting-edge, relevant, demanded and has a proven impact. It is a great pleasure and honor to recommend professor Torkel Klingberg to the Brock International Prize in Education.

Martin Karlberg

Stockholms universitet

August 11, 2019

Letter of recommendation

It is with great pleasure and honor that I write this letter of recommendation on behalf of Professor Torkel Klingberg who is being considered for the Brock Prize in International Education. I and Dr. Klingberg have known each other for the past 23 years, first as doctoral students and later as senior colleagues, initially at the Karolinska institute and later, when I moved to Stockholm university, in the larger cognitive neuroscience community in Sweden.

Professor Klingberg is today one of the most influential scholars in the field of eductional science with numerous peer-reviewed articles, book chapters and review papers. In his research Dr. Kingberg is focusing on the relation between educational science and brain science, using cutting-edge analysis methods and imaging techniques to get more insight into the neural machinery associated with different aspects of education. With this brain-behavior approach he has been able to shed new light on important questions in the field regarding the relation between memory, attention, grit and school performance.

Dr. Klingberg's research is relevant to the education of this and the next generation of children and young people. His ideas, projects and products have been tested in real teaching/learning situations and have been shown to improve education. Dr. Klingberg's ideas and products have already become globally available to some extent, but will be even more so in the future and thus have a great potential to have a global impact.

Professor Klingberg would be a great choice for this award! I will gladly answer any addition questions you may have about this recommendation.

Sincerely,

Håkan Fischer
Professor in Biological Psychology
Head of Department

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Department of Women's and Children's Health
Neuropediatric Unit
Professor
Hans Forssberg

To the Board of the Brock International Prize in Education

Dear Board members,

I am delighted to write this letter in support of the nomination of Professor Torkel Klingberg for the Brock International Prize in Education. I have known Dr Klingberg since he joined my research unit at Karolinska Institute 2001 after returning from his post doc training at Stanford. We were collaborating during several years, and Klingberg quickly developed his own research group and participated as a very successful young group leader in the Centre of Excellence for which I was the principal investigator.

Klingberg is an outstanding researcher who has translated cognitive neuroscience into practical pedagogy. His initial basic research, and subsequent implementation, has created new understanding of brain mechanisms involved in learning and memory, and how this new knowledge can be used to improve learning. His research on how cognitive training can be used and individualized in order to improve learning, has opened up a new exciting field of research in learning.

Starting up as a neuroscientist, Klingberg challenged the paradigm that working memory capacity is fixed, and could in several highly cited research articles demonstrate that working memory can be improved by training. By neuroimaging techniques, he could also identify the neural circuits involved, and how the training induced brain plasticity. Based on these findings, he developed computer based training programmes to improve working memory and attention in children with Attention Deficit and Hyperactivity Disorder. These training methods are now used all over the world.

More recently, Klingberg has demonstrated that mathematical learning can be improved by working memory training, and that there are inter-individual differences in response to the training. This research on non-verbal mathematical learning led to

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the development of an application called Vektor. After a randomized, controlled trial, Vektor is now freely distributed via a non-profit foundation and used by around 30% of 6-year olds in Sweden. Since the learning is non-verbal, distribution is without borders, and projects have been initiated in Mexico, Argentina, Uruguay, Australia, Russia and India.

Dr Klingberg is a world pioneer improving education by first creating new ideas based on his research in neuroscience, subsequently proving them by rigorously controlled studies in children. His research has led to several pedagogical tools and apps that are freely accessible and used worldwide, and he has an outstanding track record. In my opinion, Klingberg has made an extraordinary contribution to our understanding of learning processes and developing new pedagogical principles qualifying him worthy of the Brock International Prize in Education.

Stockholm 27 August 2019

Hans Forssberg, MD, PhD
Professor in Neuroscience, Karolinska Institutet
Consultant in Neuropaediatrics, Astrid Lindgren Children's Hospital
President, International Alliance of Academies of Childhood Disability

CHAPTER 11

This Will Change Everything

If you do a search for scientific articles on "learning" and "the brain," you'll find over 80,000 such papers published since 1945. Of these, eighty percent will have been published after 1990 and fifty percent since 2000. We are in the midst of a swelling torrent of knowledge about learning.

One of the 5,000 articles on learning and the brain that came out in 2009 was titled "Foundations for a New Science of Learning"1 and was published in Science, one of the most prestigious of scientific periodicals. In it, the authors argue that we're seeing a merging of knowledge from neuroscience, psychology, pedagogy, and information technology that's set to give rise to a new era of learning. For a number of years, experimental psychology and brain science have been unified into a research field known as cognitive neuroscience; pedagogy, on the other hand, still lives very much its own life. It is time to unite, for educational scientists to take on board the discoveries of cognitive neuroscience and for pedagogical issues and experience to direct the experimental work done by cognitive neuroscientists.

One interesting idea for how to bring researchers together and make them focus their efforts is to announce a prize. In 1996, the X-Prize organization announced an award of ten million dollars for the person who could construct an aeroplane able to carry people to the outer edges of the Earth's atmosphere (and bring them back alive), twice in two weeks. In 2006, a team of researchers claimed the prize and flew a plane to almost weightless altitudes a hundred kilometers up. The challenge not only resulted in a new type of aircraft but also kicked off a small private aerospace industry, a commercial field that had never before existed.

The success of the initiative has led to a string of similar prizes. The company Netflix, which distributes films via the Internet, is offering a million dollars to the person who can find a better algorithm than theirs for suggesting new films based on a customer's previous ratings; the US defense organization DARPA has announced a prize to whomever can construct a driverless car that can negotiate city traffic; Virgin has promised twentyfive million dollars to the inventor of a method for absorbing greenhouse gases from the atmosphere.

Why not an X Prize for learning? A million dollars to the one who can find a better algorithm than what we currently have for how learning is to be optimally spaced out in time; ten million to those who can create a significantly better method for helping children with dyscalculia; and a hundred million to those who can create a scientifically based, digitalized form of elementary teaching that can be sent wirelessly to developing countries. The fact is that learning is one of the areas that the X-Prize organization is considering for the future, and it is welcoming submissions of proposals for a suitable challenge.

Five Themes

As we await future progress and prizes, we can note that research has already made at least some headway, as I've tried to overview in this book. It's possible to pick out five themes, or fields, where cognitive neuroscience is influencing our view of child development and learning.

The first is the map. The human psyche has long been something of a black box, or, if you will, a car with its hood closed. Brain research allows us to open the hood and examine the engine. In its simplest version, the blueprint we get is kind of a map of the various functions residing in the brain. The map of mathematics areas enables us to understand why a prematurely born child can have problems subtracting but not learning the times tables by heart; our understanding of the role of the hippocampus explains why Jon (Chapter 4), while equipped with a serviceable working memory, cannot encode new longterm memories; and we can understand why problems such as dyslexia and dyscalculia are closely related.

However, the map does more than just explain; it can also be used as a means of prediction regarding which children might fall into the risk zone for various problems. This is the second theme, and it is a field in which cognitive neuroscience can make a solid contribution. If these children are to be helped, they must be identified in time before they lose years of schooling owing to an undiagnosed functional disability. And here we can already find methods that enable us to ascertain at an early stage whether a child risks developing reading and writing difficulties.

The third theme is intervention. Identifying children in the risk zone is only meaningful if there is some way of helping them. Methods are available for many such cognitive problems, particularly ones involving training. Knowledge of how the brain encodes numbers in a spatial dimension in the parietal lobe has spawned numerous methods for learning mathematics; and knowledge of an overlap between areas of attention and the varieties of work- ing memory has led to a method of training working memory. Unfortunately, however, the application of neuroscientific knowl- edge to methodological development is still a relatively barren field, the lack of breakthroughs being attributable, in part, to the genuine ignorance that neuroscientists possess of pedagogy as a science and the points of inquiry it raises. Bridges need to be built.

The fourth theme is sculpting, which affects our views of human development. The brains of children and adolescents are not mini versions of the adult brain any more than sperm contain micro- scopic fetuses. The brain is shaped through decades of growing and pruning. How different parts of the brain mature explains the gradual development of faculties such as working memory, and the fact that we are born with a hippocampus that matures slowly by degrees possibly explains why you probably don't remember the color of the cot you slept in as a baby. The knowledge of sculpting can also show, as in the case of Laura (Chapter 2), what disruption of the normal development trajectory can entail—in much the same way as studies of the risk taking and emotional teenage brain show that it doesn't exist on a point half- way between childhood and adulthood, but at a stage subject to its own unique conditions.

The fifth theme is plasticity. The brain creates function, but our environment and our actions influence the brain. We've seen how the brain is shaped by working memory training and playing a musical instrument, and how levels of BDNF can be boosted by a few jogs around the park every week. Dopamine affects working memory, but working memory training can also influence the number of dopamine receptors. The hippocampus determines how the long-term memory develops, but a stimulating environment and opportunities for exploration and learning also affect the hippocampus. The simple fact that brain research has shown how plastic the brain is, is in itself extremely important. It gives inspiration and hope that cognitive difficulties can be compensated for.

A pattern that has gradually emerged in the process of writing this book is how the link between brain, function, and environment often gets caught in a circle, be it virtuous or vicious. Negative expectations, such as girls being worse at math than boys, creates a stress that does indeed cause girls to perform worse when placed in a group of boys and told that they are to have their mathematical skills evaluated. This inferior performance then reinforces the prejudices that exist about girls and math.

Similarly, poor classroom performance is one of the key stress factors for schoolchildren of all ages, and stress is one of the most negative determiners of classroom performance. The protracted stress that accompanies poverty impairs working memory, which in turn leads to worse classroom performance; and a lower level of education increases the risk of poverty for the next generation. Another example is how negligent mothers raise children who are stressensitive and who have poor long-term memories, and who in turn become negligent mothers themselves over their own stress-sensitive offspring.

The vicious-circle mechanisms can only be understood through knowledge of the functional map, sculpting, and plasticity. We can't understand how prejudices can become self-fulfilling prophecies if we don't understand how stress reactions affect nerve cells, how the effect on the nerve cells influences working memory, and how working memory is linked to mathematics and school performance. The protracted stress caused by poverty has a permanent impact on the brain through its equally protracted sculpting and it's because of the energy-demanding sculpting of the brain that infections are so detrimental to its development. But there is some light in all this gloom: if we know these mechanisms, we have a better chance of breaking the cycles.

Future learning will probably be shaped by a conglomeration of scientific disciplines: experimental psychology, cognitive neuroscience, pedagogy, and information technology. I am convinced that if we are to make any progress, it will only be through scientific method and randomized studies. Teaching has been dominated far too much by political opinion and trendy pedagogical whims. No teaching method suits all students, and adapting education to individual needs means not only being quick to catch and help children with difficulties but also providing those who are fully capable and who need extra stimulation with the resources and tools they need to develop to their full potential.

A schoolgirl of the Future

Two hundred years ago, Jean-Jacques Rousseau described in his book Émile his version of the best conceivable education: personal instruction from a mentor who would contribute step by step to a child's development. Émile was a pure thought experiment. Rousseau himself wasn't a teacher, had no pupil, and didn't raise his own children. But since the book was published his ideas have been a source as much of inspiration as of criticism. Neal Stephenson's The Diamond Age—A Young Lady's Illustrated Primer is arguably an Émile for the twenty-first century.2

Stephenson's novel is set at some time in the mid-twenty-first century. The protagonist, Nell, is a four-year-old girl from the slums, who chances across the most advanced teaching tool in existence: an interactive computer program, a kind of animated primer. The primer begins by telling Nell stories, which gradually introduce new concepts and become progressively complex as the girl's abilities and knowledge expand. Eventually the stories take on the character of adventure games in which she is given missions, and the learning comes more as a side effect of their completion. At the age of sixteen, Nell reaches the end of the book's adventures, and in one of her last missions she has to outwit a cruel king and learn the art of creating nanotechnological inventions. She builds her own "illustrated primer" and creates her own world of stories.

Stephenson's digital primer is a blend of personal mentor, Wikipedia, problem-based learning, and adventure game. In his previous books he has fantasized about phenomena that have since become reality - so who knows, maybe it won't be long before we see illustrated primers on the shelves of all good bookstores.

The final objective in Stephenson's tale is for Nell to create her own computer program, her own book, and her own worlds. This educational goal - to provide children with the tools they need to create themselves - reminds me of how developmental psychologist Jean Piaget looked upon the objective of child development. "Education, for most people, means trying to lead the child to resemble the typical adult… But for me, education means making creators… You have to make inventors, innovators, not conformists."3

Piaget was wrong about children and mathematics, but in this case I cannot but agree with him.

Chris Anderson is neither a scientist nor a teacher but an inspirational visionary. He is editor-in-chief of the magazine Wired, which was ahead of its time in describing how developments in information technology would shape our society, economy, and culture. Chris has written two books, is a popular speaker, and runs TED, a forum that invites speakers from all over the world to hold lectures that are then spread free on the Internet.

Chris Anderson outlined his vision of the future in This Will Change Everything, a book containing a collection of essays by authors, artists, scientists, and other intellectuals, each with their own idea about which invention or idea could radically change the world and human lives.4 The book is packed with descriptions of new forms of solar energy, cures for cancer, life-prolonging medicines, and teleports that could transport our bodies from one place to another at lightning speed. In his essay, Chris maintains that's it's the education of the future that will really change the world.

The focus of his essay is on the role of information technology, which is natural given his background. But the computer is just a tool; it will not revolutionize education in and of itself - no more than the flannelboard or video did - and cannot unless we fill it with the right content. And this content will come from research into learning processes. I'm therefore taking Anderson's example to illustrate the importance of learning for the individual, too, and the intrinsic power that new forms of learning possess.

His essay invites us to carry out the following thought experiment: imagine a person who you think has made a profound impact on the world. It might be a composer whose music has spread joy, a poet or author who has inspired generations, a scientist who has discovered a cure, or an inventor whose new technologies have changed the way we live. Imagine, then, that this person had been born in a rural French village in the 1100s or in Ethiopia in the 1980s, with no education, no intellectual stimulation, and no ability to develop his mind and abilities. What contribution would he then have made to the world? Probably none at all. Imagine the world without this person's contribution. The difference between the two worlds is the value of his once having access to the right kind of stimulation and education. Millions of children today don't have such opportunities, and there in the undeveloped masses resides the latent potential that could change everything.

A girl born today, somewhere in southern Africa perhaps, might by the age of ten have the use of a laptop with a high-resolution touchscreen and wireless Internet for a fraction of the current cost. This little portable computer would then give her access to the best interactive teaching tools, the best scientifically developed learning methods, and the best lectures held by the best teachers. Maybe she will be the one to save the world for our grandchildren.

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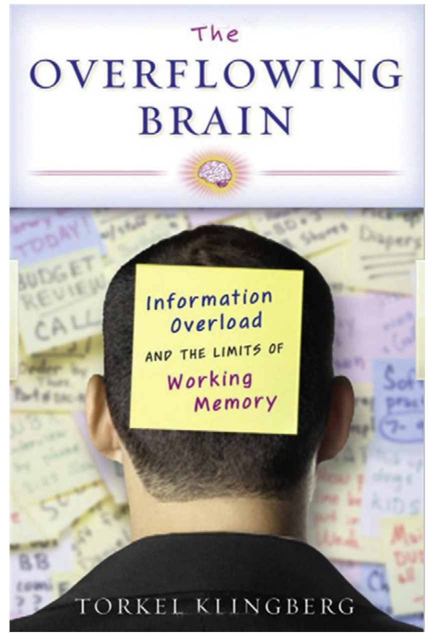
Working Memory from the Trailing Edge of Consciousness to Neurons



The Overflowing Brain: Information Overload and the Limits of Working Memory
Torkel Klingberg
Oxford University Press (2008)
224 pp., $21.95, hardcover.

This book on working memory limits by Klingberg (2009) is one to which I certainly can relate. When I was in high school in the late 1960s, I decided that the only career that made sense for me, to make the best use of a finite life span, was investigating the scientific basis of human conscious experience. In graduate school, I came to feel that two specialties could best satisfy that aim: perception and working memory, the small amount that can be kept in mind at once. There have been many exciting advances in these two topics over the years, by both neuroscientists and cognitive psychologists. So as to avoid solipsism, I also wanted my research to be of practical use to medical science and society. I could have gone various ways but ended up doing behavioral studies of working memory and its development.

Klingberg's title strikes a chord with me. In 2005, I published a book on working memory capacity limits and their neural underpinnings (Cowan, 2005). Originally, I planned to use the title "The full brain," in allusion to a *Far Side* cartoon by Gary Larsen in which a student asked to be excused from class because his brain was full. The publisher felt that the title was not appropriate for the series of scholarly essays of which mine was part. I had to agree, given the emphasis on subtle theoretical distinctions and the heavily referenced style; the "full brain" expression was used instead within the first subtitle in my first chapter. Still, after all of the work, I wistfully understood that I had not written a book for everyone. It was for academics in my field, students in the behavioral sciences, and potentially researchers from other areas, but not so much for the public.

Now Torkel Klingberg (2008) has written an elegant scientific book of the most accessible type with a like-minded title, *The Overflowing Brain*. Among other things, he highlights his research, which itself is of popular interest, demonstrating the effect of training working memory on mental performance in various people, including children with attention deficit disorder and hyperactivity (ADHD) and aging adults. This type of research finding offers an important challenge to the predominant, drug-oriented maxims of modern medicine. The book is supported by a lot of research literature, but the citations are neatly tucked into a footnote section. That section is carefully coregistered with the book pages, allowing the most relevant background information to be found easily. Yet, the main text is fully comprehensible even without reading the footnotes.

The prospect of measuring the contents of the conscious mind was important to even the first scientific investigators of psychology. One of these was Wilhelm Wundt, who is often credited with establishing the first laboratory of experimental psychology in 1879. Strangely, his voluminous writings on behavior and physiology have still only partly been translated into English; Hungarian and Russian were more important at the time. William James (1890), working at Harvard, helped make the works of Wundt and others popular in the United States, and he coined a term for the storage of information in the human mind. He called it *primary memory*, conceived as the trailing edge of the conscious present. As he further discussed, a complex human capability known as attention, which is partly under the person's voluntary control, helps to determine which information is perceived and which of the perceived events are considered further and retained for a while in primary memory. Klingberg's approach to working memory makes him (like me) a benefactor of this early approach by Wundt, James, and others. His present attention-based approach was nevertheless difficult to come by, in light of key events taking place in the century following these early researchers. It has been not so much an uninterrupted dynasty from the early days as a renaissance. Here is what happened.

As the book indicates, modern research on working memory is generally considered to have begun with George Miller and his observation in 1956 that experimental participants can repeat back a list of no more than about seven separate items. The book mentions the use of the term working memory by animal researchers in the 1960s, but the term may have been used first by Miller et al. (1960) to describe the memory by which humans carry out plans, retaining the main goal in memory while various subgoals are tackled.

Baddeley and Hitch (1974) then started a tidal wave of research on working memory by arguing for a new theoretical model of that concept. Whereas previous models considered working memory to be a single thing, Baddeley and Hitch persuasively argued that the evidence points to multiple, separate working memory stores. In addition to an all-purpose working memory store for abstract information, there was said to be a separate store for phonological information (whether from speech or print) and another for visual, spatial, nonverbal information. Then, in the spirit of parsimony, Baddeley (1986) omitted the general, abstract store for many years, though it was still advocated by some (e.g., Cowan, 1988). Baddeley (2000) was convinced that the evidence finally supported that type of store. Most importantly, though, the phonological and visuospatial stores of Baddeley and Hitch were thought of as automatically operating mechanisms that did not require attention once the information was loaded in. So Klingberg's return to an emphasis on the importance of attention in working memory is important.

There is also a long history regarding what aspects of working memory can be trained (not much described in the book) and conventional wisdom from this area, too, had to be overcome. The consensus from the skill-training literature is that effects of training, though sometimes remarkable, are specific to the skill being trained. The most dramatic example may be the case studies of improved memory span beginning with Ericsson et al. (1980). Over the course of a year, they trained an individual to increase his digit span from seven items to about 80. It was done through the application of specific practice. In a digit span task, a random series of digits is presented, and the task is to repeat the series in order. Span is defined as the longest list that can be repeated with a particular rate of success (such as error-free repetition of at least half the presented lists of that length). The participant in Ericsson et al. already knew a large number of athletic records, which served as prememorized, multidigit chunks. For example, suppose that a list began, *8, 3, 4, 1, 9, 5, 8*…. If he knew that 83.4 s is the world record time in one particular running event and 195.8 is a national record number of feet in some throwing event, then the series so far can be recoded as the two chunks [83.4] [295.8], reducing the memory load from seven items to two. The participant in this way increased his ability from about seven items to about 20, reached a plateau, and then increased further to 80 by learning to make higher-level chunks out of the first-order chunks. Still, after all of this training, the ability to perform a closely related but unpracticed task, letter span, remained at about seven items.

The type of specific-skill training described by Ericsson et al. (1980) and others seems to rely on the existence of a more abstract form of working memory storage that can hold meaningful units, including clusters of digits forming meaningful chunks. This was consistent with George Miller's concept of chunking and with the abstract store already to be found in the seminal sources in the field (e.g., Baddeley and Hitch, 1974). The method of training, moreover, was thought to be one in which specific knowledge about the material to be remembered was put to use in forming the chunks. The new findings on training highlighted by Klingberg (2008) would be seen as surprising indeed, from that point of view. He maintains that challenging working memory training exercises can raise performance on a variety of attention-demanding tasks, including intelligence tests. Training effects are generalized, rather than just task specific.

Klingberg (2008) also documents new research using brain imaging techniques, which show that improvements in attention-related training are accompanied by enhanced activity in a circuit of the brain that includes parts of the frontal and parietal lobes. Actually, there is further evidence of specialization of function within this circuit, with the frontal areas having more to do with the control of working memory and the parietal areas more with the storage of information in working memory. Postle et al. (2006) showed this using not only neuroimaging techniques but also transcranial magnetic stimulation (TMS), which momentarily impairs the stimulated part of the cortex. They found that working memory tasks activate both the frontal and parietal areas no matter whether these tasks require manipulation of the remembered materials (rearrangement of them or calculation based on them) or memory with no manipulation. TMS applied to the parietal lobes impaired both sorts of task, but TMS applied to the frontal lobes impaired only the tasks that included manipulation of the materials.

Consistent with most of the recent literature, Klingberg (2008) places considerable emphasis on the importance of filtering out irrelevant information. This is important for the efficient functioning of working memory, and Klingberg and his colleagues even have identified brain areas in the prefrontal cortex and basal ganglia that help do the job. Individuals with better working memory appear to do a better job of filtering out irrelevant information.

This emphasis on filtering has, however, underestimated the role of individual differences in information storage. Illustrating such differences, Gold et al. (2006) investigated memory for spatial arrays of objects in normal and schizophrenic individuals and found that the ability to filter less-relevant objects could not account for differences between the groups. On a trial in one experiment, for example, participants were usually tested on memory for the orientation of one sort of object in a recently seen array (such as one red bar out of several), though they were occasionally tested on memory for the orientation of another sort of object also in the array (such as one blue bar out of several). Schizophrenic patients performed better on the frequently tested objects, to the same extent that normal control participants did. Still, the patients remembered far fewer of the objects overall. As Klingberg (2008) noted, working memory for spatial arrays of objects has been strongly linked to parietal lobe areas limited to representing a few objects at a time, and I would add that we should look for group differences in these brain areas.

The book is well-organized and broad-ranging. After an engaging introduction, the discussion turns to the mind as an information portal, as in attention research (chapter 2), and the mind as a mental workbench, as in working memory research (chapter 3). Theoretical models of working memory are discussed (chapter 4), followed by a consideration of how the brain may underlie capacity limits of working memory (chapter 5). In this chapter, by the way, a fascinating point was that Albert Einstein's brain was enlarged in areas thought to underlie working memory. The emphasis of the book then returned to models in more depth, with a description of simultaneous capacity in dual tasks and the concept of the brain as a receiver of information with its own mental bandwidth (chapter 6).

In all of this, Klingberg establishes a position that differs from the norm in the field. The norm (e.g., Baddeley, 1986) is to favor the idea that there is a central executive faculty in the brain responsible for coordinating different storage areas in working memory. Conflicts between different tasks, like remembering visual objects and sounds at the same time, would come from the limit in how much the central executive can do. No conflict is expected between a nonverbal visual task and a verbal task, for example, except in the process of putting information into each type of memory store. Instead, Klingberg favors the view that there might be no such central executive processing limit. The conflict between different working memory tasks could be caused entirely by overlap in the neural circuits that would be needed for the two tasks if they were performed one at a time. To take this idea further, there appears to be a constant capacity of about three to four items that applies even when the items include disparate objects such as some colored squares and some spoken digits, provided that information specific to a sensory modality is wiped out by additional stimulation (Saults and Cowan, 2007). Therefore, there may be a general capacity-limited storage mechanism, such as the focus of attention (Cowan, 1988, 2005).

Chapter 7 steps back to examine the evolutionary value of working memory and its limits. This is an exciting topic; there are many ideas as to why working memory limits exist, all still unproven. One can focus on why a limit exists, as Cowan (2005) does, or on why a larger limit is advantageous for survival and reproduction, as Klingberg (2008) does. Working memory apparently has increased over evolutionary time as societies and technologies have become more complex. Given the need for an economy of energy, not every stimulus can be processed to the same level of detail, and it makes sense to have a subsystem that provides expertise in determining which material to give preferred treatment.

Many researchers have said that there is nothing as practical as a good theory. The next few chapters set up the reader theoretically for the training studies to follow. Chapter 8 discusses brain plasticity, the ability of the brain to grow, change, and get rewired even in adulthood, which is much greater than researchers used to think. It allows training of basic abilities. Chapter 9 discusses attention deficit disorders as possibly not medical diseases in need of drug treatments (with their inevitable side effects), but rather as the extremes of a normal continuum of attention styles. Attention function can be altered through intensive training, which, it is hoped, can even alter the neurochemical balance on which working memory depends.

In chapter 10, we are introduced to a laboratory-based program to improve our working memory and attention capabilities through training, and chapter 11 explores how to accomplish the same thing with everyday tasks. Chapter 12 discusses computer games, indicating that the pitfalls that parents usually fear (violence, loss of mental discipline) are balanced by possible benefits of some of the games as attention-training regimens.

The added technological complexity of modern life may explain why measures of intelligence are increasing all over the world compared to previous generations (chapter 13, The Flynn Effect). The benefit is explained in neurochemical terms (chapter 14, Neurocognitive Impairment). Also, futuristic aids to enhancing performance are discussed, such as computer memory that would plug into the human brain. A broad and enlightened perspective is taken. For example, people may fret over the ethics of allowing college students to take memory-enhancing drugs before a test but that mental angst tends to disappear after the enhancing drug has been around for a while, which is precisely the case with caffeine. Still, training of working memory is cast as a better option than drugs.

In the final chapter on The Information Flood and Flow (chapter 15), the target for superior cognitive performance is identified as the point at which one's attention is absorbed by the task but one remains in control. Challenges that are taken on push to the limit one's ability to cope, but do not hopelessly exceed that limit. At this point, one gets the experience of "flow" in which it feels good to work hard mentally, with full and efficient use of one's inspiration and creativity.

Not all of the conclusions in the book are for sure. For example, the increase in IQ over time, the Flynn Effect, may not occur because of the training effect. It could occur instead because the tests no longer serve their original purpose. Tests of what is called fluid intelligence, such as Ravens Progressive Matrices, were designed to measure an individual's ability to figure out how to perform a novel task. Given that the characteristics of such tasks are not very different from some computer games, perhaps these tasks no longer seem novel to today's young test-takers. It may take some creativity to keep the intelligence tests one step ahead of the populace.

There are parts of mental performance that have not been handled very well by the field at large and, understandably enough, are still not settled in the book. Consider the example of remembering where one parked one's car this morning. Laymen often refer to that as short-term memory, whereas cognitive psychologists reserve that term for information that was held in mind only within the last minute or so. But then, cognitive psychologists have no clear concept that can explain why we can remember where we parked the car this morning. The predominant concept in the literature is that there are cues that help us to recall the most recent event in a series (in this case, the series of parking spaces used on successive days). An alternative formulation is that there is some intermediate-term memory faculty, a notion that is common among neurophysiological researchers but rare among human behavioral researchers.

Another issue that has not been addressed in enough detail by the field, let alone in the book, is the massive influence of emotion on cognition. What is seen as the human ability to be rational is often actually no more than a human ability to rationalize and do or think what we want to.

The book has some general lessons. It shows how, through persistence, a few people can successfully overturn established scientific maxims, such as the one that says that the effects of practice are only narrow and specific. It also shows the practical value of theoretical thinking. A final lesson is the value of combining literatures from fields that have remained separate; probably for the sake of expedience, the neurologically and behaviorally oriented researchers of attention and working memory have tended to ignore each others' literatures and have not talked to each other as much as they should. The book helps to bring them together.

Finally, one can see in the book that there are important benefits of not being too reductionistic in one's scientific view. As an analogy, to understand computers one must grasp not only the functioning of magnetic memory locations, but also other, higher-level concepts: information encoding, simple operations and, at a macroscopic level, logical flow charts. Similarly but further afield, to understand the United States government one needs abstract concepts. One cannot point to a single part of Washington, D.C., and say that it fully encapsulates the legislative, executive, or judicial branch; the physical plants are fairly well commingled. Likewise, the intellect depends on faculties such as working memory, attention, and planning that are enacted in the brain by interwoven ensembles of neurons. Discussions incorporating all levels of analysis are necessary, and they occur in Klingberg's book.

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DAGENS NYHETER.

En utskrift från Dagens Nyheter, 2019-08-27 22:32
Artikelns ursprungsadress: https://www.dn.se/insidan/forskare-datorn-i-klassrummet-blir-annu-en-distraktion/

Insidan

Forskare: Datorn i klassrummet blir ännu en distraktion

UPPDATERAD 2019-08-21 PUBLICERAD 2019-08-20

Torkel Klingberg är en av Sveriges främsta hjärnforskare. Foto: Fredrik Funck

Han är teknikoptimisten och digitaliseringsivraren som varnar för att ”slänga in” en massa datorer och surfplattor i klassrummen utan tillräcklig kunskap om följderna.

”Vi riskerar ett nytt kunskapsras och en förlorad generation”, säger professorn och hjärnforskaren Torkel Klingberg.

Läs senare

När Torkel Klingberg i våras varnade för att digitaliseringen i skolan sker i blindo blev reaktionerna starka. Många gillar hans tankar, andra menar att han överdriver och svartmålar en nödvändig satsning för att Sverige ska hänga med i den tekniska utvecklingen.

Vi träffar Torkel Klingberg i hans arbetsrum på Biomedicum på Karolinska institutet i Solna. Härifrån leder han som professor ett team som forskar om koncentrationsförmåga, arbetsminne och matematikinlärning. Resultaten har väckt stor uppmärksamhet i Sverige och internationellt.

– Alla former av distraktioner eller störningsmoment försämrar hjärnans arbetsminne, och koncentrationsförmågan. Det har visat sig i studier av barn och unga – och är inget som ifrågasätts i forskarvärlden. Så fungerar det, slår Torkel Klingberg fast.

Fakta. Torkel Klingberg

Ålder: 52 år

Gör: Professor i kognitiv neurovetenskap vid Karolinska institutet.

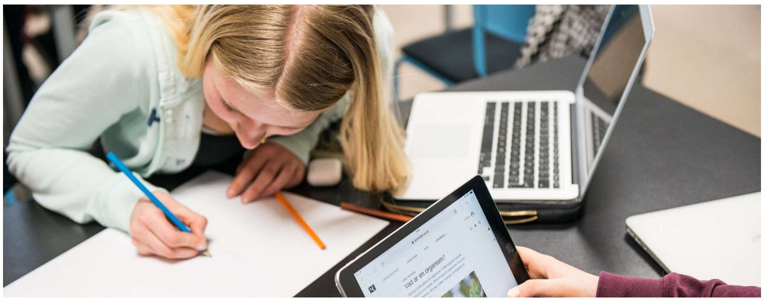
Bakgrund: Hans forskning har publicerats i Science och Nature Neuroscience och uppmärksammats i internationell media. Har tagit emot utmärkelser från International Neuropsychological Association och Gustafssons Pris i medicin och utsetts till en av framtidens forskningsledare av Stiftelsen Strategisk Forskning. Har tillsammans med olika programmerare utvecklat programvara för träning av arbetsminne och matematik.

Böcker: "Den översvämmade hjärnan" (2007). "Den lärande hjärnan" (2011), och Hjärna, gener och jävlar anamma" (2016).

Kamrater viskar med varandra i klassrummet, någon knackar ideligen i bordet med pennan medan en annan hela tiden avbryter läraren. Plötsligt händer något spännande utanför klassrumsfönstret – redan i dag finns det nog med störningsmoment som påverkar koncentrationen och arbetsminnet.

– Därför måste man alltid vara försiktig med att föra in nya distraktionsmoment i skolan och i en undervisningssituation. Typ att låta eleverna få möjlighet att surfa fritt under en lektion eller ha mobilen uppkopplad. I dag slängs datorer och surfplattor utan eftertanke in i klassrummen, samtidigt som tryckta läromedel kastas bort.

Regeringen beslutade 2017 om en nationell digitaliseringsstrategi för skolväsendet. Det övergripande målet är att den svenska skolan ska vara ledande i att använda den nya teknikens möjligheter. Syftet är att uppnå en hög digital kompetens hos eleverna och främja kunskapsutvecklingen och likvärdigheten.



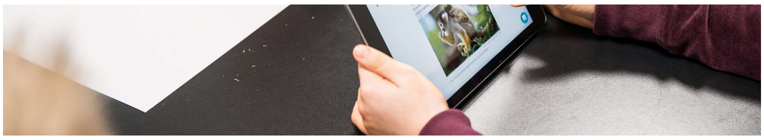


Foto: Alexander Olivera/TT

Politiker, tjänstemän inom skolområdet och många forskare inom pedagogik talar ofta om digitaliseringens positiva effekter. Men enligt Torkel Klingberg finns det väldigt lite vetenskapligt stöd för det ”gigantiska experimentet”, som han säger, som nu ska genomföras i den svenska skolan.

– Det finns en ljus framtid för en digital skola och jag har själv varit med om att utveckla program som hjälper elever med tidig matematikinlärning. Min forskargrupp har till exempel tagit fram en gratisapp som tränar arbetsminnet hos barn och unga på ett sätt som visat sig fungera bra.

Men studier visar att elevernas prestationer blir sämre om datorer och annan digital teknik förs in i klassrummen utan något mål och någon tanke, menar Torkel Klingberg. Forskare fann till exempel att när elever och studenter hade sin dator, i-pad eller laptop uppkopplad ägnade de uppemot 40 procent av lektionstiden åt irrelevanta saker som inte hade någon koppling till undervisningen.

> ***Vi riskerar att få ett nytt kunskapsras som vi inte vet hur lång tid det tar att reparera***

Torkel Klingberg efterlyser seriösa kvantitativa studier av vad som fungerar i ett klassrum. Han ger ett exempel på hur en studie borde läggas upp:

Klass A och B får använda böcker och traditionellt undervisningsmaterial, medan klass B och C får nya elektroniska läromedel och datorer som de kan använda ganska fritt. Efter ett år sker sedan en utvärdering: Vad fungerade bäst? Sedan kan man gå vidare och till exempel jämföra olika elektroniska läromedel.

– Men den typen av forskning lyser med sin frånvaro här i Sverige. Internationellt däremot finns flera studier med liknande upplägg.

Forskare vid Vermont University i USA kontrollerade hur universitetsstudenter använde sin laptop under föreläsningarna. Under 42 procent av tiden använde de datorn till helt irrelevanta saker, som sociala medier. Torkel Klingberg konstaterar att det handlade om välmotiverade studenter som betalat höga avgifter för sin utbildning.

Läs mer: ”Målet för digitaliseringen av skolan är inte ökad skärmtid”

Foto: Jessica Gow/TT

Forskaren Helen Hembrooke från Cornell University i USA lät hälften av studenterna ha sin laptop öppen under en föreläsning, den andra halvan måste ha den stängd. Efter föreläsningen fick de svara på frågor om innehållet. Studenterna som haft sin laptop öppen presterade 30 procent sämre än sina kamrater, berättar Torkel Klingberg.

I början av året publicerade han en debattartikel i Svenska Dagbladet. I den menade han att vi aldrig skulle introducera ett nytt läkemedel utan att först ha provat det i forskningsstudier. Men det är just detta som sker i skolans värld, hävdade han.

– När det handlar om barns lärande introducerar vi ny teknik utan att veta att den inte skadar. Vi riskerar att få ett nytt kunskapsras som vi inte vet hur lång tid det tar att reparera. På vägen riskerar vi att tappa en hel generation barn och unga. För mig ter det sig som ytterst ansvarslöst.

Företag som säljer datorer och digitala program, liksom läromedelsförlag, driver på utvecklingen för att öka sina inkomster, säger Torkel Klingberg. Och skolorna vill spara pengar, fortsätter han. Samtidigt kommer påbud från skolverk och andra myndigheter om att Sverige ska ligga i frontlinjen när det gäller att digitalisera skolan.

– Men ingen tar ansvar och utvärderar effekten på lärande.

Vi måste utveckla nya digitala läromedel som inte leder till sämre koncentration och motverkar inlärningen

Du anklagas ibland för att vara digitaliseringsmotståndare?

– Det stämmer inte alls. Jag är en varm förespråkare för digitalisering - men all teknik har sina risker. Elektrifieringen var fantastisk, men när de elektriska brödrostarna introducerades inträffade dödsfall eftersom de inte var jordade. Kemikalier som DDT skadade naturen innan de förbjöds.

– Jag vill ha ett bra vetenskapligt underlag när hundratusentals barn nu ska utsättas för ett gigantiskt digitaliseringsexperiment.

Datorer är inte dåliga i sig, upprepar Torkel Klingberg. Men innehållet i olika program och appar har många gånger dålig kvalitet och de används tanklöst, säger han.

– Skärmar kan användas till mycket positivt. Men vi måste utveckla nya digitala läromedel som inte leder till sämre koncentration och motverkar inlärningen – och det sker inte i dag.

Läs mer: Psykolog: Vi vet för litet om hur små barn påverkas av skärmar

Foto: Magnus Hallgren

Så hänvisar Torkel Klingberg till en rapport från OECD om sambanden mellan datoranvändande i skolor och elevernas resultat. Efter att tagit hänsyn till faktorer som skillnader i ländernas BNP fanns det ett negativt samband mellan antalet datorer och prestationerna.

I sin uppmärksammade debattartikel menade Torkel Klingberg att de negativa effekterna beror på hur datorerna används, det vill säga att skärmarna i sig inte är skadliga.

– Den andra generationens digitala läromedel kan vara till stor nytta om de brukas på rätt sätt, och det har också hundratals studier visat. Men det krävs mycket resurser för att ta fram och utvärdera sådana läromedel och det är inget som läromedelsförlagen i dag lägger någon energi på. Ansvariga myndigheter har heller inte tagit sitt ansvar.

Enligt Torkel Klingberg tar förlagen istället ofta fram fram digitala kopior av tryckta böcker, som inte stimulerar eleverna utan snarare förstärker digitaliseringens negativa delar.

> ***De vill inte, eller orkar inte, bry sig om vad den moderna hjärnforskningen kommit fram till***

Torkel Klingberg har två barn, 17 och 21 år. Han har förmedlat lite av sina tankar till dem, och samtidigt uppmanat dem att spela dataspel och att lära sig programmering.

– Jag har märkt hur de blir distraherade av mobiltelefonen när de gör sina läxor - även om den ligger avslagen bredvid dem. Den pockar på uppmärksamheten på samma sätt som datorn i klassrummet.

Torkel Klingberg studerade psykologi och biologi på universitetet. Därefter utbildade han sig till läkare parallellt med doktorandstudier på **Karolinska institutet**. Han blev allt mer intresserad av hur hjärnan fungerar, av kognition. Hur fungerar vårt arbetsminne och går det att träna? Kan man göra två saker samtidigt och hur påverkas människa av distraktioner?

Han är också författare till tre böcker. Allt lärande sker i hjärnan och nyckeln till barns utveckling finns i hur den formas, menar Torkel Klingberg, och i böckerna skriver han om hur kunskap om nervceller kan leda till en bra undervisning i klassrummet. Han tar upp vad svårigheter som dyslexi, dyskalkyli och bristande koncentrationsförmåga kan bero på. Och så förklarar han varför hjärnans mognad har betydelse för tonåringars beteende.

– Pedagogiska forskare, skolmyndigheter och politiker verkar inte på allvar inse vad som är på väg att hända i den svenska skolan. De vill inte, eller orkar inte, bry sig om vad den moderna hjärnforskningen kommit fram till.

"Kritiken bygger på missuppfattningar"

Kritiken att Skolverkets satsning på en snabb digitalisering av den svenska skolan är ogenomtänkt bygger på missuppfattningar, hävdar Peter Fredriksson, chef på Skolverket. "Målet är inte mer skärmtid i skolan och att det ska ösas ut pengar på datorer" säger Peter Fredriksson som intervjuas i nästa del i serien.

Vektor – för spel och träning.

Vektor är ett exempel på en spelinspirerad app. Den är baserad på forskning om tidig matematisk inlärning och framtaget av ledande forskare i samarbete med erfarna spelutvecklare. Torkel Klingberg är en av initiativtagarna.

Den kostnadsfria appen passar både barn utan matematiska förkunskaper och barn med ett par års skolgång bakom sig. Äldre elever med svårigheter i matematik kan också ha nytta av den.

Vektor är utformat som ett som ett spel med hjältar, monster och skatter.

Barnet (användaren) är hjälten och monstren lagom läskigt. Skatterna fungerar som belöningar och inspirerar till större engagemang och mer träning.

Träningen är intensiv och alla barn tränar hela tiden på en nivå där de utmanas lagom mycket. Barnen tränar 30 minuter per dag, fem dagar i veckan under åtta veckor.

Eftersom Vektor är så gott som fri från språk kan det användas av barn över hela världen.

Syftet är att träna arbetsminne, det vill säga förbättra förmågan att hålla information i arbetsminnet och att komma ihåg instruktioner.

Källa: Cognition Matters

Fakta. Arbetminne

Arbetsminnet är en generell beteckning för den tillfälliga lagring av information i korttidsminnet som krävs för att en person ska kunna utföra kognitiva, intellektuella, uppgifter.

Det är tack vare ditt arbetsminne som kan du läsa denna mening från början till slut – utan att glömma bort innebörden i meningen.

Arbetsminnet är ett system som tillfälligt lagrar information som är relevant för den uppgift du utför. Men arbetsminnet har en begränsad kapacitet och ju fler saker du försöker hålla i arbetsminnet samtidigt, desto sämre blir kvaliteten på vart och ett av minnena.

Arbetsminnet är känsligt för störningsmoment, distraktioner, som försämrar

koncentrationsförmågan.

Forskare har under senare år visat att det går att träna upp arbetsminnet genom olika övningar.

Thomas Lerner

Följ

Svenska skolan

Hjärnforskare varnar: Skolan digitaliseras i blindo

Foto: Jim West,Christina Lagerek/TT Ill: Staffan Löwstedt

KULTURDEBATT | Vi skulle aldrig introducera ett nytt läkemedel till patienter utan att först ha prövat det i forskningsstudier. Men när det kommer till barns lärande introducerar vi ny teknik utan att veta att den inte skadar. Digitaliseringen av skolan riskerar att resultera i ett nytt kunskapsras som det tar lång tid att återhämta sig från, skriver hjärnforskaren Torkel Klingberg.

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Skolan digitaliseras i allt högre utsträckning. Användningen av datorer under lektionstid ökar och läroböcker ersätts av digitala resurser på nätet. Utvecklingen drivs på av företag som vill sälja datorer eller digitala lösningar, liksom av påbud om digitalisering från Skolverket. Problemet är att vi inte vet vad det här får för konsekvenser. Vad säger egentligen forskningen?

Decennier av kognitiv forskning om hjärnans funktion, som jag själv också bidragit till, visar hur distraktioner och simultanutförande har en negativ inverkan på koncentrationsförmåga, problemlösningsförmåga och inlärning. Orsaken är hjärnans begränsade förmåga att hålla relevant information i huvudet, något som kallas arbetsminneskapacitet. Så snart du försöker göra två kognitivt krävande uppgifter samtidigt går prestationen på varje uppgift ned. Varje irrelevant distraktion påverkar ditt arbetsminne och koncentrationsförmåga vilket leder till att inlärningen försämras.

Principerna om distraktioner, arbetsminne och inlärning är enkla och numera välkända. De har viktiga implikationer för hur skolans arbete borde organiseras. De indikerar att vi borde sträva efter en klassrumssituation som är lugn och fri från distraktioner. Forskningen tyder också på att vi borde vara väldigt försiktiga när det gäller att introducera nya distraktioner, såsom en dator framför ögonen på en 16-åring, med alla dess möjligheter till webbsurfande, sociala medier och Youtube-tittande.

> Studenterna som haft sin laptop öppen presterade 30 procent sämre än de som inte använt datorn.

När jag själv provar ett digitalt läromedel väljer jag ett biologiavsnitt om hjärnan. Där finns en länk till en några sekunder lång film om hjärnans anatomi som jag klickar på. Men när filmen spelats dyker det upp nya rekommendationer i rutan, och mindre än en minut efter att jag loggat in finner jag mig titta på filmer om skeppsvrak i Atlanten i stället för det jag skulle läsa om.

När forskare vid Vermont University i USA registrerade vad universitetsstudenter egentligen gjorde med sina laptops under föreläsningarna, fann de att studenterna under 42 procent av tiden använde datorn till saker som var irrelevanta för föreläsningen, till exempel sociala medier. Det var frågan om högt motiverade universitetsstudenter som frivilligt valt sin utbildning och ofta betalar höga avgifter för att få studera. Mängden irrelevant datoranvändande är förmodligen inte lägre hos omotiverade, svenska högstadieelever.

I en studie av Helene Hembrooke från Cornell University i USA tillät hon hälften av studenterna att ha sin laptop öppen under en föreläsning, medan andra hälften hade den stängd. Direkt efter föreläsningen fick de en skrivning om föreläsningens innehåll. Studenterna som haft sin laptop öppen presterade 30 procent sämre än de som inte använt datorn.

Liksom elever distraheras av datorer tappar de fokus av att ha sin mobiltelefon till hands: i en sammanställning av elva studier av effekterna av att använda mobilen under lektionstid visade samtliga studier på negativa effekter. Detta är precis vad vi kunde vänta oss med tanke på kunskapen om distraktioner och inlärning.

Att läsa en text på nätet är mer krävande därför att där finns fler distraktioner, i form av annonser som måste ignoreras, länkar som man kan klicka på eller flikar med mer intressant innehåll. Men även om vi kunde reducera alla dessa störande moment finns det en stor mängd studier som visar att enbart det faktum att vi läser på en skärm i stället för en bok gör det mer krävande och att vi minns det vi läser på skärmen sämre.

Psykologiforskaren Erik Wästlund har gjort en rad uppmärksammade studier om att läsning på skärmar är mer krävande. I en amerikansk studie från 2017 av Lauren Singer och Patricia Alexander, vid University of Maryland, fick 90 universitetsstudenter läsa en faktatext i en bok eller exakt samma text som ett PDF-dokument på en 15 tum stor LCD-skärm. När man först frågade studenterna om deras preferenser svarade 73 procent att de skulle föredra att läsa en faktatext digitalt. Men när man mätte kunskapen visade det sig tvärtom att studenter som läst på skärm mindes sämre än de som läst samma text i en bok.

Varför minns man en digital text sämre? Det kan ha att göra med den starka kopplingen mellan långtidsminne och platsminne. Hur detta sker i hjärnan är forskning som belönades med ett Nobelpris i medicin 2014. Den starka kopplingen mellan plats och minne används i minnestekniker såsom loci-metoden, vilken innebär att man associerar orden till en plats i ett rum eller längs med en känd väg.

Vad boken kan göra, mer än en skärm, är att ge oss små men viktiga fysiska och spatiella associationer till det vi läst. Vi minns storleken på boken, dess omslag, tyngd och tjocklek och vi kan associera ett visst innehåll till något vi läste överst på en vänstersida av ett uppslag, alldeles i bokens början.

> Laptop-gruppen presterade 12 procent sämre än gruppen som tagit anteckningar med penna.

Läsforskaren Maryanne Wolff har liknat bokläsandet vid en promenad, där vi associerar olika delar av texten till specifika punkter på vägen. Det digitala läsandet blir mer som en rad fotografier av samma promenadväg, men utan den fysiska känslan av att förflytta oss genom texten. En sådan promenad liknar den minnespromenad man använder sig av i loci-metoden och kan förklara varför vi minns bättre från fysiska böcker.

Hur är det då att sitta på föreläsningen och skriva anteckningar med dator i stället för med papper och penna? Lärare misstänker att datorerna distraherar medan studenter oftast anser att fördelarna uppväger nackdelarna. Forskningen verkar ge lärarna rätt.

En sak är att Snapchat eller irrelevanta Youtube-klipp distraherar och försämrar inlärningen. Men hur skulle det fungera om vi kunde begränsa datorernas funktion så att de bara kunde användas till det som är relevant för lektionerna?

I en serie experiment försökte forskare från Princetonuniversitetet i USA göra just detta. Deltagarna var 66 studenter på universitetet. De fick lyssna på en 15 minuter lång TED-föreläsning medan de tog anteckningar med antingen dator eller penna och papper. Men man begränsade datorerna så att studenterna inte kunde göra något annat än att ta föreläsningsanteckningar. Efter föreläsningen samlades anteckningarna in, och de fick svara på frågor som handlade om faktainnehåll, samt mer konceptuell förståelse av innehållet.

När det gällde faktafrågor presterade båda grupper lika bra, men på de konceptuella frågorna, som kräver djupare förståelse, presterade laptop-gruppen 12 procent sämre än gruppen som tagit anteckningar med penna. Forskarnas slutsats var att ”pennan är mäktigare än tangentbordet”.

> Vi skulle aldrig introducera ett nytt läkemedel till patienter utan att

Vi skulle aldrig introducera ett nytt läkemedel till patienter utan att först göra en grundlig prövning.

I OECDs rapport "Students, computers and learning" från 2015 jämförde man datoranvändande och prestation i olika länder. Efter att ha kontrollerat för faktorer som BNP, såg man att antalet datorer i skolorna var negativt korrelerat med prestation. Ett index på hur mycket datorerna användes i skolan förklarade så mycket som en tredjedel av skillnaderna mellan ländernas prestation i matematik. Detta verkar bekräfta alla de varningstecken vi borde uppmärksamma från kognitiva neuroforskningen liksom de experimentella skolstudierna.

De negativa effekterna är relaterade till hur datorerna används, inte att skärmar i sig är skadliga. Det finns många exempel på positiva möjligheter med digitalisering, där forskare utgår från teorier om inlärning, specialdesignar digitala hjälpmedel och sedan utvärderar dem i kontrollerade studier. Detta är vad som ibland kallas "den andra generationens digitala läromedel". Det finns ett hundratal studier som visar att om dess metoder används rätt kan sådana hjälpmedel vara till stor nytta och innebär en enorm potential för framtiden.

Men dessa "andra generationens läromedel" är resurskrävande att ta fram och att utvärdera, och det är inget som läromedelsföretagen ägnar sig åt. I stället gör man enkla digitala kopior av böcker, som inkluderar alla de negativa aspekterna av digitaliseringen, men inte tillräckligt med innovationer för att uppväga dessa negativa aspekter.

Vi skulle aldrig introducera ett nytt läkemedel till patienter utan att först göra en grundlig prövning. Utgångspunkten är att varje nytt läkemedel bör betraktas som overksamt och potentiellt skadligt till dess att motsatsen bevisats genom stora, kontrollerade forskningsstudier. Men när det kommer till barns lärande överger vi alla dessa principer och introducerar ny teknik utan att någon tar ansvar.

För något år sedan föreläste jag på ett seminarium på temat barn, inlärning och digitalisering. En av de andra deltagarna representerade ett företag som sålde digitaliserade läromedel. Företaget förde över materialet från läroböcker till webbsidor dit barnen kunde logga in för att läsa och svara på frågor. En licens för en högstadieelev, vilken täcker både NO, SO och matematik kostar skolan några hundra kronor. Sju stycken nya inbundna böcker kostar runt 2 700 kronor. Det är ett erbjudande som en rektor har svårt att tacka nej till, särskilt om man samtidigt kan framstå som en progressiv teknikvän om man samtidigt kan framstå som en progressiv teknikvän.

Efter föreläsningen pratade jag med försäljaren. Jag påpekade de välkända nackdelarna med distraktioner och datorer. "Vet ni om era digitala lösningar försämrar inlärningen?", frågade jag. "Nej, det vet vi inte", blev svaret. "Men om inte vi säljer in det här gör någon av våra konkurrenter det."

> Svenska skolan kör rakt in i digitaliseringsträsket med förbundna ögon.

Svaret gav mig kalla kårar. Plötsligt såg jag framför mig hur undermåliga e-läromedel kommer att spridas, därför att både företag och skolor tjänar på det, och att ingen tar ansvaret för hur inlärningen påverkas. När jag kontaktar flera av de dominerande förlagen undviker de att svara, eller bekräftar att det inte finns någon forskning. Det man konkurrerar med är pris, inte kvalitet. Ett race mot botten.

Så vad borde då göras? Självklart borde vi göra kontrollerade studier på effekterna av digitalisering innan e-läromedel sprids. Det här är inte komplicerade studier: en skola ges nya digitala läromedel, en kontrollskola ges nya läroböcker. Så följer man resultaten med samma tester i båda skolor.

En myndighet som skulle kunna verka för relevant forskning är Skolforskningsinstitutet (SFI). Men SFI följer den tradition som är djupt rotad inom svensk pedagogisk forskning, nämligen att man inte ska mäta några resultat utan i stället ägna sig åt kvalitativ forskning, exempelvis att skriva teoretiska analyser eller intervjua lärare och elever. 2017 gav Skolforskningsinstitutet inte medel till en enda studie som inkluderade mätningar hos en kontrollgrupp. Samtidigt visar kvantitativ forskning att sådana studier ofta är irrelevanta, och ibland missledande: i studierna om digitalt läsande eller antecknande som det refererades till ovan, föredrog studenterna datorn, men när effekterna kvantifierades med mätningar visar den på motsatt effekt på inlärningen.

Skolverket har likaså helt blundat för sitt ansvar. Man ger ut policydokument med tyckande om digitalisering, och diskussioner om digital kompetens och demokrati, men ägnar sig inte åt kvantitativa studier om vilken effekt digitaliseringen har på barns lärande. Man utreder nu hur digitalisering ska utvärderas, men det finns inget i den utredningen som specificerar att några kontrollerade studier ska göras. Vi kan förvänta oss att fler miljoner spenderas på teoretiska tyckanden, och en oändlig lång rad nya intervjuer med lärare och elever om vad de tycker.

Då en expertgrupp från OECD utvärderade svenska skolan kritiserade de bland annat att det inte fanns någon som avkrävdes ansvar för hur barnen lärde sig. Denna brist på ansvar och brist på relevant forskning gör nu att svenska skolan kör rakt in i digitaliseringsträsket med förbundna ögon. Det kan bli ett nytt kunskapsras som det kommer ta lång tid att återhämta sig från.

Torkel Klingberg

Torkel Klingberg är författare och professor i kognitiv neurovetenskap vid Karolinska Institutet.

Kommentarsfältet är stängt