Cognitive Media: Understanding the Brain, Technology, and Autism

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Published online: January 2011
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Abstract Throughout life the environment that surrounds an individual works in tandem with elements of their physical ability, acting on the development of perception and thought. Like a lens, each individuals' circumstance, or *perspective bias*, colors their personal understanding of the world. These influences shape both what is learned, and what elements of that learning may be shared with others. These "lenses" change over time, often unpredictably, and are essential in defining how individuals grow and progress over the course of life. In autistic persons, exceptional biases produce an often dramatic dichotomy between ability and disability, an understanding of which offers significant insight into the limits of the human mind at a fundamental level. This literature review explores the ecosystem of this effect, from current research of the neurological foundations of learning and expression, through the advancing fronts of digital media that continue to redefine expression and literacy.

Keywords Autism spectrum disorders • Digital media • Neuropsychology • Social cognition • Social media • Augmentative and communication applications • Touch-based computing

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Milestones in informative artifacts, such as the advent of written language, have introduced new cultural and social dynamics to the human race. From the womb to the grave, the things that we are close to, that we experience conversantly, contribute continually in defining who we are as individuals (Myers, 2008). As more becomes virtual, augmented through digital technology, new media have an increasing impact on personal thought and expression (Schniederman Et Al., 2006). These shifting information platforms also accompany new modes of interpersonal development, challenging the relative boundaries and assumptions of cognitive ability and disability. Building on our genetics, our exposure to richer environments and peers elaborate not only our personal potential, but act deeply on the cultivation of our in-born humanity (Bandura, 1986). When these processes break down, as in the socio-cognitive disabilities of autism spectrum disorders, we see that they reflect the core of our behavior, touching the patterns of our neurons and the very architecture of our brains.

In a literal sense, the most singular driving force behind the advance of media is the human ability to learn. Studies demonstrate that consistent, informative stimulation produces complexity of behavior and thought. As we learn a new skill, the focus and repetitions of practice encourage neural structures within our brains to increase in both complexity and size (Ardila & Bernal, 2007). However, the corollary is also true: the breadth and detail of our perceptions are dependent on the specifics of our neural ability. The same practice that allows the violinist to play well, gives that musician the ability to perceive details of pitch and rhythm beyond other's comprehension. Consistent across disciplines, learning reflects a tightly integrated, more extensive recruitment of neural area and complexity within the brain. This growth, while expanding expressive capacity, also implies the development of a more detailed perceptive ability.

When considering the net effect of this principle, the processes of *social cognition* embody cognitive growth through the interpersonal connections within our culture (Gooding, 2006). Driven by the desire to understand, and share that understanding with others, we engage in the production and exchange of many forms of representation. This exchange not only carries individuals' messages, but engages a process of collective cognitive sophistication.

Tools such as games, written language, art, and now digital media, allow us to experience other ways of thinking, in effect advancing the sophistication of each others' neural structures.

Even in the most rigorous of applications, the representations that we create continue to project elements of our cultural and personal biases. For those with autism spectrum disorders (ASD), who vary more widely in how they use their brains to process information (Muller Et. Al., 2004), these biases are significant enough to prevent ease of communication. Compensating for a pervasive deficit, these individuals seem to adapt by applying a wider palette of cognitive structure to essential tasks such as motor coordination and visual perception, in the same process becoming more attuned to detail and specificity. Through this, autistic minds may be born into more specialized whole brain patterns of association and thought essential to creative transformation (Wolman, 2010; Csikszentmihalyi, 1997). While at times problematic regarding an individual's integration into society, these differences hint at a profoundly innovative influence in the evolution of human communication.

Considering the millions of persons affected by some form of autism disorder, and growing rates of diagnosis to nearly one in a hundred children (CDC), the role and impact of ASDs increasingly factor into the whole of how we think as a culture. For the profoundly autistic, about forty percent of whom develop no speech, research into the mind's inner workings may provide the understanding needed to realize new, more robust social connections. Given that the delicate interpersonal exchanges of communication and empathy engage more than eighty percent of our brains (Blue Brain Project, 2010), varying social ability, and ultimately perspective, also lie at the heart of understanding what it means to be human.

Through the work of neurologists and neuropsychologists, our current model of the brain's foundational intricacies extend to the smallest units of memory, thought, and action. To gather the fine details of how singular specialized neurons function, invasive electrode studies map how animal brains, such as a rat or macaque monkey, respond to specific stimuli in different situations. To verify these principles in a human context, functional magnetic resonance (fMRI) techniques display cognitive processes happening throughout the brain, on a scale ranging from two million neurons per unit, to about fifty thousand (Kanwisher, 2006). Newest to the field, neuroscientists are now modeling functional groups of thought-enabling neocortical neurons using supercomputer simulations (Markram, 2009). Together, studies conducted through these tools continue to break down age-old questions regarding the nature of autism spectrum disorders, how we learn, make moral judgements, respond to stress, and more.

Observing human behavior in this fresh light, it is thought that the acts of perception and action are nearly congruent (Iacoboni, 2008). Tightly interlinked across the range of senses, the acts of observing, imagining, and physically *doing* something activate the brain in nearly the same fashion. Until the early eighties, neuroscience proposed that these essential modalities were carried out separately, independently of each other. Today, we have learned that our brains are interconnected in such a way that simply glancing at a graspable object begins to unconsciously activate the appropriately corresponding grasping action (Gallese, et al: 1996). Studies show that while numerous specialized processing centers contribute many individual pieces to our plastic awareness of reality (Kanwisher, 2006), the overarching flow, and development, of perception, cognition, and action have no clear boundaries within the human brain, and may simply be conglomerates of similar neural activity in subtly different situational contexts.

In understanding how our encounters with others translate into personal understanding, the discovery of mirror neurons (MNs) provides essential clues. Originally found in about twenty percent of the motor cortex of macaque monkeys (Gallese et al, 1996), and later verified in human studies (Mukamel et al., 2010), mirror neurons automatically trigger matching responses to observed actions. In this way, the human brain mentally mirrors the movements, expressions, and behaviors of others almost as if it were committing them itself. As mirror neurons continue to fire through the duration of an action, two people who observe each other's actions share a momentarily parallel cognitive activity. This effect is highly differentiated and sensitive, responding to small changes in context, as well as multimodal visual and auditory cues in media, such as the spoken, allegorical, or written names of an action (Iacoboni, 2008).

MNs are currently believed to be integral in recognizing the fine aspects of others' behavior, such as distinguishing intention, learning from observation, and forming empathy. It has been proposed that MNs are central to how we extract meaning from nearly all forms of communication. For this reason, they have been popularly highlighted in the media, and thrust to center stage in the investigation of ASD. While several studies have attempted to identify MN's role in ASD (UCA San Diego, 2005; Dinstien, 2010; Iacaboni, 2008), conflicting results suggest that autism may not be the result of dysfunctional MNs specifically, but rather the impediment or degradation of neurons throughout the entire brain. This "noisy brain" theory of ASD correlates with observations of abnormal, individually variant mappings of basic motor skills in fMRI studies of autistic adults (Muller, Et Al., 2004). Implying that an early physiological divergence forces a developmental shift in sensorimotor structures, these theories offer concrete explanations for the characteristic functional and perceptual differences in autistic individuals.

From moment to moment, neurons adjust their behavior to adapt to changing situations. Given steady, prolonged stimulation, individual neurons can become fatigued, and are forced to cycle off. Single neurons may map to features as specific as a vertical line, while as few as two may identify a unique face (Kanwisher, 2006). This efficiency demands that our senses, and our mind in general, must remain in constant motion in order to function. For example, the human eye, even when trained on a fixed object, is lightly moving. If one were to stop this motion, recognizable elements of the scene would slowly disappear and reappear as the corresponding neurons in the visual cortex cycled off and on (Myers, 2008). It follows that the sense of boredom, or feelings of under/over-stimulation, are likely instincts that keep our minds functioning within our physical constraints. Combined with the limits of blood flow, energy production, and varying environmental challenges, we each develop characteristic attention spans as we test our individual neural give-and-take.

This neuroactivity forms the physical basis of our thoughts, feelings, and perceptions. As new experiences motivate our individual neurons to grow, they form novel patterns and pathways within our brain's neural map, or *connectome* (Seung, 2010). This dense neural network develops slowly over time, embodying the entirety of our individual knowledge, learned behaviors, language, and specialized skills. Studies show that this progress is highly dependent on the complexity and opportunity of our environment (Renner & Rosenzweig, 1987). Young rats, for example, living in a barren cage, develop smaller brains with about twenty percent fewer neural connections than those with toys and companions (Kolb & Wishaw, 2006). In humans, an enriched environment is critical. Infants, given too little adult supervision and contact, may be entirely unable to assimilate speech and basic social skills (Rutter, M., Et al, 1998). Although we are most sensitive to this level of development at an early age, our brains continue to mature throughout our lives, and require a constant level of stimulation in order to remain healthy.

Acquired neurological processes, such as those that support written language, demonstrate how behaviors interdependent with tool use may profoundly alter the structure and complexity of the human brain (Dehaine, Et Al., 2010). The ability to read and write, as observed in both children and adult learners, fundamentally reorganizes visual and auditory processing centers. Evidently continuing to develop throughout life, this enhancement of function spills out to other parts of the brain, impacting the scope and complexity of nearly every aspect of thought (Iacoboni, 2008). Even given a condition such as blindness, the human brain continues its pursuit of rich detail and complexity, repurposing visual areas to extract more detail from sound (auditory stimulation), touch (haptic stimulation), and braille reading (Ardila & Bernal, 2007). Similarly, adaptive differences in sensorimotor behavior can be seen in autistic individuals, through patterns of eye movement, as they fixate into islands of intense focus that contrast with their neurotypical peers' relative agility in observing several interrelated objects in motion (Sinha, 2009).

Through our primary senses of vision, touch, sound, and movement, we stimulate the attention-moderated patterns of perception that ultimately define the scope of our thought. Curiously, our brain takes this raw information from our senses and breaks it apart into separate streams of finely-filtered information. In the case of vision, we process form, color, texture, and motion in separate parts of our brain (Ardila & Bernal, 2007). Even more specialized centers are responsible for recognizing specific types of features, such as face, teeth, or buildings (Sacks, 2009; Kanwisher, 2006). These sensory centers, or superclusters, activate similarly for both perceptive and expressive tasks, and may spontaneously project stored impressions into conscious perception when lacking significant input for prolonged periods.

Over time, these neural *superclusters* become more complex, shifting to accommodate new impressions and ideas. As they develop, these processes become increasingly interconnected, tying directly into the core of our physical and emotional behavioral patterns. This physical level of complexity is referred to as *crystalline intelligence*, and has been shown to increase linearly over a persons lifetime (Myers, 2008). In this way intelligence can be seen as an internal increase of subtlety, while communication becomes the reciprocal, interpersonal exchange of these inner facets. That these behaviors differ in autistics significantly implicates a unique neurocognitive foundation.

Critically, this movement toward greater complexity is dependent on the stability and predictability of our immediate environment. If an individual does not feel safe or secure, or is confronted with too many unknowns, the body begins to produce a stress response. Even mild levels of stress begin to stall higher-order thought processes, which may be entirely shut down during moments of extreme duress (Lytle & Todd, 2009). While we can individually monitor and manage stress responses through physical discipline, this mental disconnect is rooted in the heart of our nervous system, and is a constant factor in processes, such as communication, that require a degree of learning.

The fundamental conflicts of autistic and neurotypical communication styles have historically generated extreme amounts of stress, which in turn discourages equitable exchange between the two demographics. For autistics this may escalate into chronic abuse, contributing to a BPD-like decompensatory maladaption of the sympathetic nervous system, largely inhibiting an individual's sense of well-being (Choi-Kain & Zimmerman, 2009). It follows that any intermediary entity or service, in order to address the apparent social divisions of autistics and others, must function to reduce frictions apparent in interpersonal interaction. In this light, many autistic individuals currently rely on internet-based communication to buffer social functions (Delphi Forums, n.d.).

For autistics who find spoken conversation difficult or impossible, written language is a vital connection with others. As with any degree of literacy, expression through the use of tools can enable an educated contribution to the cultural discourse. Some, though having little or no speech, exploit an intricately expressive written vocabulary through digital assistive devices (Lopez, 2010; Autisable, 2010). Similarly to the unique sensory connections of synesthesia, some autistic individual's personal accounts illustrate the formation of vivid, internally consistent non-verbal modes of thought and understanding (Baggs, 2007; Grandin, 2009; Tammet, 2007). Examinations of these mental processes, some coincident with savant-like ability, demonstrate a diverse faculty that continues to refine the theoretical limits of human perception.

However, the impediments of autism present a critically polarized situation, as the lack of appropriate access to assistance may limit an otherwise intelligent autistic person to reduced productivity, or abject silence. Non-verbal individuals, without assistive devices through which to assert their identity to neurotypicals, may become marginalized. Lacking speech, they may even be perceived as less-than-human, and suffer as victims of physical and emotional abuse (Baggs, nd). With calls for subsidized access to therapeutic *augmentative and communication applications* (AAC) on commercially available hand-held devices, social and political developments increasingly highlight this unique autistic link with technology (ASAN, 2010; Silberman, 2010).

Examining AAC devices in academic environments, autistic students have been shown to gain immediate benefit from multi-modal arrangements of information, such as text-based articles accompanied by representative symbols (Chen et. al., 2009). These same students displayed stable, internally consistent patterns of learning, with uniformly higher rates of visual comprehension and retention than age and intelligence matched peers with mental retardation. Notably, the autistic students also showed transient, modal behaviors, at times seeming to trade proficiency in one method of comprehension (such as text-only) for another (text-and-symbol).

When looking at the relative appeal of different forms of *electronic screen media* (ESM), autistic students also show similar affinities for the simplified forms of cartoon animations (Mineo et al, 2008). Measured reactions to different ESM formats also highlighted an elevated impact through digital interaction. Testing the relative excitement and engagement of both verbal and non-verbal children, the self-guided, spatial qualities of virtual reality simulation proved more compelling than both animated cartoons, virtual reality exercises directed by others, and detailed literal representations such as video. Consistent with studies that show neurotypical students' benefit from interactive learning situations (Mayer & Moreno, 2007), multimodal environments may be essential in addressing the predominant non-verbal modes of intelligence in autistics.

Many of these qualities expressed by autistic individuals, such as strong visual and spatial reasoning skills, seem most efficiently matched by the current development of touch-based devices. These tools, such as Apple's iPad, emphasize relationships of action and function more closely characteristic of real-world experiences. Physically-mapped screen elements respond to touch and gesture, condensing the digital environment into the concept of a window. Transitions between modal sections often mimic the turning of a page, or movement of one's head, placing the user in a series of single-pointed perspectives interrelated by simulated spatial arrangements.

Furthermore, in reaction to this new idiom, an emergent philosophy of interface design increasingly maps representations of function and information across overlapping visuospatial, symbolic, auditory, kinesthetic, and textual domains. Multimodal techniques, seen in elements such as icons that both change color and "dance" to denote urgency, facilitate comprehension across multiple learning styles and cognitive strengths (Mayer & Moreno, 2007). Together, these refinements in digital media appear to have crossed a threshold of intuitive connection with users, passively enhancing learning and communication activities. Heralded by the media as a "quiet revolution", autistic individuals have begun to use these tools to learn and communicate in new ways (Harrell, 2010).

Through the emergent social dimensions of these devices, we see phenomenon related to the devices themselves, and a subset of near-universally associated applications. Regarding the former, the practical task of providing competitive utility for the widest possible audience forms an ideal that embraces a vast users' perceptual needs (Saffer, 2009). In practice, this task represents the search for a near-universal "cognitive best-fit" that balances common denominators of perceptive and behavioral function. To the degree that tools accomplish this feat, in shared use, they provide a novel consensus between groups or individuals.

Through the processes of visual cognition, this plastic foundation of usability in digital media can be seen to function as a proxy, similarly to our inborn mirror-neuron systems, that in addition to facilitating communication, may adapt to, and consolidate, individual discrepancies in style and method of thought (Gooding, 2006). Successful applications of this functionality include social management platforms, such as Facebook and Twitter, that display live maps of one's own interpersonal environment. In practice, they create a constantly updating, personalized guide to other's actions and reactions. Paired with a mobile device, these tools may be elevated into a kind of social prosthetic that offers autistics a previously unavailable understanding of the people around them.

Together, the widespread ubiquity of applications such as these hint at media that are edging closer to the cognitive processes that they represent. That tools can provide new voices for individuals and communities further illustrates the relationship between our mediums of expression and the forms of thought that they embody, one that is growing in breadth of representation, flexibility, and efficiency. Given the sensitivity of interpersonal relationships, it is evident that these processes impact personal growth across the spectrum of ability at the neurological level. That technology increasingly mediates between dramatically different perspectives demonstrates a reciprocal exchange respective of a greater scope of human cognition. This interconnection, as shown in the intuitive utility of touch-based user interfaces, is widening our avenues of learning and expression. For those with ASD, the partnership with technology, as in access to robust assistive devices, is especially vital to the actualization of personal integrity and cultural impact.

Acknowledgements The author would like to acknowledge Carolyn Ogburn, Heather Vaughn, Karen Townsend, Scott Shepard, Sylvia van Meerten, and John Mason for their critical review and support.

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