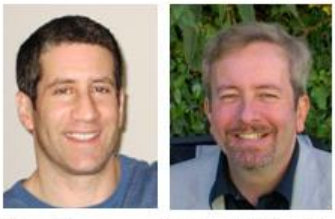
Temporal Dynamics of Learning Center

NSF Highlights 2013-2014

Personalized Review Improves Students' Long-Term Knowledge Retention



(Mike Mozer and Harold Pashler)

Outcome:
A software tool that provides individualized review of course material to middle-school students produces a 16.5% boost in retention of complete course content one month after the term's end, relative to current educational practice. Individualized review also leads to a 10% improvement over a more generic one-size-fits-all review strategy.

Impact/benefit:
A study by researchers in the Temporal Dynamics of Learning Center demonstrates that integrating adaptive, personalized software into the classroom is practical and yields appreciable improvements in long-term educational outcomes. The software addresses a problem that hasn't been tackled systematically—the fragility of newly acquired information and the curse of forgetting. The software is complementary to in-class instruction, and it allows educators to do what they do well: Introduce new material, explain new concepts, and encourage students toward achieving initial mastery. The review software aims to ensure the durability of this momentary understanding.

Background/explanation:
Human memory is imperfect. Periodic review is required for the long-term preservation of knowledge and skills. However, students at every educational level are challenged by an ever-growing amount of material to review and an ongoing imperative to master new material. To address these challenges, researchers developed an adaptive method for personalizing study that combines "big data" techniques for inferring individual differences with a psychological theory of memory. This statistical approach leverages data from a population of students studying a variety of material to infer the dynamic knowledge state of an individual student for specific material. The method was incorporated into a semester-long middle school foreign language course via retrieval-practice software which was used for about 30 minutes per week. The software provided a means of comparing the personalized review strategy with two alternative strategies. This comparison was performed by partitioning the material each student learned into thirds, each scheduled by a different strategy and matched for the number of review trials.

Lindsey, R. V., Shroyer, J. D., Pashler, H., & Mozer, M. C. (2014). Improving student's long-term knowledge retention with personalized review. *Psychological Science*, *25*, 639-647. doi: 10.1177/0956797613504302.

Face Perception

Outcome: TDLC's Kao-Wei Chua, Jennifer Richler and Isabel Gauthier from Vanderbilt University have discovered that the special strategy used to look at faces can be altered in just a few hours of training. Decades of research show that faces are processed more holistically (as wholes rather than simply the sum of their parts) than other objects, a strategy often thought to be quite automatic, even in children younger than 5 years old. The new research suggests that this strategy is due to attentional mechanisms that can be unlearned for an artificial race in less than 3 hours of a part-based attentional training. In addition, a follow-up study found that this holistic strategy can also be learned from scratch for novel non-face objects within the same timeframe.

Impact/benefit: Holistic processing is a hallmark of expert perception. In contrast, individuals with problems in face perception, such as people with autism, can show reduced or abnormal holistic processing. This research is helpful because it can provide a model for these problems. The specific manner in which normal participants processed faces after the part-based attentional training was strikingly similar to the way people with autism processed faces in prior work. The research also suggests that perceptual strategies for faces and objects may be more malleable than previously thought, which is encouraging for the development of treatments for visual recognition deficits.

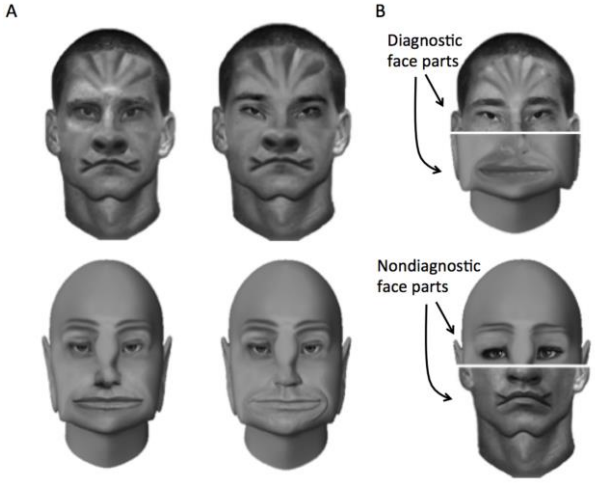


Figure. A) two Tayios that differ only in their top halves and two Lunaris that differ only in their bottom halves, used during training. B) at test, cross-race composites are new faces made of parts similar to those that were diagnostic or non-diagnostic during training.

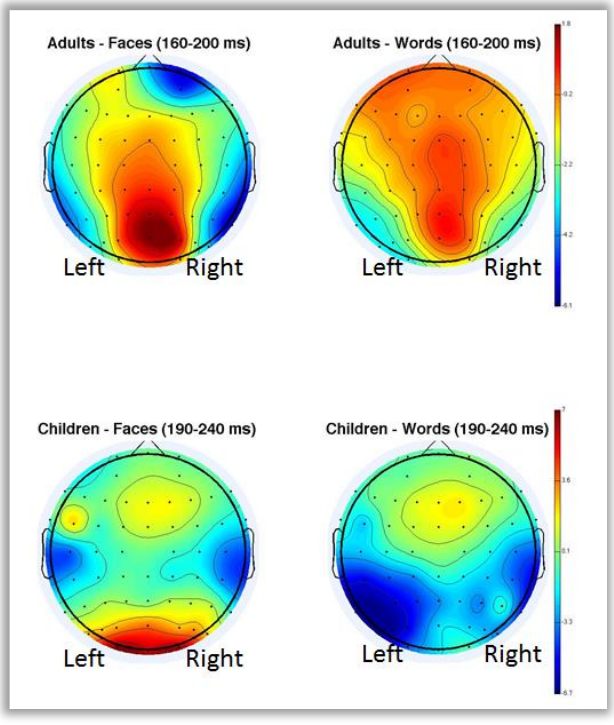
Explanation: To teach participants how to attend to faces of novel races (see Figure), the researchers asked them to learn the names of individuals whose faces differed only on the top or only the bottom. At test, holistic processing was measured in a composite task and was only found for composites made of parts similar to those that were helpful (or diagnostic) during training.

Chua, K. W., Richler, J. J., & Gauthier, I. (2014). Becoming a Lunari or Taiyo Expert: Learned Attention to Parts Drives Holistic Processing of Faces, Journal of experimental psychology: Human Perception and Perception. doi:10.1037/a0035895

Chua, K. W., Richler, J. J., & Gauthier, I. (2014). Does acquisition of holistic processing for novel objects depend on experience with diagnostic parts? To be presented at the annual meeting of the Vision Science Society.

Neural Systems for the Visual Processing of Words and Faces

Outcome:



Using behavioral and electrophysiological measures, in adults, Eva Dundas, David Plaut, and Marlene Behrmann observed the standard finding of greater accuracy and a larger N170 ERP component in the left over right hemisphere for words, and conversely, greater accuracy and a larger N170 in the right over the left hemisphere for faces. We also found that, although children aged 7-11 years revealed the adult hemispheric pattern for words, they showed neither a behavioral nor a neural hemispheric superiority for faces. Of particular interest, the magnitude of their N170 for faces in the right hemisphere was related to that of the N170 for words in their left hemisphere. Additionally, the mean gamma-band power in the N170 time range for faces in their RH was correlated with that for words in their LH. This result is really surprising, as one might have predicted that the mature brain organization would be evident earlier with faces (with which even young kids have a lot of experience) than with words. Our findings show the opposite, and the explanation is that it is only once children begin to read that the pressure for more organized brain function (for complex visual stimuli such as words and faces) begins. The acquisition of word recognition serves as the trigger for the brain to begin a reorganization that brings it to its adult-like profile.

Impact/benefits:

These findings suggest that the hemispheric organization of face and word recognition do not develop independently, and that word lateralization may precede and drive later face lateralization. A theoretical account for the findings, in which competition for visual representations unfolds over the course of development, is discussed. A paper describing these results is under review for publication.

Explanation:

This past year, the major project concerned the emergence, over developmental time, of the apparently specialized and independent neural systems for the visual processing of words and faces. Extensive evidence has demonstrated greater selectivity for written words in the left over right hemisphere, and, conversely, greater selectivity for faces in the right over left hemisphere. This research examines the emergence of these complementary neural profiles, as well as a possible relationship between them.

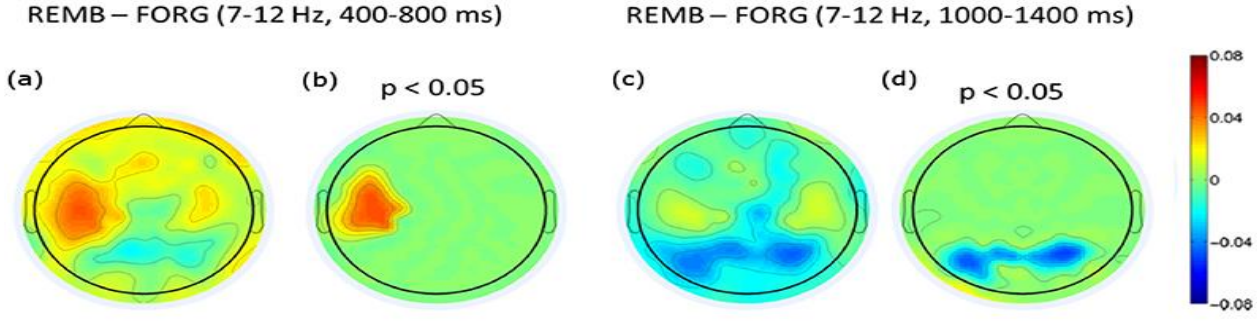
Dundas, E, M., Plaut, D. C. and Behrmann, M. (in press). An ERP investigation of the co-development of hemispheric lateralization of face and word recognition. *Neuropsychologia*.

Improving Memory Using Real-Time EEG and Spacing Analysis

Outcome: TDLC's Eunho Noh and Virginia de Sa at the University of California, San Diego and Grit Herzmann and Tim Curran at the University of Colorado, Boulder have found that they can predict (with above chance accuracy) whether someone will remember an upcoming picture from the voltage recorded at the scalp (electroencephalography (EEG)) prior to the picture presentation. The prediction can be improved, if EEG during picture presentation is also used.

Impact/benefits: This result could be used to develop improved study systems that monitor the user's brain state and present items to be memorized during predicted "good" brain states. Items that were not deemed well-encoded according to EEG measurements during presentation of the item, could be presented again. Finally extensive use of this system may lead to users becoming better able to get into attentive brain states that are good for encoding information. This may be the best benefit of all.

Background/Explanation: The system looks at both the temporal waveform of the EEG (voltage) signal during encoding and also the power in different frequency bands prior to item presentation and during encoding. Further analysis shows that the different frequency bands in the signal before the item is presented differentially predict whether the context will be remembered with the item. The higher frequency content (from 25-35Hz) of the EEG signal before item presentation distinguishes between recollection (remembering the item and the context) and familiarity (remembering the item without the context). Similarly the temporal signal in the later period (1-1.4 seconds after item presentation) distinguishes between recollection and familiarity while an earlier period (.4-.8 seconds after presentation) does not.



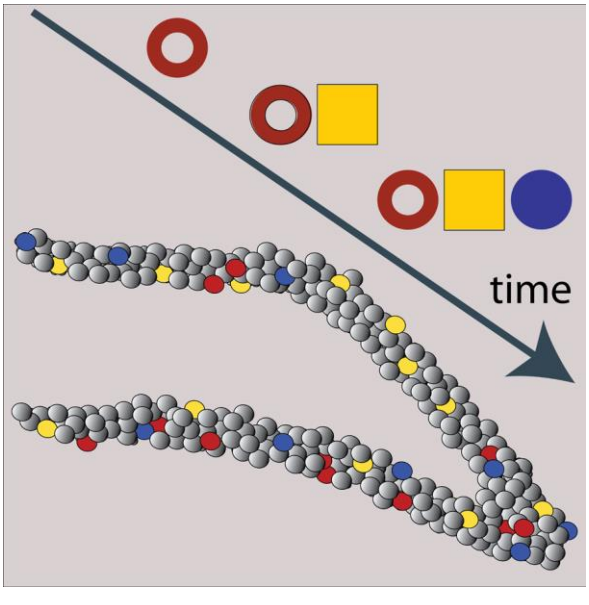
This figure shows the difference in power in the 7-12Hz frequency band for the pictures that were remembered vs. those that were forgotten. The power difference is shown for two different time windows - from .4 to .8 seconds after picture presentation ((a) and (b)) and from 1 to 1.4 seconds after picture presentation ((c) and (d)). The thick black lines show a stylistic head to reflect the location of the power differences. Parts (b) and (d) show the most significant cluster resulting from a cluster-based statistical analysis across all subjects.

Noh, E., Herzmann, G., Curran, T. & de Sa, V.R. (2014). Using Single-trial EEG to Predict and Analyze Subsequent Memory. *Neuroimage,* 84(1):712-723.

Temporal Coding in the Dentate Gyrus

Outcome: TDLC's Lara Rangel, Andrew Alexander, Brad Aimone, Janet Wiles, Rusty Gage, Andrea Chiba, and Laleh Quinn have discovered that granule cells in the dentate gyrus of the hippocampus encode the temporal separation between experiences that occur over long periods of time. Working from a model developed by Aimone, Wiles, and Gage, they tested the hypothesis that the continual addition of newborn neurons in the adult dentate gyrus enables the temporal tagging of memories. They showed that both the length of time between experiences and the levels of adult neurogenesis during the different experiences affected the ability of neurons in the dentate gyrus to exhibit activity selective to a given experience. It was previously unknown that the dentate gyrus could temporally distinguish between experiences in this manner. Their data reveal the existence of a *temporal* orthogonalizing neuronal code within the dentate gyrus, a hallmark feature of episodic memory.

Impact/benefit: Episodic memory requires the ability to distinguish events that are experienced at different times, in other words, knowing what happened when. This data indicates that the addition of new neurons into the adult dentate gyrus is an important component of temporally encoding experiences. Thus, facilitating neurogenesis could have benefits for episodic memory formation. Many things impact the ability to form and sustain new neurons in adulthood including exercise, environmental enrichment, and diet. It is now known that adult neurogenesis can continue throughout our lifespan, even into old age. If steps are taken to increase the chance of creation and survival of new neurons, deficits in episodic memory that occur with aging and other disorders may be alleviated.



Explanation: A recent model of the hippocampus by Aimone et al. predicted that the unique properties of the dentate gyrus allow for the temporal separation of events. According to their hypothesis, this temporal separation is accomplished in part through the continual generation of new neurons, which, due to a transient window of hyperexcitability, allows for preferential encoding of information present during their development. Rangel et al used *in vivo* electrophysiological recordings to test their prediction and identified a cell population exhibiting activity that was selective to single behavioral contexts when rats experienced a long temporal separation between context exposures during training. This selectivity was attenuated as the temporal separation between context exposures was shortened. To test the contribution of newborn neurons to context selectivity, temozolomide (a chemotherapeutic agent that kills dividing cells) was utilized to knockdown neurogenesis. Selectivity was further attenuated when neurogenesis was reduced in this manner.

Rangel LM, Alexander AS, Aimone JB, Wiles J, Gage FH, Chiba AA, Quinn LK. Temporally selective contextual encoding in the dentate gyrus of the hippocampus. *Nat Commun*. 2014;5:3181. doi: 10.1038/ncomms4181.