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**SCIENCE BRIEF**

# Visual attention: Its role in memory and development

**New research on how infants and children orient to their environment.**

By Dima Amso, PhD (http://www.apa.org/search.aspx?query=&fq=ContributorFilt:%22Amso, Dima%22&sort=ContentDateSort desc)

Dima Amso is an associate professor in the department of cognitive, linguistic and psychological sciences at Brown University. She has a BS in psychology from Tufts University, was trained at Cornell University and received a PhD in psychology from New York University in 2005. She then joined the faculty at the Weil Medical College of Cornell University. Amso has been at Brown University since 2010. Her research examines the development of attention and memory in typically and atypically developing populations, with an emphasis on how environmental variables shape these trajectories. Amso's research has been funded by the National Institute of Mental Health, the National Institute of General Medical Sciences and the Brown Institute for Brain Science, and she is a recipient of the James S. McDonnell Scholar Award. She serves on the editorial boards of three international journals. Author website (http://www.brown.edu/Departments/CLPS/people/dima-amso) .

An infant stares intently at her mother's face, as if memorizing its details. She reacts with laughter just when dad walks in the room. She closely tracks her sibling as he runs around at play. This lumbering, slumbering, nonspeaking person is present, attending and learning at a rate that is perhaps unmatched at any other point in her lifetime. In my lab, we study the behavioral and neural processes that are the cornerstones of such an infant's developmental journey.

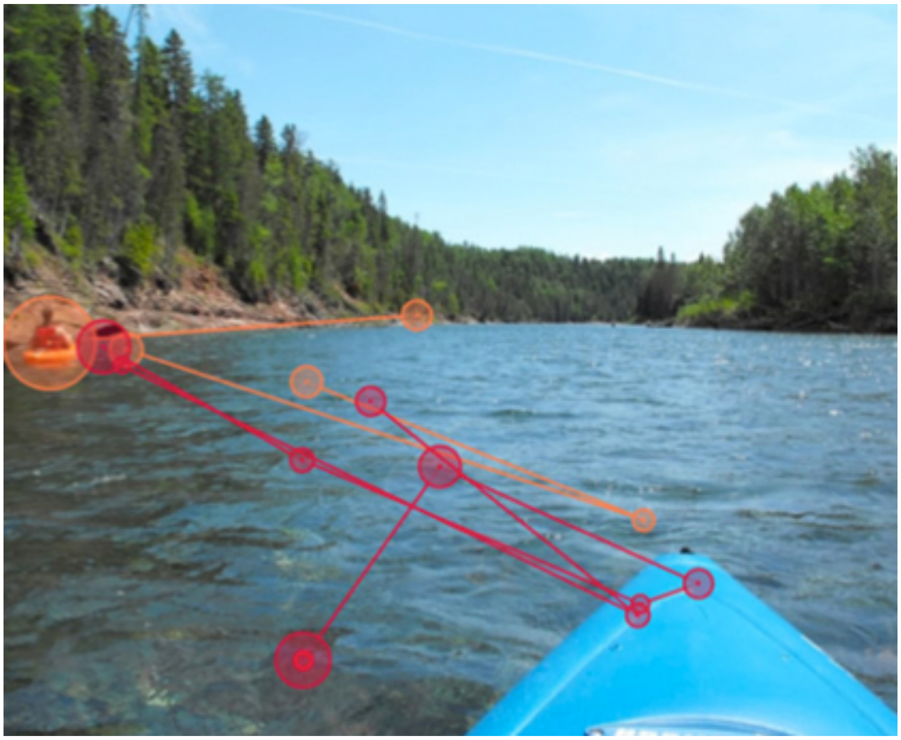
With my colleagues at Brown University, we study developmental processes including attention, memory and cognitive control from infancy through adulthood. Our approach is interdisciplinary, incorporating theories and methods from neuroscience, cognitive science, psychology, genetics and public health. Our tools include computational modeling, eye tracking, near infrared spectroscopy in infants, functional magnetic resonance imagining in children and adolescents, and genetic and socio-demographic data collection in large samples. This brief piece is focused on our work on the development of visual attention.

## Attention Development

The broad term "attention" describes a set of different but related processes, including visual attention orienting, auditory attention, executive attention, covert attention, etc. The work discussed here examines the mechanisms of visual attention orienting to a select location in space, beginning in infancy. Visual attention orienting is one of the earliest means of exploration available to human infants. Coordinated looking is an excellent source of information about their world before infants learn to walk, speak and grasp.

Visual attention orienting can be captured by external environmental stimuli and can also be driven by our own internal goals or plans. For example, imagine a photograph of a salient bright orange sunset superimposed on an otherwise black and white landscape. Upon seeing the image, we are likely to immediately orient our attention to the sunset based on its color. Alternatively, attention orienting can be volitional. We often intentionally look for a parent by searching every face in the crowd until she or he is located. These two forms of visual attention orienting have different developmental trajectories in the first year and beyond.

Our work has shown that attention to salient locations in scenes (i.e., the sunset in the photograph) develops during the first postnatal year and stabilizes soon after (Amso, Markant & Haas, 2014). We eye tracked participants age 4 months to 24 years as they scanned photographs of people in cluttered natural environments. In half of these, the face was the visually salient location in the image, while in the other half of the displays, the face was not the most salient location in the image. We examined where participants oriented their first several eye movements. We found that attention to faces in clutter increased over the first year and that it was not until after the first year that infants and children began to attend to the salient faces above and beyond the nonsalient faces. Given that the stimulus of interest (faces) was the same across both sets of images, we interpret this to mean that visual attention orienting that is driven by the visual features of the external world does not stabilize until the second year of life.



An example of an eye-tracking data while a child scans a natural scene on a computer display. The lines represent the participant's eye movements from one location to another and the circles represent fixations at each location.

My colleagues and I are concerned with what the agents of this developmental change might be. Our work suggests the possibility is that this developmental trajectory is intertwined with the development of vision (Amso, Markant & Haas 2014; Amso & Scerif, 2015). The processing of color, motion and depth cues also develops in the first postnatal year. Attenuated visual processing early in infancy, e.g., poor color vision, may result in differences in how attention orienting is allocated in younger versus older infants. As an analogy, a color-blind adult would not look at the sunset in the black and white photo as quickly as would someone with typical color vision would. Thus, developments in vision may be important building blocks in visual attention development.

Our data indicate that during natural exploration in infancy, changes in vision and their impact on visual attention may guide infants to look at parts of the world that do not always match what adult caregivers are attending to. This mismatch may seem counterproductive. Why would our brains be built in this way so early in life, when optimal interaction with caregivers is critical to healthy social development? We offer here the speculation that the benefit of the immaturity in the infant visual system may be that it forces infants to rely on caregivers' direction, and it forces caregivers to direct infants' attention to objects or events of the caregivers' choice. Of course, this also means that attention is directed to caregivers' faces, as they provide information, emotional support or label objects with names. In support of this hypothesis, we found that socio-demographic factors, including number of siblings in the home, were predictors of developmental change in orienting to faces in otherwise cluttered natural scenes in infancy (Amso, Markant & Haas, 2014). In this way, infants may be both learning about the world and also that people are an important part of it. Adults naturally work to attract infants' attention with loud voices, motherese, extreme gestures and bright colorful toys with a lot of contrast. In a sense, these attention hacks are obviating the need for an adult-like attentional mechanism.

These findings have implications for both typical and atypical development. In a different study using the same natural scenes with 3-5 year-olds with autism spectrum disorders (ASDs) and age- and sex-matched typically developing (TD) children (Amso, Haas, Tenenbaum, Markant & Sheinkopf, 2014) we found that children with ASDs outperform matched TD children on our visual attention orienting task, in that they relied more on external salient visual features of the world to guide visual attention orienting. In future work, we will examine how early in development this difference in orienting emerges in infants at high familial risk for ASDs, and whether this more mature pattern disrupts the need for the attention hacks adult caregivers use to guide infants visual orienting early in life.

## Attention and Memory

The study of attention is made particularly important by the fact that its development has been linked to learning and memory. Memories are units of experience that over time accumulate to build robust and intricate knowledge structures. We have shown in multiple studies that where infants attend determines what they see, learn and remember (e.g., Amso & Johnson, 2006). More recently, work in my lab by former postdoc Julie Markant (now assistant professor at Tulane University) showed that the development of inhibitory processes during attention orienting, which begin to develop as early as 4 months, is an important variable in how well information is encoded for later recognition memory.

A great deal of information is learned simply by orienting, or looking around cluttered spaces. As infants move their eyes from one location to the next, any information carried over from the previously attended location has the potential to distract from learning what one is currently attending to. Our work in infants as early as 4 months of age shows that the ability to suppress this distraction during eye movement sequences is important for learning and memory for information at the currently attended location (Markant & Amso, 2013; Markant & Amso, 2015). Moreover, using fMRI in adults, we showed that cortical activity representing both attentional enhancement at the currently attended location and suppression of the previously attended location, correlated with recognition memory for learned images in a subsequent memory task (Markant, Worden & Amso, 2015). The upshot of these studies is that paying attention helps us learn as early as in infancy. Hypothetically, this attentional bootstraping of memory may serve as an important education or intervention tool.

We found indirect support for this hypothesis in a study of children 7-17 years of age on our attention/memory task (Markant & Amso, 2014). Specifically, we found that individuals with lower IQs have poorer recognition memories. However, the dynamics of attention, and whether we elicited inhibition of the previously attended location during visual attention orienting to target images for incidental encoding into memory, was found to mitigate the affects of individual differences in IQ on memory performance. That is, only when inhibitory attention orienting processes are engaged during encoding, did individuals with lower IQs perform similarly on the subsequent recognition memory task to their higher IQ counterparts. This exciting finding may have important implications for education and training programs designed to improve memory performance moving forward. Instead of training memory per se, it may pay to train focused attention instead.

## Conclusions and Future Directions

To date, our work has been predominantly laboratory based. However, visual attention, learning and memory are all happening in nature. Recent developments in large-scale digital data collection are making it possible to obtain precise measurements from infants and children engaging, playing and socializing in their natural habitats. We have built a space in our lab at Brown University, in collaboration with Profs. Kevin Bath and Thomas Serre, which is wired with cameras to capture children at all angles. Infants and children wear portable eye trackers and devices for collection of heart-rate data and galvanic skin response and for linguistic recording. The short-term goal is to capture subtle patterns of behavior that give us information about the physiology, environmental variables and dynamics of attention orienting in the wild and during development. The longer-term goal is to combine these measurements with big data tools, including computational vision and machine learning, to automate the coding of human behavior. This approach has the benefit of reducing the human bias and burden in management of large data sets involving human behavior in real time. It also has the benefit of allowing scientists to discover which patterns of behavior are most predictive of optimal and sub-optimal outcomes in both typical and atypical populations.

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