Chapter 8
A Look Toward the Future of Social Attention Research

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8.1 Next Steps

A good deal of our brains and our everyday activities are devoted to interacting with people, and so it stands to reason that we should be keenly interested in how these interactions occur. The chapters in this volume represent a small sample of a broad multidisciplinary effort to understand how humans navigate their labyrinthine social world. Social attention has occupied a central role in this endeavor because the social information available to the perceiver will depend first and foremost on what we select to encode either consciously or unconsciously. In this final chapter we begin by summarizing some of the major findings from each chapter in this volume and then discuss why these findings are still tentative and incomplete. We conclude with some recommendations on how social attention should be investigated in the future. We argue that social attention should be broadened and studied as a dynamical system—a system that is high-dimensional, multilevel, multicausal, and nonlinear.

Before beginning our summary, we digress to point out that until recently laboratory studies of social attention have followed the standard practice of presenting stimuli that were simple and easy to control. For example, isolated static photos of faces or schematic faces consisting of a few features in a circle were often used to study gaze cueing and its neural correlates. Likewise, biological motion was reduced to point-light displays, but these impoverished stimuli obviated the opportunity to learn what might occur in the presence of more complex information, such as we would encounter in daily life. Each of the preceding chapters represents a "sea change" in the study of social attention in that new research was reviewed that

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included more complexity than has heretofore been typically studied with a view to understanding how our social attention systems are taxed in everyday life. This complexity takes on a number of forms, from dynamic stimuli depicting human facial motion to complex visual scenes from the real world. As a consequence of these new research directions, a number of unanswered questions have emerged that merit serious and concerted future research efforts. The future is bright for the field of social attention: There are many new exciting research directions to pursue using more complex stimuli and data collection/analysis methods. It is also important to note that these new research directions could not have been undertaken without the careful, laboratory-based investigations that have been devoted to investigating social attention over the past 50 years.

Each chapter in this volume represented a different perspective on social attention ranging from developmental to cognitive to social neuroscience to clinical. Our goal was to show that these different perspectives are necessary and complementary for understanding how social attention forms a basis for many of our social behaviors. Given the diversity of views covered in this volume, we note that there was considerable variation with regard to what sorts of social information was reviewed. Moreover, we feel obliged to point out that there did not appear to be any standard definition of social attention in the literature. In our introductory chapter we attempted to define social attention in a broader sense, so as to encompass the many facets of this multidisciplinary area of research. Some chapters in this volume focused primarily on faces and eye gaze, whereas others focused more broadly on the actions represented, and interpretations made, of both the stimuli, as well as subjects' responses. In fact, the direction taken in some of the chapters suggested that social attention can be considered mainly from the standpoint of the stimulus information processed by the observer (e.g., eye gaze of the stimulus). In contrast, other chapters viewed social attention primarily from the standpoint of selection and orienting by the observer, and were thus more concerned with how the observer attends to the social information. This variation in focus might, in part, arise from the different disciplines in which these studies of social attention were based. Most chapters in this volume reviewed research germane to both approaches, but it is helpful to keep in mind that while the goals of these two research questions are complementary, their emphases are somewhat different.

8.2 Summary of Chapters

We began the volume (Puce and Bertenthal, Chap. 1, this volume) by examining how social attention research has evolved over the past 50 years since the term "social attention" was first coined, considering also other developments in science and technology. We also provided definitions for the most commonly used terms in social attention research, and examined a number of emerging themes in the field.

Bertenthal and Boyer (Chap. 2, this volume) noted that social attention is a dynamic process that begins at birth, but continues to develop in association with many other skills, including perceptual development, action understanding, and the coordination of joint actions. By emphasizing social attention as a process and not just a product of development, they were proposing a new research agenda. No longer it is sufficient to study how infants look at faces and eye gaze, because the key questions now revolve around the *dynamic* distribution of attention to social stimuli and how attention changes with experience, task, and context. Although much can be learned from well-controlled and rigorous laboratory experiments, it is too often the case that these types of experiments strip away what is most essential to the study of attention, i.e., the process of attentional selection and contextual modulation. For example, evidence was presented that 8- and 12-month-old infants attend to faces differently in semi-naturalistic social interactions depending on the gaze direction and object-directed actions of the social partner. Furthermore, infants' distribution of attention to social and nonsocial information will depend a great deal on age and experience. As infants continue to develop during their first year, attentional orienting becomes more controlled by endogenous (goal-directed) processes, and as such, offers a window into the cognitive and social development of the child.

Currently, the majority of research in early cognitive and social development focuses on the specific skills that develop at different ages. The unfulfilled promise of studying attention is that we can learn more about how infants acquire these skills with age, for example: Do infants direct their attention to the most relevant locations in a scene? Do they share attention with a social partner? By operationalizing attention in terms of eye movements, researchers are able to obtain a direct read-out of where and what infants are looking at and how this changes over real and developmental time. One important implication of focusing more on social attention as a process is that it becomes apparent that it is *interconnected with other processes* and does not simply function as the first stage in a unidirectional sequence of social information processing. Instead, social attention is reciprocally related to social understanding, and thus any experience that contributes to the development of social attention will, in turn, contribute to social understanding and vice versa. It is for this reason that Bertenthal and Boyer claim that action understanding will develop not only as a function of motor experience (e.g., Woodward & Gerson, 2014), but also as a function of more focused attention on the relevant actions themselves.

Reid and Dunn (Chap. 3, this volume) also focused on infants and continued the theme of studying social attention as a process; in this case, the emphasis was on neural processes. Different components of ensemble event-related potentials (ERPs) computed from noninvasive electrophysiological measurements of brain activity reveal early evidence of face and eye gaze processing (N170), memory processing and attentional orienting (mid-latency negative component, Nc), as well as context updating (positive slow wave, PSW). A very interesting finding associated with this latter component is that 4-month-old infants show an increased PSW to direct as opposed to averted gaze, but only for angry faces. This finding is reminiscent of the results reported by Bertenthal and Boyer (Chap. 2, this volume) demonstrating that infants' attention to faces is contextually modulated. Importantly, the evidence presented in this chapter suggests that context updating occurs not only for gaze cues, but also for the processing of objects that are the *targets* of these cues. These findings reveal that infants begin to learn about objects from bouts of joint attention much earlier than is typically reported, and moreover underscore that social attention interacts with other processes, such as object perception, to facilitate the cognitive and social development of the child.

Given the limited repertoire of behaviors available to young infants, it is certainly advantageous to measure infants' processing of information without the need for a behavioral response. In spite of the benefits of this measure, its use for studying the development of social attention has been limited in part because of the technical complexities associated with studying brain activity and also because of high attrition rates. Reid and Dunn discussed a number of procedures for minimizing drop-out rates, including the use of live and dynamic stimuli, which are preferable when studying social attention. In addition, Reid and Dunn advocated using electroencephalography (EEG) analyses that examine oscillatory activity because there are new techniques emerging to analyze these data based on less data than required to analyze ERPs.

Reid and Dunn also briefly discussed the promise of these early measures of social attention for predicting later development, and especially the development of social disorders, such as autism. While thus far the results have not been that promising, there is reason for optimism given the advent of new techniques using discriminant function and machine-learning methods that can improve the reliability and predictive validity of these measures. Lastly, Reid and Dunn suggested that the predictive validity of early measures of social attention benefits from longitudinal testing and repeated measures, a claim that is directly supported by Schultz, Jones, and Klin (Chap. 6, this volume).

Similar to the preceding chapter, Puce, Latinus, Rossi, daSilva, Parada, Love, Ashourvan, and Jayaraman (Chap. 4, this volume) focused on the neural correlates of social attention, but in this case it was in adults. Most of the review was concerned with one particular behavior associated with social attention, i.e., changes in gaze direction. Eye gaze communicates a good deal of information about the intentions and motives of the subject and simply perceiving the eyes shift toward or away from the observer will change one's interpretation of the current situation. As the authors discuss, the "social brain" consists of at least four brain networks or subsystems that have been identified mainly with functional magnetic resonance imaging (fMRI) studies. Two of these are especially relevant to how gaze behavior is processed (a mentalizing network and an amygdala network). The behavior of the brain regions comprising these two networks has been extensively studied with fMRI, and is reviewed briefly. In addition, by studying the neurophysiology (with either EEG or magnetoencephalography [MEG]) elicited by changes in gaze direction that are presented in specific contexts, we are able to glean important insights into the time course of processing this information.

The N170 is an ERP that has been linked to face processing, and that is also sensitive to changes in eye position. Intriguingly, a robust N170 is elicited to the gaze stimulus regardless of whether the eyes are stationary (in the onset of a static face or isolated eye stimulus) or shifting (in a persistent dynamic face), and whether the head is oriented in the same or a different direction from the eyes. Important processing differences are revealed, however, by measuring N170 amplitudes and latencies in response to different gaze behaviors, including opening and closing of the eyes, and in different social contexts. Some of these processing differences are attributable in part to low-level changes, such as the changing local luminance/contrast between the iris and sclera of the eyes when they move. It is therefore critical to distinguish ERP modulation that is produced by changes in low-level features from that which reflects the processed meaning of the social information. Puce and colleagues provide a comprehensive overview of both what is now known about the N170 as a neural correlate of gaze behavior as well as identify open questions for continuing research in the field.

This review is somewhat paradoxical in that its content is narrower than any of the other chapters, yet the issues addressed are some of the most complex and difficult to disentangle. An important contribution by Puce and colleagues is to propose a new model potentially capable of resolving some of the seeming contradictions in the literature. This model is based on two modes of social information processing: a “Default” mode and a “Socially Aware” mode. In the Default mode, the social meaning of the stimulus is irrelevant to the task and elicited neural responses: stimulus information is processed primarily at a sensory level in terms of low-level features (e.g., spatial frequency, luminance/contrast, and basic facial features). During this mode of processing N170 amplitude and latency is modulated by the strength of the incoming sensory information. This modulation of N170 activity can provide some information regarding the stimulus, should a sudden shift to Socially Aware mode be required. In the Socially Aware mode, where the meaning of the gaze behavior is consciously evaluated, sensory gain increases so that there are no differences in N170 across different social attention conditions. This increased sensory gain allows for the modulation of later ERP activity beyond 350 ms by stimulus condition, which maximizes the interpretation of the incoming stimulus relative to the existing social context. Although this model is still preliminary, it offers some key insights into how the time course of neural processing maps onto the goals and intentions of the observer.

Nasiopoulos, Risko, and Kingstone (Chap. 6, this volume) began by questioning the sufficiency of traditional laboratory research to study social attention. They provided compelling evidence for disputing the generalizability of findings derived from well-controlled, yet simplified, experimental paradigms, because the social world is filled with situational complexities that influence social attention behavior. Moreover, the simple act of looking at someone else’s eyes is not sufficient to explain why this occurs, especially when looking at another real person, because looking serves a dual function. On the one hand, it is designed to acquire information from the individual who is viewed by the participant, while, on the other hand, it is signaling information about the motives and intentions of the looker. Based on decades of research in social psychology on the effects of *social presence* on one’s behavior, Nasiopoulos and colleagues discuss the implications of this research for studying social attention.

As also discussed in previous chapters, this research demonstrates that social attention is contextually modulated, but now the focus turns specifically to *implied* social presence. A simple reminder or cue, such as a camera, that the subject is being observed can be sufficient to influence how they will respond. These responses reflect a conformance to normative social behavior. This is thought to be the reason why participants modulate their looking behavior depending on their distance from the viewer (e.g., avoiding the gaze of an approaching stranger), or whether the target is live or merely a two-dimensional photo or video recording. Intriguingly, wearing an eye tracker can induce the same effects of social presence because participants believe that their eyes are being monitored. Some of these effects may be short-lived, i.e., exhibit habituation, but nevertheless the results are robust and thus present a caution to researchers studying social attention in the laboratory or in more natural situations. In particular, social responses are determined not only by what the researcher intends to study but also by what the participant is thinking about the situation, or the experimenter's intentions.

This chapter highlights the importance of considering how other people or simply their implied presence influences social attention. As Nasiopoulos and colleagues point out, the findings that implied social presence is often sufficient to influence one's behavior in the same way that real social presence does represents both an opportunity and a challenge for research. In contrast to manipulating the effects of social presence with real people and sacrificing experimental control, it is possible to manipulate and control implied social presence without compromising the social authenticity of the testing situation.

The chapter by Schultz, Jones, and Klin (Chap. 6, this volume) is the last of the three that focused on infants and early development. They emphasized how seeking social information is an adaptive response by typically developing infants, and how departures from this response will result in atypical development because of the cascading effects associated with less social interaction. This seeking of social information is present from birth, and is important not only for its survival value, but also because it enables social interactions and social learning. As such, social attention is conceptualized as a means of preparing infants to benefit from their social environment through an interactive process with the environment that leads to social information becoming more finely attuned with experience. The *canalizing role of early experience* explains why successful adaptation to the social environment leads to new and more advanced social behaviors, but these same processes also explain why less motivation to seek social information leads to atypical social experiences. This is in essence an epigenetic view of development that offers a valuable framework for evaluating the contributions of social attention not only during infancy but also later on in life as well.

One of the major strengths of this developmental view is that it underscores the need for longitudinal research in order to identify the root causes for social cognition disorders, such as autism. The authors devoted considerable attention to a longitudinal study that focuses on early departures from attention to eye gaze. By focusing on the developmental trajectories of both typical infants and those at risk for autism spectrum disorders (ASD), they were able to identify deviant patterns of behavior in children who were subsequently diagnosed with ASD. These results are not meant to suggest that less attention to others' eyes is a cause of ASD, but it represents a marker of emergent social disabilities as well as a mediator of subsequent social and cognitive development. This is a theme that runs throughout the volume and emphasizes that social attention is integral to how we process social information, and that social attention does not function alone. Rather, it is a part of a dynamic and complex process that emerges in both real and developmental time.

Bush and Kennedy's (Chap. 7, this volume) review of social attention deficits in individuals with ASD is a natural complement to the preceding chapter because the focus is on the consequences of aberrant social experiences rather than the early experiences themselves. They discuss both behavioral and neural evidence suggesting that individuals with ASD show differences in their visual scanning of relevant social information in a visual scene, as well as differences in the neural activation of three brain regions (fusiform face area [FFA], amygdala, superior temporal sulcus [STS]) that are involved in processing facial identity, facial expressions, and gaze direction. It is clear from this review that the evidence for social attention deficits is often inconsistent—which is to be expected given the heterogeneity of the ASD participant samples, in terms of both etiology and also behavioral expression. More importantly, these discrepancies reflect the multifarious ways in which social attention can be measured and how the same response can reflect different processing strategies. For example, ERP studies show abnormal N170 responses to faces by individuals with ASD (McPartland, Dawson, Webb, Panagiotides, & Carver, 2004; Wagner, Hirsch, Vogel-Farley, Redcay, & Nelson, 2013), but these responses become more typical when attention is explicitly directed toward the eyes of the face stimuli (Webb et al., 2012). In this latter case, the results do not necessarily imply the same mechanism as found in neurotypical adults, but rather a compensatory mechanism that is guided by some bottom-up process. Likewise, individuals with ASD were able to identify emotional expressions as quickly and as accurately as neurotypical adults, but in a more complex Stroop-type task that included matching and mismatching emotion labels the ASD group's accuracy declined relative to the neurotypical adults (Grossman, Klin, Carter, & Volkmar, 2000).

It is instructive to note that the likelihood of finding differences between ASD and neurotypical adults seems to be related to the complexity and often the subtlety of the presented stimulus information. The failure to detect a fleeting emotional expression or a quick glance in a naturalistic situation may be sufficient to explain why ASD individuals can misinterpret the intentions and motives of others. Although this hypothesis awaits more rigorous empirical testing, it aligns with the suggestions from other chapters that laboratory assessments of social attention can sometimes obscure or even eliminate the critical information necessary for eliciting an appropriate response to incoming social information. The findings reported by Bush and Kennedy offer a number of pertinent suggestions as to which sorts of real-world social interactions are most likely to reveal a misunderstanding of social information due to a deficit in social attention.

8.3 Opportunities and Challenges

8.3.1 New Technologies

Collectively, the chapters in this volume offer testament to the view that social attention is a complex and dynamic process that is interconnected with both higher and lower levels of processing social information. Sensory processing, social cognition, and social categorization are all processes that are interdependent on social attention. Just as visual attention, more generally, is influenced by higher-level processes involving goals and motivation, the same is evident for social attention, and thus it is overly simplistic and misleading to consider social attention in isolation. Yet, this conclusion introduces a serious challenge for both neural and behavioral research that capitalizes on the type of technologically advanced methods (e.g., eye tracking, fMRI, EEG/ERP/MEG) that are becoming increasingly common in the field. These methods have physically constrained the participant as well as the presentation of stimulus information, resulting in rather impoverished activation tasks. Most notably, participants have been typically precluded from moving, and yet this is exactly what they would be doing during a normative social interaction.

In spite of these apparent challenges, there is much room for optimism given the rapid advances in the development of these technologies and in data analysis methods. The advent of wireless technologies is freeing many recording systems from the “umbilical cords” that currently constrain movements. Some laboratories are beginning to experiment with recording EEG while participants are moving (Gramann et al., 2011; Sipp, Gwin, Makeig, & Ferris, 2013), and other laboratories are beginning to conduct hyperscanning experiments with recording of EEG from two participants simultaneously (Lachat, Hugueville, Lemarechal, Conty, & George, 2012). These new approaches require specialized data preprocessing methods that can identify and remove artifacts that are generated by participant movement (Gwin, Gramman, Makeig, & Ferris, 2010). In addition, there is the push to make real-time analysis of these data possible (Mullen et al., 2013). This type of approach has necessitated new developments in EEG amplifiers, which has also been stimulated by developments in video gaming and personal monitoring technology, the latter of which has typically focused on measuring steps, general activity, heart rate, and distance traveled. New options to measure and monitor continuous EEG exist, with smartphone and computer software interfaces to log, analyze, and display data that have been developed. For example, a relatively new low-cost Bluetooth device for crowd-sourced brain research is available from EMOTIV (Everleigh, Australia) and includes 14 electrodes and 9-axis motion sensors for monitoring head movement, and associated gaming software as well as the potential to record EEG data for research. A more basic EEG Biosensor System uses dry electrodes to record a single channel of EEG at a sampling rate of greater than 500 Hz (Neurosky, San Jose, CA) with data viewing applications available for the most common types of smartphones, tablets, and computers.

Naturally, there is much spadework to be done before these new methods are capable of providing reliable data for the interested researcher, but we now live in an age where most technological limitations are short-lived, especially if they are coupled with some commercial application. We suspect that EEG methodology will further benefit from the continuing advances in the video gaming industry that is beginning to introduce wireless brain recording systems with their computer games (SmartBrain PlayStation 3 System & Microsoft Xbox 360 Combo that work with thousands of Sony PlayStation 3 & Microsoft Xbox 360 video games).

Similarly, head-mounted eye-tracking systems are becoming very lightweight and much easier to use with ambulatory participants (e.g., Franchak & Adolph, 2010; Land & Tatler, 2009). Importantly, the latest systems feature two cameras—one that monitors the gaze position of the participant, and a second that monitors what the participant is looking at. This technology is also likely to benefit from other related technologies, such as future incarnations of computer–user interfaces such as Google-glass, or whatever the next generation of wearable technology produces. In spite of the excitement and optimism offered by the new emerging technologies, we must remain sobered by the cautions raised in the Nasiopoulos and colleagues' chapter (Chap. 5, this volume). With each new technological development, the *technology itself can become part of the experiment* and will inevitably influence the perceptions and responses of the participants.

8.3.2 Multimodal Data Collection

As the technological advances that we outlined above become more commonplace, researchers will have increasing opportunities to integrate multiple measures into their studies. The challenge is to develop methods that not only reliably measure all the stimuli and behaviors, but also ensure that they are synchronously recorded. For example, studying individuals who are freely moving about with head-mounted eye trackers supplies continuous information about where the person is looking as well as detailed information about the visual scene. It is critical that this information is synchronized if it is going to be used together to measure coordinated behaviors between individuals. In the future, it will become possible to add continuous EEG information as well as motion analysis information about the movements of the individuals, which will add to the complexity of synchronizing all the data streams. Nevertheless, it is our impression that the real challenge presented by these new technologies will not be the reliable and synchronous collection of data, but rather developing effective strategies to optimize the analysis of multiple time series of data simultaneously.

One of the keys to developing these strategies is the development of new analysis and visualization tools that enable researchers to characterize stimuli and multiple responses as they change over time. An example of such a visualization software tool is one developed by Yu, Zhong, Smith, Park, and Huang (2009) for displaying the eye-tracking behavior of freely moving infants while their motor behaviors and the visible stimuli in the visual scene are also synchronized and

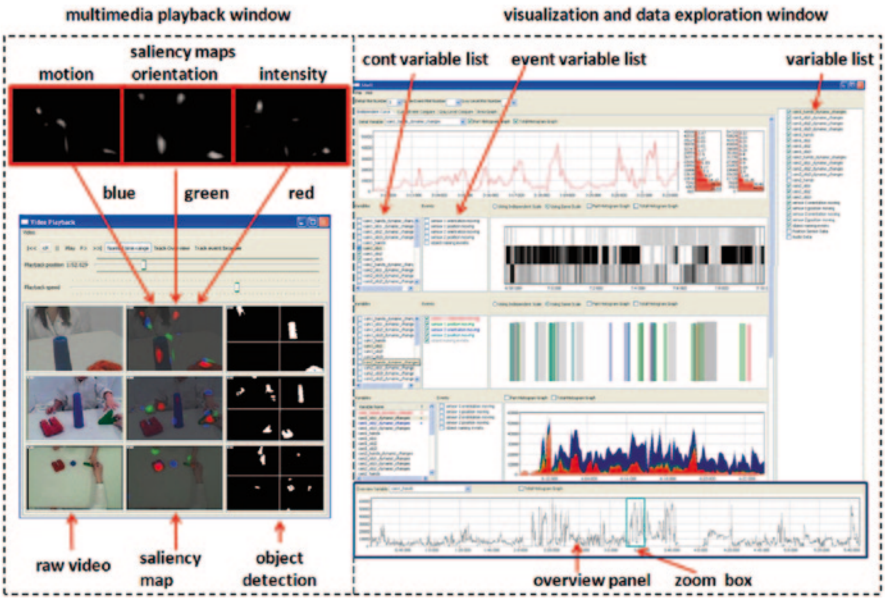

Fig. 8.1 Visualization software of data collected with a head-mounted camera. Saliency maps of image data *(left panels)*, and machine- and observer-coded data during infants' interactions with parent and objects *(right panels)* are shown. These windows are examples of an existing modular system that can be easily modified and extended to suit the goals of the project. (Reprinted with permission from Yu et al., 2009)

shown simultaneously (see Fig. 8.1). The amount of information provided by eye-tracking and video recordings is enormous and can easily become overwhelming. By enabling researchers to visualize multiple data streams at the same time, this tool provides a means for data mining, which is especially useful when theories and principles from the literature have not yet been well formulated. For example, data mining might begin with first observing covariations between different measures (e.g., gaze cueing, head movements, pointing, vocalizations, object-directed actions, and social referencing), and then testing the frequency of these dependencies. If the experimenter was specifically interested in participants' eye movements or neural or autonomic responses to facial expressions, then this behavior could be selected and stored every time it appeared in the video, and the corresponding eye movement or EEG or pupil dilation activity could be displayed and stored as well so that it was available for further analysis. If there is a systematic relation between facial expression and one or more of these variables, it is likely to be first noticed during the dynamic display of the multiple data streams. By using this visualization tool, the experimenter can apply a combination of experience, intuition, and domain knowledge to the problem to decide how to perform quantitative analyses in a modular and flexible fashion (Yu et al., 2009).

A multimodal data analysis system called Mobile Brain and Body Imaging (MoBILAB) has been developed for integrating ambulatory EEG data with motion capture, surrounding audio, video, and other physiological data (Gramann, Jung, Ferris, Lin, & Makeig, 2014; Makeig, Gramann, Jung, Sejnowski, & Poizner, 2009; Ojeda, Bigdely-Shamlo, & Makeig, 2014). Systems such as this will allow the observed behavior and associated EEG phenomena to be assessed in a holistic context that is typical of a real-world environment, and will be ideal for studying processes such as social attention.

8.3.3 Live versus Prerecorded Stimuli

A persistent theme throughout this volume has been that social attention is driven by both bottom-up and top-down processes. It is generally assumed that the bottom-up processes are automatic and reflexive and are influenced by the featural, semantic, social, and affective salience of the stimuli (Gottlieb & Balan, 2010; Todd, Cunningham, Anderson, & Thompson, 2012). In contrast, top-down processes are directed by the goals of the current behavior and are influenced by the participant's evaluation of the social demands associated with the task at hand (e.g., Laidlaw, Foulsham, Kuhn, & Kingstone, 2011). It is worth noting that an individual's goals change from moment to moment, and thus the scan patterns that they display while viewing a specific scene or conversing with someone else will depend on the agenda currently being pursued by the individual. Indeed, this finding was a key contribution of Yarbus' (1967) pioneering work on eye movements in which he reported that individuals would show different scanpaths to the same picture depending on the instructions they were given before looking. Regrettably, the implications of these findings have often been neglected in more contemporary research. One of the current challenges in assessing brain–behavior relationships underlying social attention is how bottom-up and top-down processes dynamically *interact* and contribute to both the perception and production of contextually and socially appropriate behavior. This is a challenge that is not unique to the field of social attention; systems neuroscience and cognitive/social neuroscience, among other fields, are also grappling with this same challenge.

The review by Nasiopoulos and colleagues (Chap. 5, this volume) on the effects of social presence on gaze is a refreshing exception to this current state of affairs. Early in their chapter they review evidence suggesting that task and context will affect gaze behavior, and, in particular, point out that looking at the face and eyes of a live person is much less common than looking at these features in a picture or a video recording. Although there is no reason to dispute this finding, we wish to emphasize that it is certainly not the complete story. During live conversations individuals will look at the other 75 % of the time while listening and 40 % of the time while talking; mutual gaze occupies 30 % of the time (Argyle, 1988). Likewise, parents and infants will devote considerable attention to each other during social interactions (Bakeman & Adamson, 1984).

There are two reasons for raising this issue. The first is to simply make explicit that social attention in the company of strangers is likely to be not comparable to social attention occurring between acquaintances or intimates. Curiously, this point was not discussed in any of the previous chapters. The second reason is that there is the potential to learn a good deal more about the neural processing of social attention in live situations, but only if people devote their attention to each other in these situations. Reid and Dunn (Chap. 3, this volume), Puce and colleagues (Chap. 4, this volume), and Bush and Kennedy (Chap. 7, this volume) all comment on how the measurement of brain activity is more robust and sensitive when social stimuli are presented live as opposed to presented on a computer as two-dimensional pictures or recorded events. Presumably, these stimuli are more arousing and salient, but also the task demands change in the live interaction. A participant will respond to the social attention cues of their partner, who will in turn respond to the behaviors of the participant, and so on. These dynamic interactions between two or more individuals are significantly more stimulating and complex than what can be realistically generated in a static or recorded stimulus display in a laboratory setting. Obviously, there is much more to analyze in these interactions because the current gaze response will be influenced by both previous responses as well as the anticipation of future responses.

8.3.4 First- versus Third-Person Perspectives

It is also useful to keep in mind that social attention can be studied in observers from both a first-person and a third-person perspective. The majority of research discussed in this volume focuses on social attention from a first-person perspective, but the interpretation of social information from the standpoint of viewing an ongoing social scene in the real world or in a movie or video is becoming increasingly informative (e.g., Hasson, Malach, & Heeger, 2010; Torralba, Oliva, Castelhano, & Henderson, 2006; Zacks, Speer, & Reynolds, 2009). When participants view a social scene from a third-person perspective, especially if it has been prerecorded as a movie or video, the number of people on the screen will vary from one to many. This varied visual stimulus has consequences for brain activity: neural activity is monotonically increased with the number of viewed faces (Puce et al., 2013). In the case of viewing a movie, there seems to be fairly good uniformity with regard to whom or what will be attended to by the participant observing this scene because the camera angle and behaviors of the actors will direct attention toward a specific location (Smith, Levin, & Cutting, 2012). One significant limitation of this approach is that the participant is merely a passive observer and does not need to be concerned with how he or she is perceived by the actors. Borrowing from Nasiopoulos and colleagues (Chap. 5, this volume), we could say that there is no social presence to affect the responses of the participant viewing the movie. This situation changes dramatically if the group of observed people is live rather than recorded. Now the participant is not merely a passive observer, even if he or she is relegated to merely watching the behavior of the others. In all likelihood, the presence of the others will trigger some sense of the observer being watched and evaluated which will constrain his or her behaviors. Some research relevant to this issue (e.g., Gallup et al., 2012) was briefly reviewed by Nasiopoulos and colleagues.

What about the study of social attention from a first-person perspective in groups of people? Imagine, for example, a multiparty discussion during a planning meeting with four individuals seated around a table. Do we expect that everyone will focus on whoever is talking, or will attention be more distributed among the different participants? Will participants always look and gesture toward the same individual, or might looking and gesturing function somewhat independently? What role does social status or dominance play as to which individual will be gazed at the most in the four person interaction? These are but a few of the questions that emerge when we scale up the social situation from a two-party dyadic conversation to a group discussion. The study of groups has been a major focus in social psychology for decades (e.g., Lewin, 1947; Zajonc, 1965). Yet, there is little known about how individuals within these groups distribute their social attention during communicative exchanges where the eyes serve as *both a signal and a channel for accumulating information*. We suspect that the role of social attention in group activities represents one of the new frontiers in this field that will require a host of novel methods and models for understanding the complex interactions that will be observed.

8.4 Is Social Attention Specialized?

At an intuitive level, most of us are likely to agree that social and nonsocial attention is different because the information selected serves different communicative functions. Social signals, such as eye gaze or facial expression, are intrinsically alerting because they communicate interest or warnings by conspecifics (Tomasello, 2008). This information appears to take priority over other information and is responded to rapidly and often automatically (e.g., Birmingham & Kingstone, 2009). In contrast, nonsocial symbolic information affects attention because of extensive experience with the symbol and its associated response. For example, an arrow will cue a person in a specific direction because of an overlearned association between its meaning and the correct response. These differences, however, may or may not imply any form of specialization. Both social and nonsocial information could be processed by the same mechanisms, and the only difference therefore might be a function of the stimulus information itself. In actuality, this hypothesis is but one of a number of possible responses to the question of specialization.

A similar diversity of claims about specialization have arisen with regard to language and face perception (e.g., Bruyer & Velge, 1981; Farah, 2000; Hauser, Chomsky, & Fitch, 2002; Kanwisher, McDermott, & Chun, 1997; Pinker & Jackendoff, 2005; Puce, Allison, & McCarthy, 1999; Saffran & Thiessen, 2007; Tovee, 1998), but it has been very difficult to achieve consensus on this issue. One reason for this problem is that there are significant differences in definition and interpretation of what constitutes “specialness” (Liu & Chaudhuri, 2003). At least part of the lack of agreement stems from not distinguishing between three logically separable issues: innateness versus acquisition of expertise, the existence of domain specificity, and brain localization (Bates, 1994). For example, face processing may be domain-specific but not innate, or it may be innate but not localizable within a discrete anatomical brain region. Although a comprehensive discussion of the specialness of social attention is beyond the scope of this chapter, we offer a brief synopsis of some of the issues discussed in the preceding chapters that are germane to this issue.

8.4.1 Innate versus Learned

As reviewed in multiple chapters, neonates are preferentially sensitive to face-like stimuli and they track moving faces longer than other moving patterns of comparable complexity, contrast, and spatial frequency (Easterbrook, Kisilevsky, Hains, & Muir, 1999; Johnson, Dziurawiec, Ellis, & Morton, 1991; Valenza, Simion, Cassia, & Umilta, 1996). Newborn babies less than 3-days-old prefer attractive faces based on internal features and their sensitivity is restricted to the upright orientation (Slater et al., 2000). Young infants are especially sensitive to the presence of eyes in a face (Batki, Baron-Cohen, Wheelright, Connellan, & Ahluwalia, 2001), and distinguish faces whose gaze is directed toward as opposed to away from them (Farroni, Csibra, Simion, & Johnson, 2002). These behaviors ensure that newborns attend to face-like patterns, but this by no means implies that face processing is innate and does not require a good deal of learning.

Shultz, Jones, and Klin (Chap. 6, this volume) present a compelling case for how the development of normative social interactions evolves from the spontaneous seeking-of and acting-upon social information which neonates are preferentially biased to encounter. From these iterative experiences, infants gradually learn about the social information in their environment such that they become more attuned to the cues that promote social interaction and learning. In somewhat different terms, this is what Bertenthal and Boyer (Chap. 2, this volume) referred to as interactive specialization: 4-month-old infants were cued equally by a pointing hand and a foil, but 6-month-old infants were cued more effectively by a pointing hand. The implication is that infants' response to a pointing hand became more specialized with age and experience.

In addition, recent research is beginning to provide new details about how the visual information available to infants changes with age and experience (Jayaraman, Fausey, & Smith, 2015). Infants from 1 to 11 months of age who wore a head-mounted camera during daily activities showed a decline in their attention to faces during the first year. At the older ages, infants increased their attention to viewing hands (Jayaraman, Fausey, & Smith, 2013), which is consistent with the findings reported by Bertenthal and Boyer (Chap. 2, this volume). In sum, these changes in social attention do not reflect the unfolding of some genetic blueprint, but rather the continuing adaptation of a developing child to the social and cognitive demands of the environment.

Based on the evidence presented above, there is little doubt that infants receive a head-start in learning about social information, but it is an empirical question as to whether this learning is any way different from learning about objects. From the evidence presented by Shultz and colleagues, we know that infants who are later diagnosed with ASD fail to show the same preference for faces as typically developing infants. This departure from normative social experiences is believed to retard the development of successful social adaptation and as a consequence increase the likelihood of atypical outcomes. The intriguing question presented by this evidence is whether infants at risk for ASD would show more successful outcomes if they attended more to social information, or if the problem is compounded by an additional deficit in learning about social information.

8.4.2 Brain Localization

In considering whether social attention is specialized, it appears that some of the specific deficits revealed by individuals with ASD provide some of the most compelling evidence. According to Bush and Kennedy (Chap. 7, this volume), the research literature reveals that individuals with ASD show differences in responding to eye gaze as well as orienting to and scanning of faces, and scanning of social scenes more generally. Critically, the evidence on differences in neural activation of three brain regions (FFA, amygdala, and STS) that may underlie abnormal social attention is mixed and seems to depend on how much visual attention is directed to the face or eye region. This evidence thus calls into question whether social attention can be differentiated in terms of brain localization because social deficits associated with ASD cannot be attributed to the functioning of these brain regions.

Admittedly, the preceding evidence relating to localization is incomplete, which is why the neuropsychological evidence presented by Puce and colleagues (Chap. 4) is perhaps more relevant to the current discussion. They review a report of a patient with a circumscribed lesion involving the right superior temporal gyrus (STG) who could not correctly detect left averted or direct gaze. Critically, other directionally oriented stimuli, such as arrows, did not significantly affect performance (Akiyama et al., 2006). A similar behavioral dissociation was reported in 5 patients with amygdala lesions (Akiyama et al., 2007). This evidence should not, however, be taken to imply that the STG/pSTS is localized for processing gaze behavior, because the pSTS is also selectively active for other biological motions, such as mouth, hand, and leg movements. Interestingly, these findings are consonant with the views expressed in some chapters that social attention includes a wider range of actions than just gaze or facial expressions. An additional reservation about considering social attention processes localized in the STG/pSTS is that it is possible that the locus of the problem may actually reside in the white matter pathways that carry this social information to, or from, that region rather than a function of problems in the region itself. It is possible that the connectivity between the STG/pSTS and regions such as the amygdala and fusiform cortex (see Bush and Kennedy, Chap. 7, this volume) may be aberrant. This could arise because the white matter pathways have aberrant connections, or alternatively, that these three brain regions do not send properly coordinated signals between the brain structures making up parts of the social brain (see Stanley & Adolphs, 2013). Currently, studies of functional and effective connectivity are beginning to address these questions (e.g., Ethofer et al., 2013).

8.4.3 Domain Specificity

Lastly, we consider whether social attention is domain-specific, which is often defined as a specific class of information that constitutes the input to some perceptual mechanism or process. Critically, these inputs are inseparable from the psychological processes that operate on them, but the relation is not necessarily one-to-one because there could be multiple classes of stimuli that are processed the same way or there could be more than one process that operates on the same class of stimuli (Atkinson, Heberlein, & Adolphs, 2011). For example, faces and objects may be separate classes of stimuli, but they may be both individuated by the same process, such as an object file (e.g., Kahneman, Treisman, & Gibbs, 1992), or by different processes based on whether they are perceived configurally or featurally (e.g., Farah, 2000). Thus, domain specificity does not necessarily imply that orienting to social and nonsocial stimuli will be functionally different as will become evident in the following discussion.

As has been discussed repeatedly in this volume, humans possess remarkable social attention skills that involve eye gaze, head and body orientation, as well as pointing gestures (Langton, Watt, & Bruce, 2000; Nummenmaa & Calder, 2009). Extensive research over the past decade reveals that the eyes, in particular, convey a great deal of personal information and direct our attention to specific people, places, and objects (Birmingham & Kingstone, 2009). A good deal of this research has benefitted from the use of a spatial cueing paradigm (Posner, 1980). When a face is presented in the center of the screen prior to the onset of a peripheral target, detection is faster if gaze is directed toward the side where the target will appear (e.g., Driver et al., 1999; Friesen & Kingstone, 1998). The finding that these shifts in attention are very fast (ranging between stimulus-target onset asynchronies of 0 and 300 ms) and occur when gaze direction is not predictive or even counter-predictive of target location has been interpreted as reflecting an automatic, reflexive, and stimulus-driven (exogenous) orienting of attention which is very difficult to inhibit (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004; see Frischen, Bayliss, & Tipper, 2007 for a comprehensive review).

Once it was established that people follow central eye gaze cues automatically or reflexively, researchers began asking whether this response was specialized for social stimuli. Some neuroimaging studies indicated that shifts of attention triggered by either gaze or arrows rely on different neural structures (Hietanen, Nummenmaa, Nyman, Parkkola, & Hamalainen, 2006; Hietanen, Leppanen, Nummenmaa, & Astikainen, 2008), or at least engage the same areas differently (Tipper, Handy, Giesbrecht, & Kingstone, 2008). Likewise, Kingstone, Friesen, & Gazzaniga (2000) showed that reflexive orienting to eye gaze was lateralized to the right hemisphere in a split-brain patient, whereas no such effect was found using arrows (Ristic, Friesen, & Kingstone, 2002). Furthermore, two recent studies (Greene & Zaidel, 2012; Marotta, Lupianez, & Casagrande, 2012) demonstrated a right hemisphere specialization for gaze cues that was not present for nonsocial cues. Consistent with these findings, a few behavioral studies reveal a processing advantage for gaze cues relative to symbolic cues, such as arrows (Friesen et al., 2004; Ristic, Wright, &

Kingstone, 2007), but the majority of the evidence fails to support differential processing of gaze and a range of nonsocial cues (e.g., Brignani, Guzzon, Marzi, & Miniussi, 2009; Dodd, Stigchel, Leghari, Fung, & Kingstone, 2008; Hommel, Pratt, Colzato, & Godijn, 2001; Kuhn & Kingstone, 2009; Tipples, 2002, 2008). This finding is especially noteworthy given that the neuropsychological lesion studies of Akiyama et al. (2006; 2007) discussed earlier as well as the neuroimaging studies discussed above all suggest that gaze and arrow cues are processed by different neural structures. Nevertheless, there is scant behavioral evidence that orienting to gaze cues and arrows is different.

How can we reconcile evidence for dedicated processing of eye gaze by the brain with so little empirical support suggesting a difference in responses to gaze and arrow cues? One possibility is that symbolic arrows are omnipresent and overlearned by adults, and thus result in the development of automatic stimulus-response mappings (Kornblum, Hasbroucq, & Osman, 1990; Ristic & Kingstone, 2012) that offset the dedicated processing by the pSTS for gaze cues. A second possibility is that specialized attention to social stimuli may be more related to the selection than to the shifting of attention (cf. Birmingham & Kingstone, 2009). It is typically assumed that spatial orienting to social cues primarily involves shifting attention in the direction cued by the stimulus, but it is also necessary for the observer to first selectively attend to a stimulus before orienting attention in the direction cued by it. One problem with previous research using the spatial cueing paradigm is that it compares social and nonsocial stimuli on a dimension in which both stimuli are very similar—communicating the direction of a target (Gibson & Kingstone, 2006). Conceivably, differences in selective attention may be the key to differentiating between social and nonsocial stimuli, but the standard spatial cueing paradigm eliminates this process entirely because the stimulus cue is preselected for the participant (Birmingham & Kingstone, 2009).

Clearly, there is no definitive answer with regard to whether social attention is specialized. The answer depends as much on how the question is conceptualized as it does on the empirical data (Liu & Chaudhuri, 2003). Throughout this volume, authors have referred to the processes associated with social attention as complex. We would therefore like to conclude this chapter by summarizing the value of conceptualizing social attention as a complex dynamical system.

8.5 Social Attention from a Dynamical Systems Perspective

Social attention and interpreting others' actions are foundational to how we communicate, learn about the social and physical world, regulate emotions, and develop attachments with others. Disorders in social attention are associated with several neuropsychiatric disorders, including Autism, which has been increasing over time and now has a prevalence of one in 88 children by the age of eight years (Baio, 2012). These social processes begin to emerge at birth leading some theorists (e.g., Baron-Cohen, 1995) to suggest that they are primarily innate. Yet, recent research reveals that this conclusion is overly simplistic and neglects how developmental changes in social cognition are a function of an interactive specialization between maturational changes in the brain and specific experiences of the infant (e.g., Grossman & Johnson, 2007; Senju & Johnson, 2009). This research is also demonstrating that responses to social cues vary among individuals and even within an individual across time. Moreover, many other factors, such as social cognition or state or emotion regulation, contribute to interindividual variability, and thus make it extremely challenging to observe systematic changes across individuals (Rothbart & Derryberry, 1981). These complex interactions illustrate that social behavior cannot be investigated within a deterministic and stationary model of human development.

In spite of this evidence, the prevailing paradigm for studying the development of social attention is analysis by decomposition and investigations limited to studying the neural, autonomic, or behavioral systems one age and one measure at a time (Bertenthal, 2007). Research on human social behavior and emotion has been limited to hypotheses linked to one system at a time, such as the autonomic nervous system, specific regions of the brain, such as the STS or the prefrontal cortex, or hormones (cortisol) or neuropeptides (oxytocin or vasopressin). This piecemeal and fragmented approach to the study of social behavior results in incomplete and often inconsistent models. Paradoxically, many of these systems are interrelated in terms of both common structure and function. New research is needed to enable the development of more integrated neurophysiological and behavioral models of social attention and social cognition.

The study of social attention encompasses different models and methods, but virtually all posit that behavior can be analyzed by decomposing the problem space into static variables or systems that are linearly related to each other. Human behavior needs to be studied as a dynamical system. By definition, such a system is high-dimensional, multilevel, multicausal, and nonlinear (Bertenthal, 2007). A dynamical system approach provides useful tools for describing the time evolution of systems with many interacting degrees of freedom. Although the study of dynamical systems has had a long and venerable history in the physical sciences, it has yet to have a major impact in the psychological sciences (Ward, 2002). This seems somewhat paradoxical given that psychologists are interested in a wide range of phenomena that change over time, including learning, memory, thinking, and especially development.

What has been lacking in most studies is a way of modeling how behavior is dynamic and interactive, and how it unfolds over multiple time scales. For a number of years, one of us (B.I.B.) was involved in the development of the Social Informatics Data (SID) grid (Levow et al., 2007), which was a web-based test-bed for collecting real-time multimodal behavior at multiple time scales. Multimedia data (voice, video, images, text), time series from different sensors, such as motion analysis, EEG, etc., corpuses of written and spoken languages, behaviorally coded data, as well as survey data were all stored in a distributed data warehouse employing web and grid services that supported data storage, access, exploration, annotation, integration, analysis, and mining of individual and combined data sets. The goal

Table 8.1 A summary of the transformative effects of the SID grid infrastructure

	Today	Tomorrow with SID grid	Milestones
Theories and models	Static Single cause Linear Component processes Symbolic models	Dynamic Multiple causes Nonlinear Systems or networks Embodied models	
Collaboration	Single labs annotations by single investigators Local access only	Community of collaborators Collaborative annotation Remote and distributed access	Collaborative annotation tool
Query and analysis	Standard statistical analyses Single stream Nonstandard formats and coarse alignment Single location Standalone application	Automated query, exploration, and analysis services Multiple streams Tools to acquire, transform, and align multiple data streams Multiple locations Extensible SID grid application	Query and analysis services
Measurement and annotation	Single measure Unimodal Single time scale Manual coding	Multiple measures Multimodal Multiple time scales Automated coding	Multimodal data stream tool
Data collection	Single investigator populating database on single workstation	Community of Collaborators creating SID grid data resources on grid	SuperLab legacy data sets

was to stimulate multidisciplinary and collaborative research among diverse groups of researchers. As these goals are attained, it will transform how research is conducted. See Table 8.1 for a summary of what the developers of the SID grid consider the most noteworthy transformations.

If we are to continue to make progress in understanding the underlying developmental pathways and networks responsible for social attention in children and adults, then it is incumbent on us to begin exploring the complex and dynamic interactions that occur between neural, autonomic, hormonal, and behavioral systems during development and throughout adulthood. Although we are not the first to highlight this knowledge gap, this idea has not gained traction due to the many theoretical, methodological, and analytical obstacles to implementing this objective. Overcoming these obstacles requires the combined knowledge of multidisciplinary teams of researchers with expertise in social and affective neuroscience, social neurobiology, developmental science, social psychology, cognitive science, computer science, and computational neuroscience. By coordinating and complementing each other's knowledge and skills, these teams will be able to create a much more ambitious

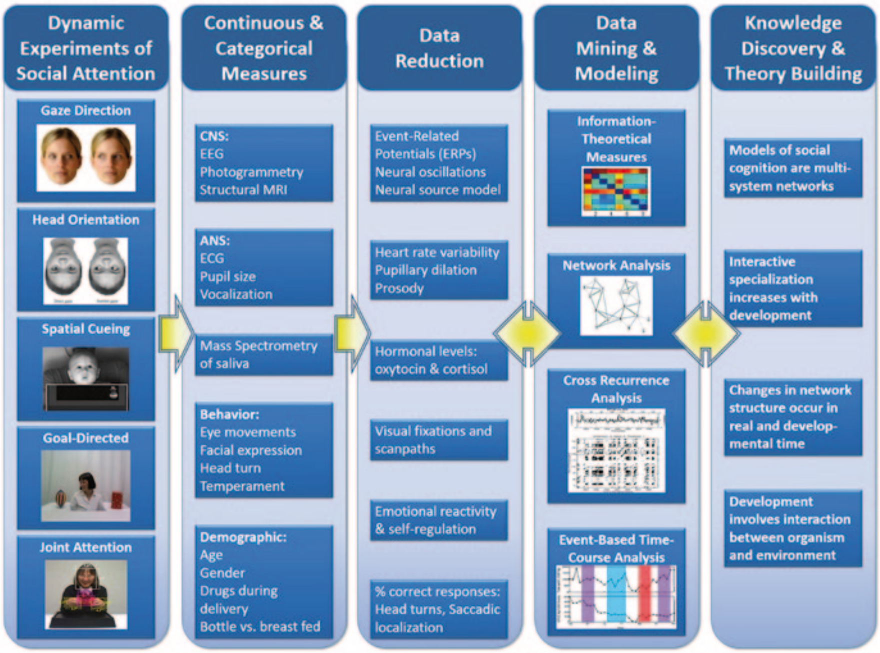

Fig. 8.2 Experimental workflow summarizing the complementarity *between* theories, models, and data. Dynamical stimuli and multimodal measures are displayed in the two *leftmost* panels. The *middle* panel focuses on data reduction and standardization. The two *rightmost* panels depict data analysis/results (including data mining and modeling) and knowledge gained/theory building, respectively

research agenda for the future. We have been involved along with a number of collaborators in developing such a research agenda for the study of the development of social attention, and this program of research along with its goals for contributing to knowledge discovery and theory development are summarized in Fig. 8.2.

As illustrated by the entirety of this volume, the study of social attention encompasses multiple models and methods, and it represents a multidisciplinary field of study, par excellence. The next step is to begin coordinating this multidisciplinary research into a more systematic program of research as exemplified by the type of workflow outlined above. It is our sincere hope that this book will have inspired some investigators to pursue this research agenda.

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