# Session B

## Learning numbers: Effects of learning new number symbols on number processing-related brain activity

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Humans develop a system of exact number representation in which number symbols (words/numerals) represent a fixed and unique quantity. The acquisition of numerical symbols during formal schooling, learning that the numeral “2” represents two objects, has been shown to predict growth in arithmetic skills longitudinally. There is still a lack of consensus about how this symbolic system is acquired. The present study aimed to elucidate the neurocognitive mechanisms underlying the acquisition of such symbol-number magnitude knowledge. Adults (N=22) performed a trial-and-error learning task, requiring them to attach numerical meaning to abstract symbols. Non-symbolic (dots representing quantities 1-9) - symbolic (abstract symbols) stimulus pairs were presented and participants decided whether the non-symbolic and abstract symbolic stimuli represented the same or a different magnitude, while recording EEG over parietal-occipital sites. Expectations were that acquisition of accurate (exact) symbol – quantity mappings would be reflected by larger gradual improvements in accuracy and speed of mapping responses across learning blocks in trials requiring same (vs different) responses. The behavioral results indeed showed significant increases in accuracy and speed of decisions on trials requiring same (vs different) responses across learning-blocks, but only for symbols representing numbers 1-4. Symbols 6-9 showed reversed same/different effects, leading to the conclusion that accurate exact non-symbolic – symbolic mappings were only acquired for numbers 1-4. Analysis of ERP activity in this lower number-range (1-4) showed a differential response to same and different trials related to the acquisition of non-symbolic-symbolic mappings on a left-lateralized parietal Late Negativitiy (LN), not on earlier components (N1,P2p,LP).

# Mind-wandering in children: Examining task-unrelated thoughts in laboratory and classroom settings, and the association with executive functions

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Mind-wandering is a common experience during which attention unintentionally shifts from an ongoing task towards self-generated Task-Unrelated Thoughts (TUTs). TUTs disrupt learning and have been linked to worse educational outcomes in adults. Mind-wandering in children is however largely unexplored, despite its relevance for education and the still immature meta-cognitive and executive control skills during childhood important for recognizing and correcting mind-wandering. The current study aimed to measure and compare mind-wandering in laboratory tasks and in a classroom setting, and to examine the association between mind-wandering and executive functions (EF) in typically developing children. Fifty-two, 10-year old children performed 3 laboratory tasks measuring core EFs (working memory, inhibition and attention flexibility) and a classroom listening task (regular lesson), during which performance was periodically interrupted by thought probes asking children whether their preceding thoughts were on or off task (TUT). Children reported TUTs in 20-25% of the probes. More TUTs during laboratory EF tasks predicted more TUTs during the classroom lesson, and vice versa. Regression analyses revealed that response inhibition but not working memory capacity or attention flexibility predicted mind-wandering, but only during the classroom lesson. Children with higher interference costs during a flanker task (i.e., lower inhibition capacity) showed a higher frequency of TUTs (mind-wandering) during the classroom listening task. Together, these results suggest that mind-wandering occurs frequently and can be reliably measured in children in laboratory as well as classroom settings and inhibitory control seems to be the most important EF related to mind-wandering during a classroom lesson.

# How does the form of feedback influence the way we process the message? An EEG study

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Within education, both Evaluative Feedback (EF; how you have performed) and Directive Feedback (DF; how to improve in future) is used to promote learning. A recent study by Nash et al. (in press) has shown that DF is often forgotten or misremembered in a recall task compared to EF. The current study investigated whether this could be due to differences in the ease of decoding (with EF being easier to decode) and utility (with DF providing more utility) of feedback. Electroencephalogram (EEG) measures were utilised by the researchers to understand whether there are underlying brain processes that explain this difference in behaviour. The feedback related negativity (FRN) signal is an event related potential that is used to measure feedback processing, however, no study has yet measured DF using these measures. Thus the current study aimed to investigate whether DF produced an FRN signal similar to that of EF, and whether this component is sensitive to the ease of decoding or utility of feedback provided. Behavioural results highlighted the importance of ease of decoding and utility of information provided. Feedback that was easy to decode and easy to utilise produced the highest accuracy and fastest reaction times. Conversely, the easy to decode but hard to utilise feedback proved to have the lowest accuracy and slowest reaction time. Within the EEG data a signal similar to the FRN was found in DF, as well as EF. Explanations for these findings and suggestions for future research in this area are discussed.

# Executive functions explain unique variance in mathematics but not science performance, in primary school children aged 5-10 years

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There is growing evidence to support a positive relationship between executive functions (EF) and academic achievement in children. Studies have identified a positive association between working memory (WM) and mathematics performance, while the relationship between inhibitory control and mathematics is less clear. Research examining EF and science is sparse, although the few studies hint at a positive relationship. This study extends the current literature, with a cross-sectional study of 135 primary school children from Years 1, 3 and 5 (aged 5-10 years), examining the relationship between EF (verbal WM, visuo-spatial WM and non-numerical semantic inhibitory control), and performance in standardised tests of mathematical reasoning and numerical operations (WIAT-II), as well as novel tests of science reasoning, and science and mathematics misconceptions.

After controlling for age and gender, both verbal and visuo-spatial WM positively correlated with mathematical reasoning and numerical operations, while only verbal WM correlated with science reasoning. Inhibitory control did not correlate with any mathematics or science measure, and there was no significant association between EF and performance on the misconceptions test. After accounting for variance due to age, gender, and IQ, verbal WM remained a significant predictor of performance on mathematical reasoning and numerical operations.

This study supports previous findings of a positive association between WM and mathematics, and does not provide evidence of an association between mathematics and inhibitory control. In addition, the results suggest that EF is more closely linked to mathematics than science performance.

## Eye tracking as a measure of strategy use in number sense and mathematics

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Number sense is an important precursor of mathematical performance. A large number of tasks have been used to study number sense in children and adults. Performance on these tasks is often measured by accuracy and reaction times. Insight into solution strategies in addition to performance may be informative to develop more targeted education and interventions for low performing children.
Here, I discuss some of our recent studies using eye tracking to examine strategy use in number sense tasks. In the first study, we showed that lower performance on the number line task by children with mathematical learning disability (MLD) in comparison to children without MLD is accompanied by less adaptive strategy use. In a second study, we found that adults with MLD showed similar performance and strategy use to adults without MLD on the traditional number line and the unbounded number line task. In contrast, we found that children with MLD differ from children without MLD in strategy use when solving an unbounded number line task, while task performance was similar. Moreover, this study indicated that eye tracking seems a more valid measure of strategy use compared to children's verbal reports. A last study examined strategy use on a digit comparison task in children with and without MLD.
Together, these studies show that children with MLD frequently use other strategies than children without MLD. Unraveling the relations between performance and strategy use may be a promising direction to develop interventions and education that are more tailored to an individuals' needs.

# White matter alterations and tract lateralization in children with isolated spelling deficits and dyslexia

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The present study addressed the question whether children with isolated spelling deficits show a different pattern of structural white matter alteration compared to participants with typical dyslexia profiles and to typically developing peers. Previous literature on the topic is rather scarce, relies on very small sample sizes and suffers from the limitations of classical tensor-based methods. The present Constrained Spherical Deconvolution study reports results on 27 children with typical reading and spelling skills, 21 children with isolated spelling deficits and 21 children with dyslexia (showing both reading and spelling deficits). Group differences along major white matter tracts were quantified with the Automated Fiber Quantification software and a lateralization index was calculated to consider the structural asymmetry of the tracts. The two deficits groups mostly displayed different substrates of white matter alteration in comparison to children with typical development, located in the frontal part of corpus callosum and the left arcuate fasciculus for the group with isolated spelling deficits, in the bilateral inferior longitudinal fasciculus, right cingulum, superior longitudinal and arcuate fasciculi for the group with dyslexia. Furthermore, the typical leftward asymmetry of the arcuate fasciculus was not found in the group with dyslexia, whereas children with isolated spelling deficits showed absent rightward asymmetry of the inferior fronto-occipital fasciculus.

# Suboptimal processing of print in dyslexics can not be explained only by their poorer reading - fMRI study

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Dyslexics process print in a suboptimal way, underactivating left hemispheric language circuits when compared to their peers. However, this pattern of brain activation is characteristic also for the typically developing, but less proficient readers. Here, we aimed to uncover print processing patterns typical for dyslexics that are not merely associated with reading expertise. We selected 25 dyslexic readers (DR), typical readers (TR) who entered the study on the same reading skill as DRs, but later on succeeded in reading training; and advanced readers (AR) who at the beginning of the study were able to read as well as dyslexics two years later. All groups participated twice in fMRI task presenting words. With TR and DR comparisons we tracked developmental trajectories of impaired and typical reading development. AR TP3>TR TP3 comparisons allowed to observe reading-related effects, while AR TP1>DR TP3 – effects not related to the performance. We could not observe differences between DRs and TRs for reading processing, when both groups read on very low lever. Two years later differences were found: DRs underactivated IFG and FG when compared to TRs. When DRs were compared to younger ARs, again LH IFG and FG were found to be underactivated in DRs. Decreased activation of left vOT and IFG could be a specific marker of dyslexic brain response to print. This hypoactivation cannot be explained solely by lower reading skills. Our study provides an evidence that neural processes underlying reading in dyslexics do not merely associate with their smaller expertise in reading.

# The componential nature of arithmetic: implications for interventions for children with arithmetical difficulties.

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Research in neuroscience, including studies of the effects of brain damage on adults' numerical abilities, and brain imaging studies of children and adults with typical and atypical numerical development, has provided much evidence that arithmetical ability is not a single entity. Rather, it is made up of many components; and marked within-individual discrepancies between performance on different components are not uncommon. The componential nature of arithmetic is important in planning and formulating interventions with children with arithmetical difficulties. Given the varied nature of mathematical difficulties, it is important to devise and use individualized and targeted interventions for children with mathematical difficulties. This poster describes the Catch Up Numeracy intervention for primary school children with arithmetical difficulties, which is based on the principle of assessing and targeting different components of arithmetic. It is a relatively non-intensive targeted intervention for children who are low-attaining in mathematics, which involves 30 minutes per week of individualized teaching. Two studies show that children receiving Catch Up Numeracy intervention attained average gains more than twice that expected of typically attaining children over the same period of time, and significantly more than controls. Thus, the evidence suggests that Catch Up Numeracy is effective for children who are low-attaining in mathematics. More generally, it suggests that many children's arithmetical difficulties are highly susceptible to intervention based on assessing and targeting the components with which they are experiencing difficulties.

# Language development in preschool children participating in a multimodal music-based pilot project

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The present project seeks to propose another avenue of language support by adding musical awakening workshops based on the latest neuroscientific, linguistic and educational knowledge. The multisensory education proposed here by the musical awakening underlies a particular pedagogy that goes through several senses, including hearing, vision and kinesthesia, to facilitate learning but especially to develop oral language in children. By crossing several meanings in real time, the educator will promote, in the child, the capacities of integration by the senses, **called multimodal integration** - research that has demonstrated the benefits it brings in terms of brain and language development (Habib, 2013, Recanzone, 2003 and Ernst and Banks, 2002). In Quebec, our project follows the directives lines of the Institut national d'excellence en santé et services sociaux (INESSS) concerning the recommendations of the services organization for the 2 to 9 years old children with language developmental delay.

# Mind or avoid your errors? An (electro)physiological study of ability beliefs and goal achievement in students

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Making mistakes is inherent to learning. Students, however, may hold different views on what these mistakes mean to them. Past research shows that students may have different ability beliefs and goal orientation. Some students think abilities are malleable with effort (incremental belief) and aim to improve themselves (learning goals), while others belief abilities are fixed and cannot change with effort (entity belief) and aim to prove themselves (performance goals). The current study (N= 60, Dutch undergraduate students) addresses the underlying electrophysiological correlates of confrontation with errors, in relation to ability beliefs, goal orientation, and helpless attributions (measured with self-reported questionnaires). Heart rate (variability), skin conductance level, and EEG power spectra are measured during the Math Effort Task (MET). During the MET, students solve 5 runs of 10 arithmetic problems with a difficulty level of their own choice. After the MET, helplessness attributions are measured to investigate whether individuals attribute their mistakes towards an uncontrollable/external cause. Preliminary results (N = 17) showed no significant correlations between ability beliefs and goal orientation and performance on the MET task. However, there was a significant correlation between entity beliefs and helplessness attributions after the MET ($r = .71$, $p < .001$). The opposite was found for incremental beliefs ($r = -.57$, $p = .008$). Also, individuals who reported more helplessness attributions, tended to choose lower difficulty levels, but this correlation was not significant in the preliminary analysis ($r = -.44$, $p = .078$). Further analyses are in progress to investigate the underlying (electro)physiological correlates.

# What skills predict children's understanding of causal processes?

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Children's science learning is seen as important as their development of literacy and numeracy, but the cognitive skills underpinning it are less understood. Recent research has examined the possible influence of spatial abilities, but we hypothesize that another dimension, spatiotemporal processing, is central. This allows children to envisage the transformation of one physical state into another over time, an ability we argue is core to understanding of causal processes. To test this, we employed a set of tasks addressing causal processes (prediction, description and explanation of contrasting instances of sinking, solution and capillary action) to assess children's understanding; and examined its relationship to both spatial and spatiotemporal skills in 5-6, 7-8 and 9-10 year olds (N = 107), controlling for verbal (expressive vocabulary) and non-verbal (block design) IQ. Regression analyses found the main predictors of science performance were scores on a spatiotemporal task (flow of liquid) and non-verbal IQ. However, non-verbal IQ only predicted differences at lower levels of science. Scores on a spatial task (mental rotation) similarly only predicted science in the youngest age group. In contrast, spatiotemporal ability was the sole significant predictor across all age groups and levels of science performance, including higher; and was the main difference between children who showed good grasp of causal processes and those who did not. The data indicate the capacity to visualize spatial transformations over time is a key driver in growth of causal understanding. This capacity is largely independent of language and non-verbal IQ, suggesting a unique ability in grasping causation.

# Physical activity and sedentary behavior in adolescents in vocational education and training: Compositional patterns and predicting executive performance

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Purpose: More physical activity is beneficial for executive performance, while higher levels of sedentary behavior are related to lower executive performance. Over 40% of the Dutch adolescent population is enrolled in vocational education and training (VET). Still, research regarding these relations in adolescents in VET is almost absent. It is therefore important to know whether and in which students increases in physical activity and decreases in sedentary behavior are effective.

Methods: In an observational study investigating the association between physical activity patterns and executive performance, 231 VET students from different educational tracks participated. An accelerometer was worn for one week, taped to the thigh. Executive performance was measured at the end of the week using digital versions of the Color Shape Test and the Letter Memory Test, from which shifting, inhibition, and updating were derived. Linear regression models were used on multilevel data.

Results: The data of the accelerometers have been fully processed and also all executive performance data have been processed. The analyses will be completed before the end of February 2018.

Conclusions: It is hypothesized that differential compositional patterns regarding physical activity exist for VET-students, at least when it comes to their chosen educational track. It is expected that students from sports or security tracks will be highly active when compared to students from administrative track and that students from health care tracks will be in between. In addition, it is expected that students who are more physically active and less sedentary will have the highest executive performance.

# Reconsolidation of memory: The case of learning a foreign language

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Reconsolidation is a cognitive process, which occurs after the retrieval and reactivation of long term memory. Reactivation returns memories to a labile state, which allows them to change and then reconsolidate the memory in long term. The aim of this study was to examine whether there is evidence of reconsolidation in declarative memory in learning English as a Foreign Language (EFL) in the classroom. Fourth grade pupils in elementary school learned vocabulary in context from the curriculum. The experimental group learned a list of words, were tested and after two days, these words were reviewed (retrieval) and an additional set of words were taught. Two days later, the level of recall of the first list of words was checked and two months later as well. A two-way repeated measures ANOVA showed that there was no difference between the first and the second measurements. However, when retested after two months, there was a significant decrease in the level of recall of the first list. These results differ from the two control groups, in the first group no retrieval took place thus there was no reconsolidation after the retrieval, whereas in the second control group the first list of words was retrieved without learning a second list of new words.
These results have important theoretical and pedagogical implications. First, there is evidence to show that reconsolidation does take place, and second, the process is sensitive to interference. The significance of this research demands teaching-learning planning to address these brain processes.

# The effect of classroom noise on creativity in primary school children

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During a school day, pupils are exposed to 72dB of noise on average (Shield & Dockrell, 2004). Following adult findings (Mehta, Zhu & Cheema, 2012), we investigated whether classroom noise promotes children's creativity. To better understand the mechanisms behind noise effects, we assessed the relationships between executive functions (working memory, attentional control) and creativity performance in silence and noise.

Forty-four children (from 4.92 to 11.33 years-old; M = 8.17) were prompted to find unusual uses for a pencil/bottle (AUT) and to suggest consequences of two imaginary situations (JS). Each pupil performed these creativity tasks in silence, and under 65dB of classroom noise. The number of ideas and their originality were measured. Attentional control, visuospatial and verbal working memory were assessed in silence.

Noise selectively impaired the originality, but not the number of ideas given by pupils. There were no significant correlations between executive functions and creativity scores in silence. However, when children performed the AUT under noise, better attentional control was associated with a higher number of ideas, and higher visuospatial working memory with more original answers.

To summarize, multi-talker noise seems to affect children's and adults' creativity differently.

# Learning by moving: Unraveling the mechanisms of physical activity's effect on cognition by examining functional changes in the brain

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Physical activity is positively related to cognition and academic achievement. Two types of mechanisms try to explain this relation, both referring to underlying changes in the brain. Cognitive stimulation mechanisms state that cognitively demanding physical activity activates the same brain regions as those used for higher-order cognitive processes, leading to more efficient recruitment during cognitive tasks. Physiological mechanisms assume that physical activity results in changes in brain structure and function, which consequently aid cognition. The exact mechanisms remain unclear. Therefore, the present study examines whether two types of physical activity (related to the mechanisms described above) lead to enhanced academic performance in primary school students, and whether this relation can be explained by functional changes in the brain. Two 14-week physical activity interventions were implemented at 22 primary schools: one focusing on moderate-to-vigorous physical activity (physiological mechanism), the other on complex-coordinative physical activity (learning/developmental mechanism). Eight-hundred-sixty-five students took part in a cluster randomized controlled trial, of which a subsample of 90 children participated in a MRI protocol. Before and after the intervention, functional magnetic resonance imaging data was acquired during a visuospatial working memory task. Changes in brain activity in the intervention groups will be related to intervention effects on academic achievement to see whether 1) physical activity improves academic achievement via functional changes in brain areas supporting executive functioning and b) whether different types of physical activity improve achievement via different mechanisms. These results will be useful for the design of physical activity interventions aiming to improve cognitive performance.

# Tailoring the individual learning experience to primary school children

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Adaptive educational games provide a way to tailor the individual learning experience, enhancing children's motivation and engagement. Current online learning systems allow adaptive exercises and instruction to the ability level of the child. Two important aspects can be extended to this approach: Firstly, adapt the exercises and instruction to the individual differences in student's learning; Secondly, adapt feedback and instruction to the task-specific strategies used and type of errors made by children. Personalised instruction and feedback require inferring the perceptual and cognitive processes during the games, which is usually based on reaction times and accuracies obtained from discrete responses. Eye- and mouse tracking enable us to measure above and beyond this discrete form of thought representation and capture how multiple internal states evolve over time and how these processes interact.

In this project, we use eye-, mouse- and facial features tracking with 8- to 10-year-olds in games requiring multiplication, addition, inhibitory control and working memory. Analyses will focus on whether and how the task-specific errors, the level of executive functioning and used strategies are linked to where children look on the screen and where their mouse moves. Additionally, we look at ways to monitor the level of engagement during the games through facial feature detection. With these advanced analyses, we aim to get a better understanding of online reasoning and strategy use and develop novel approaches to tailoring the instruction and feedback to every child's unique needs.

# Constructivist against direct instruction approaches to teaching: Empirical evidence from a study exploring the effects of different learning environments on primary school students' decision-making competence

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A long standing debate in educational and psychological research is the effectiveness of constructivist teaching methods over direct instruction. One of the main arguments against constructivist teaching techniques is based on the upgrade of our knowledge on information-processing system – human cognitive architecture. Current findings about human cognitive architecture provide evidence that direct instruction is significantly more efficient than discovery learning ('minimal guidance during instruction') in teaching scientific concepts and processes. However, some of the critiques on direct instruction advocates concern important aspects of schooling that have been left out from their approach such as how to motivate students, how to attend to the social contexts of the instruction and how to support the development of more broad schooling purposed such as produce scientifically informed citizens. The focus of the present study is to explore different ways of training late primary school children to make informed decisions on socio-scientific issues that involve scientific knowledge and affect their local community and the society in general. The main research aim is to identify which learning environment is superior and establish some of the factors that predict the efficacy of one type of instruction over the others (e.g. previous content knowledge on the subject matter, previous decision-making skills, academic achievement, gender). An experimental pre-test post-test design with three learning conditions (explicit instruction, guided discovery and unguided discovery) and whole-class interventions was adopted. The sample consisted of 180 11-year-old students from four primary schools in central Greece. Preliminary findings will be presented.

# Cognitive neuroscience in the classroom: relationship between education and neuroscience in Italy

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There is a growing interest in basing educational decisions and practices on empiric evidence. Past studies have shown that teachers are keen to reap the benefits of neuroscience. Nevertheless, literature regarding these aspects in Italy is absent. For this reason, we interviewed 207 Italian teachers about neuromyths repeating the Howard-Jones (2009) survey. Subjects were working in Kindergarten (3-6 years), Primary School (6-11), Middle School (11-14), upper Secondary School (14-19). Results are consistent with international data.
In order to verify the influence of the method on the results, a further online survey was conducted with the same sample. In this new survey, a contrastive method was used instead of a correlational one. Questions investigated applied knowledge in general, linguistic and numerical cognition. The purpose was to investigate the correlations between the goodness of the performance and: a) personal data b) explicit evaluations on neuroscience c) the influence of neuromyths.
Teachers showed high level of interest in neuroscientific contents but it did not correlate to the performance. However, neuromyths did not lure answers and gathered lower approval, as compared to the correlational surveys. Significant differences in the different levels of the sample did not emerge. Although neuromyths were not chosen too much, it emerged that many teachers asked for a higher training in neuroscience education, and this was confirmed by their implicit performance. This research turns out to be the first benchmark in Italy regarding the relationship between education and neuroscience.

# Learning to play a videogame: The effects of in-game tutorials on players' affect and cognition

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Learning involves cognitive and affective processes unfolding moment by moment over the entire activity. However, traditional data such as observations and self-report measures are not sufficient to accurately model how cognition and affect unfold in time. To fully explain the requirements for a successful learning episode, ways to measure and link those processes over time are needed, accompanied by an appropriate modeling of a dynamic learning context. The goal of this presentation is to show how in-game tutorials modulate aspects of players' affect (e.g. arousal, valence) and cognition (e.g. cognitive load, cognitive engagement) during an initial episode of play with a video game, which aims at learning the game's core mechanics.

Thirty-five undergraduate students familiar with the first-person shooter genre played FarCry PrimalTM for 90 minutes. Psychophysiological measures involved 96-channel electroencephalography, electrodermal activity, eye-tracking and a close-up video of the participant's face capturing facial expressions of emotions. After playing, participants were administered a self-report questionnaire regarding their motivation, engagement, and learning of game mechanics.

Results suggest that on most occasions, tutorials and prompts represent an additional burden on cognitive processing while playing the game . In circumstances when the player should switch from "business as usual" to a "careful monitoring" mode, prompts can help support players' adaptation to various contexts. The effect of tutorials and prompts on players' excitement are dependent on the context.

This characterization of learning as the dynamic interplay of affect and cognition in a changing context could inform the design of multiple contexts of learning.

# Spaced learning: An approach to minimize the forgetting curve, or much more?

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Background - While the forgetting curve is considered by cognitive psychology as a major obstacle to the learning process, repeated retrievals and spacing are found to be very effective for preserving the consolidation process. Though much study has been done in the laboratory, there is a lack of knowledge about how spaced learning pedagogy relates to cognitive abilities or to higher order levels of thinking in field studies.

The aim of this study was to investigate the novel pedagogy of spaced learning in higher education. Determining whether connections existed between students' cognitive skills and memory enhancement, and whether such connections helped students conceptualize science material was most important.

Method - 176 college students participated. The control group studied two lessons using massive teaching, while the study group was taught the same subject in a single-spaced learning lesson. At weeks 1 and 4, after the lessons, participants' memory and high order thinking were evaluated by tests that included recognition and recall questions. Academic data, personality profiling, and metacognitive evaluations were conducted for each student.

Results - In addition to timesaving benefits, as opposed to massive learning, spaced learning was significantly more beneficial for higher order thinking that requires creativity or synthesis of new concepts. Moreover, the study group showed greater accuracy in higher order recall questions in the week 4 testing, especially those students with high psychometric abilities.

Conclusion - spaced learning can be used as a teaching strategy to enhance higher-order thinking, especially for students with high psychometric abilities.