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PERSPECTIVES

Attention in Urban and Natural Environments

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With advances in technology and increases in global urbanization, the complexity of our sensory environment has increased dramatically in the last few hundred years. However, our brains have remained essentially unchanged. The cognitive resources that support complex goal-directed behaviors operate differently in urban versus natural environments. In this short perspective, we consider how the attention system, designed for interacting with nature, is taxed by urban environments and discuss how exposure to nature may support its rejuvenation.

INTRODUCTION

The modern world presents information at a dizzying pace, yet our cognitive constraints allow us to process only a fraction of a vast array of stimuli at any given time [1]. The basic mechanisms that support our cognitive processes have not advanced anywhere near the pace of technology and urbanization [2]. As late as 1800, only 3 percent of people lived in cities [3]. Today, more than half (55 percent) of the world's population lives in urban areas and that proportion is expected to rise to 68 percent by 2050, according to a United Nations report [4]. Given that cities impact attentional functioning [1], the current and projected levels of urbanization [3,4] have import for human behavior. Nevertheless, evidence suggests that the attention-depleting effects of urban living may be offset by spending time in nature [5,6]. In this short perspective, we'll discuss attention in urban and natural settings, some consequences of depletion of limited resources on real-world behavior, and the restorative effect of nature and natural stimuli on attention and cognitive resources.

ALLOCATION OF ATTENTION

Our sensory system is constantly bombarded with information, far more than we could possibly process at once. Our attentional system is responsible for filtering incoming information and allocating limited resources to a subset of input [7]. For instance, attention is distributed in visual space according to an attentional priority map; a combination of "top-down" (observer-related) factors, such as a person's goals and expectations, and "bottom-up" (stimulus-related) factors, such as stimulus salience [7]. Properties such as luminance changes, sudden onset, and motion make visual stimuli highly salient, and therefore prioritized for selection—regardless of relevance [8,9]. Bottom-up attentional capture is effortless and automatic; in fact, effort is required to *ignore* salient input [10]. For example, imagine that you are searching for your black wool coat from a crowded guest closet after a party. Top-down attention would prioritize objects that share target characteristics (*e.g.*, dark color). Now, let's say one of the coats in the closet is neon orange and cov-

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ered with flashing sequins! Despite not matching search criteria, the bright coat would capture attention from the bottom-up [9]. Of course, noticing the sequined coat would not have interfered with your simple task; you'd just resume looking for your coat after the brief distraction. Under different circumstances, such as navigating a visually complex urban environment, or in conjunction with other tasks, distraction is more likely to interrupt the primary task [10-12].

Potential interference from distracting input is controlled by selective attention, which operates in two stages: perceptual and post-perceptual. In the first stage, perceptual resources are focused and spatial attention narrowed; in the second stage, distractors are blocked by cognitive control mechanisms [13]. Selective attention in the later stage is affected by stimulus salience and response interference, which are managed by limited-capacity cognitive processes. Evidence suggests that selection at the perceptual level is affected by perceptual and cognitive factors; according to the dual-control model, perceptual resources are more focused under high perceptual load— but *less* focused under high cognitive load [13]. Perceptual errors are more likely to occur in situations that are cognitively demanding. The ability to successfully disregard interference, at the perceptual and post-perceptual levels, is therefore dependent on limited-capacity cognitive control resources [13]. The attentional priority map is maintained by the same limited resources; thus, under high cognitive load, allocation of visual attention may return attention to a stimulus-driven (bottom-up) default [14].

ATTENTION IN URBAN ENVIRONMENTS

In a city, even relatively simple tasks are cognitively taxing. Let's consider another visual search-type task. This time, you're a pedestrian trying to locate a particular street intersection during midday traffic [15]. Top-down attention will prioritize goal-relevant information. But wait—you're on foot, and the visual space is full of static and moving objects—this means multiple goals, which changes the scope of what is "relevant." The street signs that indicate the intersection— your target—are relevant to your search. But, other input in the search space, despite not meeting search criteria, may be relevant; for instance, crossing signals are important for safe navigation. The street signs and signals would probably appear overhead. But, if you only attend to that spatial location, you might trip over a fire hydrant! Along with static obstacles, you'd need to be aware of other pedestrians, bikes, strollers, etc. Of course, you're in a city, so there will be a lot of distractions. Many are designed to capture your attention with features of luminance and motion (*e.g.*, flashing advertisements). And, some distractors will be salient *and* in the search space (*e.g.*, neon overhead signs for sidewalk eateries). The cognitive control required to manage the interference of salient distractors would further deplete limited resources [13]. And, if this scenario were more realistic, you'd probably be on your phone too.

Given the limits of our cognitive resources and the demands of city life, it's no wonder that urbanites and city-dwellers process information differently. People living in urban areas show a global processing bias; large-scale visual information is perceived before individual elements [16]. Moreover, this is not attributable to cultural differences; traditional Himba, a remote people, show a strong local processing bias which is reduced by urban exposure [16]. This reduction of local bias is stronger among Himba that have resided longer in cities, which is further evidence that urbanization is driving the global processing bias [16]. Another effect of city living appears to be diminished attentional control and engagement; this may be due to depletion of controlled cognitive resources [3,4]. An alternative explanation for the finding is that urbanization drives a shift toward an exploratory mode of attention, wherein controlled resources may be available, yet are not deployed [13]. Proponents of the latter argue that exploratory attention is consistent with the higher tonic alertness observed among urbanities and may constitute an adaptation to city living [3,13]. Irrespective of the possibility that exploratory attention may be beneficial at the level of an individual, the cost to attentional control and engagement may be a liability to others in a city—which, by definition, is characterized by high population and dense infrastructure.

A typical cityscape imposes unique perceptual demands [14,17]. The visual clutter generated by dense signage, vehicles, and people amplifies competition early in visual processing; larger, more salient objects will dominate over smaller objects. Consequently, although we perceive the gist of a scene very quickly, we may fail to detect smaller objects—even when the objects are expected [17]. Errors may be worsened under high cognitive load; defocusing of perceptual resources increases the likelihood of errors in small object perception [14]. The combination of high perceptual and cognitive load amplifies the global processing bias, which may have serious implications for detection of vulnerable road users (pedestrians, bicyclists, and motorcyclists) [17]. Moreover, failure of object detection may occur at the post-perceptual level—we may not notice objects due to attentional failure [17]. This "inattentional blindness" is worsened under higher perceptual load (visual clutter) [18].

In an example posed earlier, we considered the task of locating an intersection while traveling by foot in the city; what if that task were performed while driving? Let's assume the driver has read the studies finding that cell phone use—even in hands-free mode—compromises attention [19]. So, the driver only uses the phone's GPS feature (to locate the intersection). Yet, in-vehicle technology devices create visual competition, and research has shown drivers pay less attention to their periphery when using these devices [20-22]. This would pose a danger to pedestrians who may be approaching from the sidewalk. The risk to these vulnerable road users would be compounded by visual clutter, for two reasons: the driver might fail to perceive the pedestrian due to interference early in visual processing [17], and the driver may not notice a pedestrian due to inattentional blindness (which is heightened under visually cluttered conditions) [18]. In addition to driver-related factors, the pedestrian introduces another source of error. This person's attention may be impaired by a cell phone conversation [23]. And, an urbanite in a rush is less likely to wait for a designated cross-walk before stepping off the curb [24]. The pedestrian may or may not notice a vehicle in traffic, just as the driver of the vehicle may miss the pedestrian; thus, the combined influence of visual clutter, attentional demands, and a fast-paced urban lifestyle may lead to errors and accidents [25,26]. Fortunately, city stress may be reduced by spending time in a non-urban area [27], where attention is in its natural environment [28,29].

ATTENTION IN THE WILD & THE RESTORATIVE EFFECTS OF NATURE

The visual system is specifically adapted to the properties of natural visual stimuli; for instance, features of biologically relevant stimuli, such as motion, are detected effortlessly [28]. Similarly, whereas the interpretation and classification of artificial stimuli requires controlled attention, natural stimuli and scenes are interpreted almost automatically [29]. Natural stimuli engage default attentional settings, which are ideal for detection of infrequent or unexpected stimuli [30]. Studies of remote populations, such as traditional Himba, suggests that attention operates comparatively well in a natural environment [31-33]. Individuals living in remote areas are less distractible [31] and exhibit greater control over attentional selection in response to task demands [32]. Moreover, people living in remote areas are better able to attend to relevant information and ignore distractors, relative to individuals living in more urbanized environments [33]. As it turns out, the attentional benefits of living in a remote area may be accessible by a return to nature.

Attention Restoration Theory (ART), proposed originally by Rachel and Steve Kaplan [34-36] distinguishes between controlled or directed attention, which is fatiguing, and involuntary attention, which is restorative. They argue that controlled attention, while necessary for much of modern human activity, may be fatiguing because directed attention is not optimal in a natural environment [34]. Natural environments promote scanning the environment and attending to many things freely; urban environments require sustained concentration [28,29]. Furthermore, nature is inherently interesting, but the modern world requires attending to information that may be less engaging but nonetheless relevant to the task at hand. Attending to uninteresting input may be effortful, and thus fatiguing [36]. Nature, on the other hand, is restorative because the attention is effortless or involuntary [37]. Specifically, Kaplan [34] argues that there is "fascination" in nature that has an evolutionary basis. People are inherently interested in nature because it is unpredictable; watching a squirrel run up a tree or a bird seeking prey is a mystery that engages people in the same way that other unpredictability (reading murder mysteries) is engaging. Second, nature is "soft" on a soft-hard dimension that is exemplified by the contrast between manmade objects (race cars, buildings) and natural ones (clouds, sunsets, snow patterns, leaves). Third, nature has large spatial extent with vast open spaces and long distances. Finally, nature is "away" from that which is of everyday concern to most urban dwellers. Because nature enhances inherent interest, it captures attention in a bottom-up way that does not require top-down control [37].

Attention Restoration Theory argues that spending time in nature is not just relatively effortless, but that it actually replenishes the attentional and cognitive resources that are depleted by urban environments [34]. Specifically, nature gives direct attention a break allowing those limited cognitive resources to replenish. A number of studies have found that, in fact natural environments do seem to benefit directed attention [5,6,38-41]. For example, one study compared backpackers who went on a 4 to 7 day wilderness vacation, a non-wilderness vacation, or no vacation (control) who completed a proofreading task before and after their vacation. The wilderness group slightly improved on the proofreading task whereas the two other groups actually declined on that task suggesting specific impact of nature on attention to detail [6]. In another study, Berman and colleagues [5] randomly assigned college students to one of two conditions: an approximately 50-minute walk through the school's arboretum versus a similar length walk through downtown. Participants performed the backward digit span task (an attention and working memory task that requires participants to remember a series of digits in backwards order). Participants remembered longer sequence of digits after walking in nature compared to walking in the city. In a second study, Berman *et al*. assigned to viewing photos of nature or urban scenes and took both the backward digit span task and also the Attention Network Task. The Attention Network Task involves viewing a computer screen and, when a stimulus arrow appears, reporting the direction that the arrow is pointing; other arrows flank the stimulus arrow and are either pointing in the same or opposite direction as the stimulus arrow. Controlled (or executive) attention is measured as the difference in time and accuracy in responding to incongruent trials (flanking arrows in opposite direction compared to same direction), the alerting component of attention is measured by the ability to use a preceding central cue indicating that a target will soon appear, and orienting of attention is measured by the ability to use a spatial cue indicating where the target will appear [5]. As predicted by the Attention Restoration Theory, viewing nature pictures benefited performance on the backward digit span and the executive attention measure, but not on alerting and orienting (which do not require controlled attention) [5].

Numerous additional studies have found benefits to either walking in nature or viewing nature scenes on attention-demanding tasks [38-41]. Depressed individuals, for example, also showed improvements in backward digit span following a nature walk compared to a city walk [41]. And ADHD children, who generally have difficulty with controlled attention, were also found to show improvements on backward digit span following a 20-minute walk in nature compared to a 20-minute urban [42]. Another study found improvements on the Attention Network Task in older adults following viewing nature scenes [43]. For a relatively recent systematic review of studies that assess the cognitive benefits of nature, see Ohly *et al*. [44].

The studies discussed above all show benefits to interacting with nature on attention-demanding tasks. However, they do not directly test two aspects of the Attention Restoration Theory: that nature is inherently fascinating, or that the mechanism of improvement is due to rest of voluntary attention processes in nature. Recent studies have addressed both of these questions [45,46]. To address whether or not nature is inherently fascinating, several studies have explicitly asked participants what scenes hold interest to them. Felstein [45], for example, asked participants to rate nature murals with water, nature murals, nature murals with some buildings, and non-nature murals and found that the nature murals (especially those with water) were rated as more engaging (using questions such as "How much does this setting draw your attention without effort and easily engage your interest?") than non-nature murals. They also found that participants rated nature images as more restorative (*e.g.*, "Overall, how much do you agree that this setting would be excellent for taking a break and restoring your ability to study for an exam or work effectively on a demanding project?").

To better understand the mechanism by which nature may be fascinating, Van den Berg, Black, Fountaine, and Knotts [47] asked participants to rate natural and non-natural scenes in original size enlarged 400 percent and 1600 percent and found that natural scenes were rated as more fascinating. Furthermore, the complexity of the enlarged scenes served as a mediator and more complex enlarged scenes were thought to be more fascinating even in original size. Studies that find improvements in controlled attention as a function of exposure to nature do not make clear what the underlying mechanism of this effect might be. One possibility is that the improvement is due to decrease of use of controlled attention processes during the exposure phase and an alternative possibility is that natural environments capture involuntary attention. Neuroimaging studies attempt to address this question by testing how exposure to nature versus urban environments impacts attentional processes in the brain. For example, one study exposed participants to natural scenes (mountain, forest, and river) versus urban scenes while they were in an fMRI scanner [48]. When viewing urban scenes compared to mountain or river scenes, participants had greater activation in the cuneus, suggesting that urban scenes required greater controlled attention. Furthermore, there was greater activation for urban scenes relative to river scenes in the dorsal posterior cingulate cortex, also suggesting greater controlled attentional demands for the urban scenes [48]. A similar neuroimaging study found that scenes rated as higher in restorative potential activated areas linked to involuntary (bottom-up) attention, while scenes rated low in restorative potential activated brain areas that support effortful, controlled attention [49].

In summary, Attention Restoration Theory suggests that interacting with nature is less demanding of controlled attention than interacting with urban environments and thus is restorative [34-36]. Behavioral studies that measure impact of exposure to nature (both real and in photos) both find improvements in attention relative to exposure to urban environments. Furthermore, individuals rate urban images as less restorative than nature images and this difference appears to be a function of the visual complexity of the natural environments [44]. And, neuroimaging studies corroborate the relative attentional demands of viewing urban and rural scenes. Surprisingly, adults spend only 7 percent of their time outdoors [50]. Considering the high-stakes risk of depleted attention in an urban environment, and the simple and enjoyable solution of restoring attention through exposure to nature, one can only wonder why we spend so little time outdoors in nature.

CONCLUSIONS AND OUTLOOK

The objective of this perspective was to provide a glimpse into the effects of an urban environment on attention and how these effects may be reversed by natural environments. The restorative power of nature has a number of practical applications; city dwellers might benefit from the mentally refreshing effects of an urban vacation or lunch break in the park. Urban designers and human factors engineers might also find inspiration in natural environments and stimuli. By modeling the properties of the environments and stimuli to which our sensory and cognitive systems are exquisitely adapted, urban elements might be made to impose fewer cognitive demands. Beyond these possibilities, the synergy between our sensory/cognitive processes and nature has another, more far-reaching implication; the relatively slow pace of evolution and the limited nature of our cognitive resources must be taken into account as we blaze new frontiers in technology and urbanization.

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