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Research Statement

The perceptual and cognitive systems take advantage of the stability and predictability of the world to guide attention to significant changes in the external environment (Swallow & Jiang, 2013, *Frontiers in Psychology*; Zacks & Swallow, 2007, *Current Directions in Psychological Science*). My research is concerned with how these events shape attention and memory over time and space. It is grounded in the view that changes to the external situation, either by virtue of the appearance of a task-relevant item (a goldfinch when bird-watching) or by a change in a nearby persons' activity (one's dinner companion grabs a menu when asked about dessert), can be exploited to efficiently acquire information about the external situation and, over time, learn how the world typically is. Understanding these mechanisms requires an approach that spans traditional sub-disciplines in the psychological sciences. It also requires exploration of bi-directional interactions between the people who do the attending, remembering, and learning, and the environments they are immersed in throughout their lives. My research therefore takes a multi-pronged approach, using tasks and stimuli that tap into everyday perception, attention, and memory as well as tasks that afford careful, methodical investigation of mechanisms that support everyday cognition. By combining these approaches with behavioral, neuroimaging, and eye-tracking methods my research has shown that attention, memory, and perception are linked to external events in unexpected ways.

Temporal Selection of Behaviorally Relevant Events

Much of what is known about attention has been learned by asking people to search for and respond to behaviorally relevant items (targets). This work has focused on how attention influences the way targets and subsequently presented information are processed. However, my research suggests that the temporal selection of behaviorally relevant events has unanticipated effects on how concurrent information is perceived and remembered. It challenges the long-held and well supported view that increasing attention to one stimulus or task always interferes with processing other information.

1) Temporal selective attention in dual-task situations: The attentional boost effect

A major line of my research focuses on the effects of detecting goal-relevant changes in events on the way other information is processed and remembered. For this research I developed a novel experimental paradigm in which participants perform a target detection task at the same time that they encoded a second, unrelated image into memory (Figure 1a). Of interest is how detecting a target influences performance on the

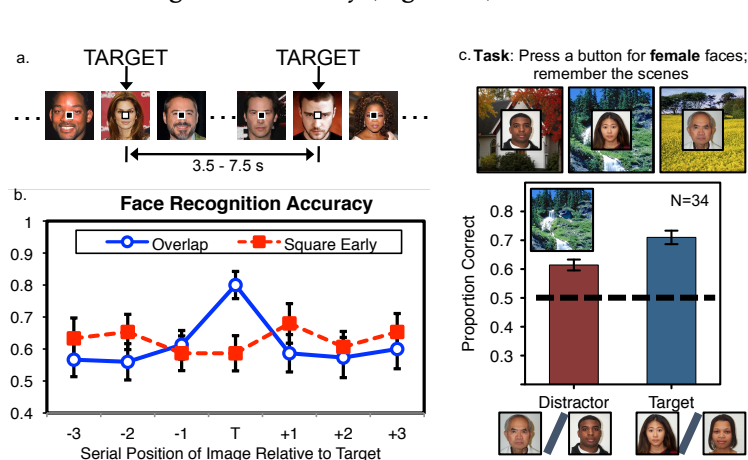


Figure 1. When targets (T) appear for a detection task (a), later memory for concurrently presented images is enhanced (b, solid line), but not for scenes presented 100 ms later (b, dashed line). (c) Relational memory for which of two target faces appeared with a scene (upper left of the plot) is also enhanced.

secondary encoding task. The majority of work on dual-task performance predicts that detecting a target for one task will impair performance on the secondary encoding task (e.g., dual-target cost, Duncan, 1980, and the attentional blink, Raymond, et al., 1992). Surprisingly, however, my research has repeatedly demonstrated the opposite effect: Memory for an image is better if it is presented at the same time as a secondary target, rather than a distractor (e.g., Figure 1b, solid line), or on its own. Detecting targets for one task boosts performance on an unrelated encoding task, a phenomenon we call the

attentional boost effect (Swallow & Jiang, 2010, *Cognition*; Swallow & Jiang, 2013; Swallow & Jiang, 2014, *AP&P*).

Since I initially described the attentional boost effect, I and others have shown that it is highly replicable and occurs for encoding stimuli with a range of complexity and semantic content (Makovski, Swallow, & Jiang, 2011, *Neuropsychologia*; Swallow & Jiang, 2010; Spataro, et al., 2013), when targets require a button press or are counted (Swallow & Jiang, 2012, *AP&P*; see also Makovski, Jiang, & Swallow, 2013, *JEP:LMC*), when targets are perceptually similar to distractors (Swallow & Jiang, 2014, *JEP:HPP*), and when memory is tested immediately or after a delay (Li, Swallow, Chiu, De Rosa, & Anderson, 2019, *Biological Psychology*; Lin, et al., 2010; Makovski, Swallow, & Jiang, 2011; Swallow & Jiang, 2010). At the same time, I have demonstrated that the attentional boost effect does not conform to several phenomena related to attention, including alerting, arousal, cuing, predictive learning, perceptual grouping, and oddball processing (Swallow & Jiang, 2011; 2012, *AP&P*).

Another possibility is that target detection facilitates memory by changing the perceived value of the background items. Work on attention and memory has demonstrated that items associated with greater reward in the past, or that are likely to be rewarded in the future, are more likely to be attended and remembered than other items (Anderson, et al., 2011; Cohen, et al., 2014). Images that are paired with targets rather than distractors may be more valuable because they provide information that is immediately relevant for task performance. Indeed, like others (Schonberg, et al., 2014), my lab has found that target detection increases how much people want or like concurrently presented objects and faces (Swallow & Atir, 2018, *QJEP*). If this increase in perceived value is responsible for the memory benefit, then memory should be greater for items that are valued more. However, our data show that value and motivational significance appear to have little effect on memory in this task (Swallow & Atir, 2018).

The attentional boost effect is consistent with theories claiming that changes in ongoing events and activities lead to enhanced processing of and better memory for those moments (Newtson & Engquist, 1976; Swallow, Zacks, & Abrams, 2009, *JEP: General*; Zacks, Speer, Swallow, et al., 2007, *Psychological Bulletin*). Though this work served as the main motivation for my original attentional boost effect studies, the effect of target detection on memory for events, rather than specific items, was unclear (Mulligan, et al., 2015). Because event memory consists of items bound to their spatiotemporal context (Davachi, 2006; Yonelinas, et al., 2019), recent work in my lab has addressed three central questions. First, does target detection enhance memory for task-irrelevant information? Second, does it increase recollection of the event in which an item appeared, and not just familiarity with the item? And, third, does it improve memory for the relationship between an item and other item that appeared at the same time? Our recent data demonstrate that the answer to all of these questions is 'yes.' Participants better remember task-irrelevant images that are paired with targets than those paired with distractors (Broitman & Swallow, submitted; Jiang & Swallow, 2014; Swallow & Jiang, 2014; see also Swallow & Jiang, 2011). Using the dual-process signal detection model, we have also demonstrated that target detection increases estimates of recollection of the encoding event as well as familiarity with the background image. This 'recollection boost' is present even for ignored images and images presented once (Broitman & Swallow, submitted). Benefits to context memory are also detectable in direct tests. In several experiments, participants were better able to report which detection task item a scene, object, or face appeared with if it was paired with a target rather than a distractor (Swallow & Atir, 2018; Turker & Swallow, 2019, *Memory & Cognition*). Participants also were better able to indicate the task-irrelevant features of detection task items that were targets (e.g., the item's shape when participants responded based on color), as well as which of two target faces appeared with a particular scene, than which of two distractors appeared with another scene (Turker & Swallow, 2019).

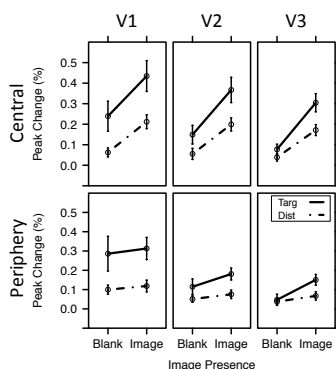
In contrast to the typical interference effects, our data show that attending to a behaviorally relevant item boosts the encoding of events into memory, enhancing memory for individual items and their spatiotemporal relationship with other information from that time.

2) Mechanisms of temporal selective attention

The data point to a selection mechanism that briefly enhances the processing of information encountered at a given moment but whose effects are not limited by modality, spatial location, or task-irrelevance. To account for these data I have proposed that they reflect a mechanism that reactively selects behaviorally relevant moments (*temporal selection*; Swallow & Jiang, 2013; cf. Schroeder, et al., 2010; Nobre & van Ede, 2018). Such a mechanism would serve to temporarily increase the influence of external information on internal representations of the current situation. Consistent with this possibility, I have used pupillometry and functional magnetic resonance imaging (fMRI) to find that behaviorally relevant events, like targets, can have surprisingly widespread effects on how information is processed and represented in the brain.

The behavioral consequences of temporal selection clearly deviate from the well documented effects of dual-task interference on behavior. Using fMRI, I showed that these behavioral effects are mirrored in widespread increases in brain activity that are inconsistent with the effects of spatial selective attention (Swallow, Makovski, & Jiang, 2012, *Journal of Neurophysiology*; Moyal, Turker, Luh & Swallow, in prep). Participants monitored a stream of auditory tones, and pressed a button whenever a tone of a particular pitch occurred. Surprisingly, activity in visual cortex increased following auditory targets (Figure 2, solid lines), but not distractors (dashed lines). This *target-mediated boost* was not spatially localized or specific to auditory processing; it was also observed in both visual and auditory cortex when participants responded to visual targets, and activity in visual cortical regions representing the peripheral visual field increased in response to centrally presented visual targets. These findings indicate that temporal selection has qualitatively different effects on visual cortical activity than does spatial selection (see also Jack, et al., 2006).

Figure 2. Early visual cortical areas V1-V3 increase more in activity following auditory targets (solid line) than distractors (dashed line).



The relationship between the magnitude of the hemodynamic response to an event and how information is processed is unclear (Haxby, et al., 2014). My lab therefore used multi-voxel pattern and beta series analyses to test whether target detection influences how information is processed and represented in hippocampal and ventral visual areas (Moyal, Turker, Luh & Swallow, in prep). The Euclidean distances between patterns of activity that were evoked by different images were greater on target tone trials than on other trials in the hippocampus and ventral visual areas (e.g., fusiform gyrus and V2). Connectivity between hippocampus and visual cortical areas also was greater when target tones were presented than in the other conditions. Attending to behaviorally relevant auditory targets therefore increases activity in visual cortical areas, increases the separation of activity patterns for different images, and increases connectivity between the hippocampus, involved in representing spatiotemporal contexts, and visual cortical areas.

Temporal selection in these tasks could be mediated by the locus coeruleus (LC; Swallow & Jiang, 2013), brainstem nuclei theorized to play a role in network reset and neural gain (Aston-Jones & Cohen, 2005; Bouret & Sara, 2005). Because projections from the LC are highly collateralized and reach most of the brain, including the hippocampus, it could produce the widespread enhancements to perception and memory observed in our prior work. Consistent with this possibility, we recently showed that pupil diameter, an indirect index of LC activity, increases more following target tones than distractor tones in this task. Importantly, this difference was greater when the images were later remembered, and when targets and distractors occurred with equal frequency (Swallow, Jiang, & Riley, 2019, *Scientific Reports*).

Because pupil diameter is influenced by multiple brain areas (Joshi, et al., 2016), additional approaches are needed to determine whether the LC is involved in these tasks. However, the LC is small and located near a large source of noise in the brain (the fourth ventricle), making it critical for fMRI studies of the LC to isolate its activity from nearby regions and to reduce the contributions of noise. In recent work (Turker, Riley, Luh, Colcombe, & Swallow, submitted), my lab has found that individually localizing the

LC using neuromelanin T1 imaging rather than probabilistic atlases better excludes activity from nearby brainstem areas (Figure 3a, 3b, see also Swallow, et al, 2003, *NeuroImage*). The use of multi-echo data, rather than single-echo data increased the signal to noise ratio in the LC by a factor of 2.9 (cf., Kundu, et al., 2013).

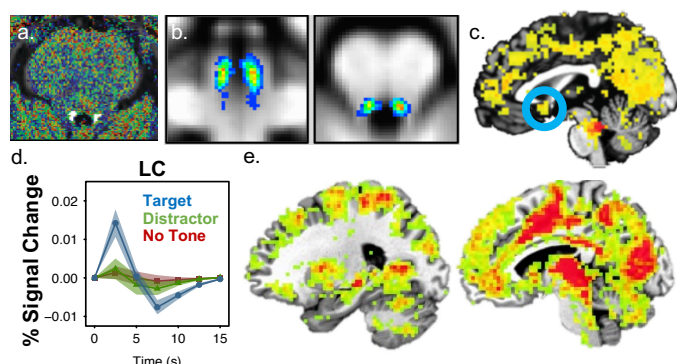


Figure 3. a. Neuromelanin images were used to individually localize the LC (white spots). b. LC overlapped across individuals, but varied in location (red = 85%, blue = 5% overlap). c. Voxel-wise correlations with activity in the individual LC during rest (green: $r=0$; red: $r=.4$). d. Changes in LC activity following different types of trials. e. Regions modulated by tone type (type \times time, $FDR < .001$).

These differences were consequential: different methods produced intrinsic functional connectivity maps of the LC that only moderately overlapped, and only those maps generated with individually defined LC regions and multi-echo data included a cluster of correlated voxels in the basal forebrain (Figure 3c, circled). The basal forebrain is also involved in regulating attention and memory (Ljubojevic, et al., 2014), receives modulatory input from the LC (Schwarz & Luo, 2015), and is difficult to measure with the more common, single-echo fMRI. Importantly, all approaches found that activity in the LC is correlated with activity in the visual cortex and the hippocampus during rest.

Building on these methods, we have used individually defined LC regions and multi-echo fMRI to demonstrate that LC activity increases following the presentation of a target tone, but not following a distractor tone or a baseline trial (Figure 3d, 3e, Moyal, Turker, Luh & Swallow, in prep), providing additional support for a role of the LC in the temporal selection of behaviorally relevant events.

Future Research

Our work paints a broad strokes picture of a system that selectively enhances the processing of behaviorally relevant moments. In future research I will explore the idea that temporal selection is associated with the reset and updating of internal representations of the current situation. As part of this I will examine whether temporal selection influences learning about the structure of the world, and the utilization of that knowledge to form expectations about what is about to happen. It will also be important to understand the degree to which temporal selection facilitates the integration or segregation of information encountered over space and time, how it promotes the rapid formation of representations of the current situation in memory, and its interactions with other forms of attentional selection. Work in my lab, already in its early stages, will better characterize the hippocampus' interactions with mechanisms that guide attention over time and space. Further, although our recent work has focused on the LC, this nucleus is part of a larger neurochemical regulatory system associated with attention, reinforcement learning, and arousal that needs to be addressed. Along these lines, my lab has started looking into the motivational significance of events. For example, ongoing collaborative work also examines how temporal selection influences racial attitudes towards faces encountered at behaviorally relevant moments. Finally, my research is beginning to examine temporal selection and LC function in disorders that affect attention and episodic memory. New collaborations with researchers at the Nathan Kline Institute will characterize LC function in children with autism or attention deficit hyperactivity disorder to capture how dysfunction of this system during development (London, et al., 2018) impacts the ability to tune attention, learning, and memory to significant external events. Analyses for one of these projects are underway, and I submitted an ROI to support this work. Another ROI is planned to investigate whether the decline of LC function with aging and mild cognitive impairment (Lee, et al., 2018) impacts the ability to select and remember behaviorally relevant moments (cf., Bechi Gabrielli, et al., 2018).

Perceiving and Remembering Everyday Events

The questions I wish to address are grounded in understanding the cognitive and neurophysiological mechanisms involved in learning about and responding to changes in more naturalistic, and therefore less controlled, situations. Using everyday activities and commercial film, I also investigate how people identify changes in everyday events and the impact of those changes on perception, attention and memory. This research has important implications for our understanding of everyday cognition, demonstrating that changes in events have nearly immediate effects on what information is available in memory.

1) Event boundaries impact what is remembered, when it is remembered, and how it is remembered

Event segmentation structures the perception of ongoing activity, dividing continuous experience into meaningful events. According to Event Segmentation Theory (EST; Zacks, Speer, Swallow, et al., 2007, *Psychological Bulletin*), event boundaries mark the moments in time when active representations of the current situation (event models) are reset and updated with new perceptual information. It proposes that these moments in time coincide with changes in the current situation that reduce the ability to accurately predict incoming perceptual information. I directly tested these claims by measuring participants' ability to remember objects that were recently encountered in narrative films (Swallow, Zacks, & Abrams, 2009, *JEP: General*; Swallow, et al., 2011, *Journal of Cognitive Neuroscience*). In a series of four experiments (one using fMRI), participants viewed clips from four narrative movies. The clips paused about once a minute for a recognition memory test on an object that was presented 5 seconds earlier. When they had to be retrieved across events, participants more accurately recognized objects that were on the screen when an event boundary occurred. This suggests that boundaries are better encoded into memory than nonboundary periods (see also Newtonson & Engquist, 1976). In addition, performance was near chance when nonboundary objects had to be retrieved across an event boundary, consistent with segmentation resetting representations

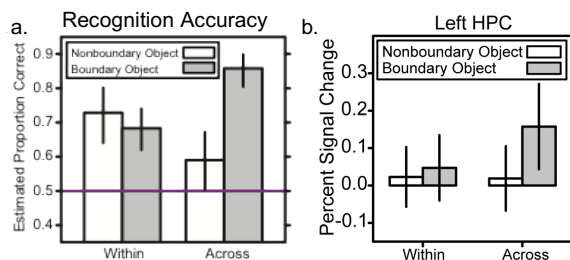


Figure 4. a. Object recognition depended on whether event boundaries occurred during object presentation and during the delay. b. Retrieving a boundary object across events was associated with greater activity in the hippocampus.

of the current event. Surprisingly, eye movement data indicated that these effects were present even for objects that were not directly fixated, suggesting that event segmentation can facilitate the encoding of information that is outside the current focus of attention (similar to the attentional boost effect, Swallow & Jiang, 2013; see also Dubrow & Davachi, 2013). Changes in behavioral performance occurred alongside a change in the recruitment of the hippocampus and medial temporal during object recognition, which showed greater activation when retrieving objects across events rather than within events (Swallow, et al., 2011). Like

the attentional boost effect, this research strongly suggests that event boundaries have nearly immediate effects on the way information is encoded and retrieved from memory.

2) Event boundaries are more likely to be perceived when situations change along concrete and abstract dimensions

EST suggests that events should be segmented when internal representations of the current situation fail to accurately predict current perceptual input. Consistent with this claim, my colleagues and I have demonstrated that segmentation is more likely when there are quantitative and qualitative changes in the situation depicted in film or text. Changes in visual motion, actor posture, and goals all increase the likelihood that an observer will identify an event boundary during a segmentation task (Newtonson, et al., 1977; Zacks, Speer, Swallow, & Maley, 2010, *Frontiers in Human Neuroscience*). During normal, task-free viewing of films, the moments people identify as event boundaries are also associated with increased activity in a network of brain regions in medial cortex and lateral frontal and temporal occipital regions (Speer, Swallow, & Zacks, 2003, *Cognitive, Affective, and Behavioral Neuroscience*; Zacks, et al., 2001; Zacks, Speer, Swallow, &

Maley, 2010). The increased neural responses to changes in the current situation, such as increases in visual motion, changes in actor-object interactions, and changes in spatial location, also partially account for activity in a network of brain regions that is active when event boundaries are encountered in movies and narrative text (Speer, Reynolds, Swallow, & Zacks, 2009, *Psychological Science*; Zacks, Speer, Swallow, & Maley, 2010; Zacks, Swallow, et al., 2006, *Brain Research*). Event segmentation and its neural correlates appear to be strongly associated with both concrete changes in the situation (e.g., a change in an actor's posture, or location), and more abstract changes in the situation (e.g., a change in an actor's goals).

3) *Disentangling the contributions of visual features, perceptual change, and knowledge to event segmentation*

Because many of the features associated with segmentation are correlated with each other, the contributions of low-level sensory information, more abstract information that must be inferred or extrapolated about events (e.g., goals), and an observer's knowledge about events and how they're structured have been difficult to tease apart. In recent research I have begun to address this issue in two ways. First, to partially separate low-level visual features such as motion and actor posture from the activity itself, I have examined whether segmentation of the same activity differs when it is viewed from first- or third-person perspectives (Swallow, Kemp, & Candan Simsek, 2018, *Cognition*). In addition to differing in visual features, first- and third-person perspectives reflect actor and observer viewpoints (performing a task and viewing another's activity from a first-person perspective differ in other ways) and encourage different ways of thinking about an activity (Libby & Eibach, 2011; Nigro & Neisser, 1982). People also learn about events through their own actions as well as by observing others. Yet, I found that differences in the placement of event boundaries across perspectives were difficult to detect, if present at all. Remarkably, observers identified similar events when they could see the actor's body, and when they could not. Instead, the relationship between segmentation and objective video features (e.g., frame to frame visual change) differed for first- and third-person perspectives. These data suggest that event segmentation may be invariant across large changes in how an experience is presented to the senses, flexibly using whatever information is present in the stimulus to identify its underlying structure.



Figure 5. Examples of stimuli used to study the effects of perspective (left) and cultural setting (right) on event segmentation.

Second, if segmentation is not tied to specific features of an experience, such as visual motion, an actor's posture, or the onset and offset of actor-object interactions, it may then be based on knowledge of how actions and events typically unfold. However, while the statistical structure of action sequences influences how people segment and attend to activities (Baldwin, et al., 2008; Swallow & Zacks, 2008, *Psychonomic Bulletin and Review*), other work suggests that knowing what type of activity one is viewing has little effect on how it is segmented (Zacks, et al., 2009; Hard, Tversky, & Lang, 2006). My lab is exploring these issues by asking whether individuals with different cultural backgrounds segment the same activities in different ways. In one study (Swallow & Wang, submitted), Indian and US participants segmented activities recorded in the US and activities recorded in India. Despite the fact that both groups rated the activities from the other culture as less familiar and less similar to their own activities, we found no detectable effects of the match between the viewer's culture and the activity's setting on segmentation. Rather, Indian and US viewers appeared to segment the events at different levels of granularity and prioritized different sources of information when they did so (visual change for US viewers; goal changes for Indian viewers). Rather than influencing segmentation by changing participant's knowledge of how an observed activity is being performed, culture

appears to have influenced the types of information observers used to identify event boundaries. How events are defined may therefore be influenced by the cultural context in which observers develop.

Future Research

Our work on event segmentation and memory touches on several issues that require further exploration. Several accounts of segmentation suggest that it is driven by prediction error. However, outside of the confines of well controlled experiments, which aspects of everyday experience are being predicted (and compared to the state of the world) are unclear. My work on segmentation across perspectives and cultures highlights this issue, raising questions about what kind of information people use to segment and remember events, and whether this changes as a consequence of the types of information available (captured by perspective changes), momentary changes in an observer's goals and expectations (which may influence attentional selection), and longer term effects of the demands of an observer's social and developmental context (as captured, in our case, by culture). I hope to better characterize whether observers learn about which features of events are important for comprehension and communication of events and generalize these to novel situations. It will also be important to address whether knowledge about activities plays a greater role in segmentation and memory when the sensory and narrative input is less consistent over time (e.g., when the camera view changes with each head movement, or scenes are viewed out of order). A related but underexplored issue is observer's sensitivity to changes in the features that are associated with segmentation, such as changes in an actor's goals. Finally, it will be important to better understand the relationship between changes in the external situation (e.g., other's activities) and changes in one's own activity or task (e.g., Dubrow & Davachi, 2013; see also Jiang, Shupe, Swallow & Tan, 2016, JEP:LMC; Swallow, Jiang & Tan, 2017, JEP:LMC). To better characterize the relationship between event segmentation and temporal selection I am developing new projects with the Nathan Kline Institute to investigate the relationship between segmentation and LC function, sensory sensitivity in autism, and episodic memory decline with aging and mild cognitive impairment (cf., Sargent, et al., 2013).

Attentional Guidance by Learned Environmental Regularities

Adaptive behavior may be enhanced by learning when and where to expect behaviorally relevant events to occur. In one line of research, I explore how people learn and use statistical structure in the environment to guide attention. By characterizing how visual statistical learning influences attention, this research provides new insight into the nature of statistical learning and even attention itself.

1) Spatial attentional biases can reflect regularities in the environment

In multiple studies, we have investigated how spatial statistical structure influences attention. For these experiments participants searched for a T (target) among L's (distractors). Although participants were not aware of it, the T was three times as likely to appear in one *rich* quadrant of the screen than in any of the other *sparse* quadrants (Figure 3a). Halfway through the task, the spatial distribution changed, such that targets were now equally likely to appear in each quadrant. Participants learned and used the uneven target distribution to speed their responses to targets (*probability cuing*). This bias persisted long after the target became evenly distributed, demonstrating that it reflects long-term learning (Jiang, Swallow, et al., 2013a, JEP:HPP). Moreover, search was more efficient in the rich quadrant than in sparse quadrants, suggesting that learning where a target is likely to occur guides attention (Jiang, Swallow, et al., 2013b, JEP:HPP).

2) The nature of attentional biases from statistical learning

Spatial attentional orienting is often thought to be driven by two separate sources: endogenous goals and exogenous perceptual salience. Because statistical learning influences attention as a result of internal knowledge, one might expect it to operate in the same way as endogenous attention. However, endogenous

cuing interferes with both the learning and expression of probability cuing (Jiang, Swallow, et al. 2013b). In addition, whereas the latter can be flexibly tuned on a trial-by-trial basis, the former persists for at least a week after it is acquired, does not change with changes in the target's spatial distribution (Jiang, Swallow, et al., 2013a), and persists when participants are told that the previously learned knowledge about the target's location has changed (Jiang, Swallow & Sun, 2014a, *JEP:LMC*). Incidentally learned knowledge about a target's likely location therefore does not appear to produce the same attentional effects as explicit knowledge about where a target is likely to occur.

We have proposed that probability cuing reflects procedural knowledge of how to move attention through space for a particular task. In fact, first saccades are more than twice as likely to be directed to the part of the display that is likely to contain the target (Jiang, Won & Swallow, 2014, *JEP:HPP*). These effects are task specific: learned biases do not transfer between inefficient search, efficient search, change detection, or foraging tasks (Jiang, Swallow et al., 2015, *AP&P*). The claim that probability cuing reflects procedural learning is strongly supported by observations suggesting it is viewer-centered (Jiang & Swallow, 2013a, *Cognition*; Jiang, Swallow & Capistrano, 2013b, *Journal of Vision*; Jiang Swallow & Sun, 2014a; Jiang & Swallow, 2014b, *Journal of Vision*). When participants change their seating position relative to the search display halfway through the task, the learned bias moves with them (Figure 3). Yet, no learning occurs if the observer moves to a new seating position at the beginning of each trial, even when the display is a rich visual landscape (e.g., a satellite image; Jiang & Swallow, 2014b).

Of what use is a mechanism that learns which part of the visual field is likely to contain a valuable object? Simply approaching a search space from a new direction would ensure that attention prioritizes the wrong spatial location. However, the reference frame of incidentally learned attention can be updated under some circumstances. For example, when participants acquire the attentional bias with their heads or their bodies tilted in one direction, they prioritize both the rich region of a display and the rich region of their visual field after tilting their head or body in the other direction (Jiang & Swallow, 2013b, *Journal of Vision*). Probability cuing in large-scale environments may be amenable to spatial updating as well. When participants searched for a coin in a large outdoor environment, they learned to attend to the environmental locations that were likely to contain the target (Jiang, Won, Swallow & Mussack, 2014, *JEP:HPP*).

Future Research

Once acquired, learned attentional biases are remarkably resistant to change. However, the data

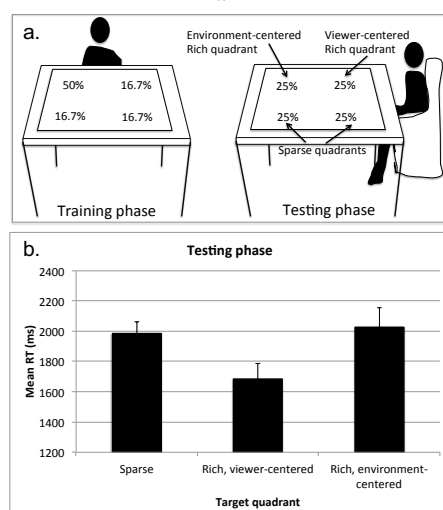


Figure 3. a. After performing a search task with unevenly distributed targets, participants were re-seated and the target distribution made even. b. The attentional bias from training moved with the participant.

argue against the notion that they are another form of goal-driven attention. They point to a separate form of attentional bias, one that could reflect incidentally acquired knowledge about *how*, rather than *where*, to move attention through space. Evidence for or against procedural learning could be obtained by manipulating the effectors that are used to find targets (e.g., eye movements or moving a cursor to reveal hidden search items), measuring mouse trajectories during search, using reinforcement learning models to predict changes in eye movements through task performance, by manipulating the likelihood that an eye movement in a particular direction will be successful regardless of gaze location, and by examining whether learning is tied to particular contexts.

Summary

My research lies at the intersection of many classical areas within cognition: attention, visual cognition, episodic memory, learning, and perception. I am interested in how these domains work in

concert with the demands of the external environment to produce goal directed, adaptive behaviors over short and long time scales. I examine how these processes interact in situations that more closely approximate everyday environments. This approach has yielded sometimes unexpected findings that (1) responding to goal relevant events such as a target in a detection task can facilitate, rather than impair, the encoding of events into memory, elicits activity in early visual cortex and the LC, and increases the amount of information about concurrently presented images in visual and hippocampal brain regions; (2) the perceived structure of events influences what, when, and how people remember recently encountered information; (3) changing perspective or familiarity with an activity does not strongly influence the perceived structure of events, but a viewer's cultural background does; and, (4) incidentally learned attentional biases may reflect learning how, rather than where, to move attention for a particular task. These findings point to several potential mechanisms that regulate when and where people take up sensory information, tuning attention and memory to the structure, both predictable and not, of the external world.

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