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# A Nexus Model of the Temporal-Parietal Junction

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## Abstract

The temporal-parietal junction (TPJ) has been proposed to support either specifically social functions or non-specific processes of cognition like memory and attention. To account for diverse prior findings, we propose a Nexus Model for TPJ function: overlap of basic processes produces novel secondary functions at their convergence. We present meta-analytic evidence that is consistent with the anatomical convergence of attention, memory, language, and social processing in the TPJ – leading to a higher-order role in the creation of a social context for behavior. The Nexus Model accounts for recent examples of TPJ contributions specifically to decision making in a social context, and it provides a potential reconciliation for competing claims about TPJ function.

## Introduction

The term "temporal-parietal junction" (TPJ) refers to the region of the cerebral cortex that lies along the boundary of the temporal and parietal lobes. This abstract label – which in practice does not map precisely onto any specific anatomical features – has become increasingly common in the cognitive neuroscience literature. Neuroimaging studies have found activation in the TPJ within diverse experimental paradigms that manipulate memory [1–3], attention [4–6], language [7,8], and social cognition [9–12] (Figure 1). Perhaps more strikingly than for any other cerebral region, the properties of TPJ have been subject to continual debate. There exists no consensus on whether a common function can account for these diverse experimental results, whether there is spatial heterogeneity across these functions, or even whether the TPJ should be considered a unified brain region (see Box 1).

### Box 1

#### TPJ: Combining Processes to Create Novel Functions

A diverse set of cognitive functions has been linked to the TPJ: attentional reorienting, language processing, numerical cognition, episodic memory encoding, and various processes of social cognition. No consensus yet exists as to whether these functions are each supported by distinct subregions within TPJ or whether they all rely on some similar computational process, at least in part. A recent theoretical review by Cabeza and



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colleagues [68] advances the perspective that all these diverse functions rely on bottom-up attention, which is considered to involve capture of attention both by external stimuli and by information entering working memory from long-term memory. This view supports an overarching function of ventral parietal cortex – which subsumes TPJ – and argues against the idea that the ventral parietal cortex is fractionated into domain-specific subregions. The core idea of this perspective – that convergent processes produce novel functions – can be generalized to other combinations of processes known to engage lateral parietal cortex. By relaxing the constraint on spatial homogeneity and incorporating the anatomical positions of contributing pathways (two potential changes alluded to by Cabeza and colleagues), the TPJ could be envisioned to play an even broader integrative role, one that goes beyond interactions between attention and memory.

The challenge of understanding TPJ function has become most evident in research on social cognition. One perspective holds that the TPJ plays a critical role in processes related to social cognition, such as mentalizing [13], perspective taking [14], and detection of social agents in the environment [15–17]. Supporting this perspective is a wealth of data from functional neuroimaging studies – which reveal almost ubiquitous activation in the TPJ during social cognition tasks (Figure 1) – as well as less-extensive electrophysiological [18,19] and lesion data [20,21]. Recent work, for example, has linked TPJ structure and function to pro-social tendencies like altruism [16,22]. An alternative perspective contends that the TPJ plays no specific role in social cognition. Neurologists have long recognized that damage to the right inferior parietal lobe can lead to the condition of hemispatial neglect, which is characterized by frank deficits in attentional control, but not necessarily by specific deficits in social cognition (reviewed [23,24]). Accordingly, activation of the TPJ in social cognition tasks could reflect component processes (e.g., selective attention) that are critical for, but not unique to, social interactions [25,26].

In this review, we evaluate evidence for each of these perspectives. While each makes distinct predictions for the cognitive function supported by TPJ – if the region is to be considered a single functional unit – the perspectives can be reconciled by relaxing the assumption that TPJ is an integrated whole. Here, we propose a *Nexus Model* for TPJ function. We contend that the functionally defined TPJ reflects anatomically convergent streams that support distinct cognitive processes. The combination of those streams in TPJ supports the construction of a social context for behavior, which in turn alters modes of processing elsewhere in the brain.

## Social Contexts Shape Behavior

Research from economics, psychology, and other social sciences indicates that – under some circumstances – the establishment of a social context can change behavior. If a logical reasoning problem is reframed into a question about social norms, then it can be more easily and accurately solved [27]. Decisions in economic games change depending on whether the opponent is a human or computer program, even if there is no difference in that opponent's objective play [28,29]. These and other examples could be criticized, however, as being more engaging than their non-social counterparts [25]. While such criticisms can be answered within individual studies by controlling for familiarity or task difficulty, it is difficult to completely rule out all possible confounding factors.

To obtain conclusive evidence that social context represents a qualitatively distinct state, researchers would need to demonstrate that the presence of a social context does not simply exaggerate or dampen behavior but rather qualitatively changes it. Such evidence comes from studies of the effects of monetary incentives on social behavior [30,31]. Beginning in the early 1970s, economists recognized that money sometimes served as a disincentive for engaging in pro-social behavior; e.g., paying people to donate blood leads to lower rates of donation [32,33]. In a landmark study, Gneezy and Rustichini introduced fines to discourage parents from being late when picking up their children from daycare [34] – but the fines actually increased the number of late arrivals. Across this and many other studies [35,36], it has been shown that the introduction of economic incentives can eliminate social motivations for decision making (e.g., concern for others' time), changing behavior dramatically. This phenomenon has become known as "reward undermining" or "motivation crowding" [37] and has been demonstrated to coincide with changes in value representations in the brain [38].

Reward undermining provides a prototypic example of how establishment of a social context – or elimination of that social context – determines the decisions people make. But, it is hardly the only such example. An artificial social context can be created within the laboratory through a minimal-group paradigm, in which unconnected individuals are separated into groups by some random or arbitrary assignment (e.g., distributing t-shirts; [39]). After such groups are established, individuals become more willing to allocate money to in-group individuals [40] or to punish out-group individuals [41]. These effects are exaggerated by the administration of the hormone oxytocin [42], and dampened when a personal relationship is established with an individual from within or outside the group [43]. The common thread across these disparate areas of research is the idea that the presence or absence of a social context changes the mode of processing, in turn altering the decisions people make.

## Social Function in the TPJ

Select lesion [20,21,44] and stimulation [45,46] studies provide evidence for social function in the TPJ (Figure 1, black outline), but more generally, findings are highly dependent on spatial location. As described above, the best evidence for social function in the TPJ region comes from neuroimaging studies [47,48]. To establish the replicability of these findings, data from a large literature base can be readily combined using meta-analytic techniques that evaluate how selectively activation in a particular brain region is linked to specific cognitive processes; this practice is labeled *reverse inference* [49]. Reverse inference, especially when based on the results of a single study, may have limited utility beyond guiding future hypothesis testing [50]. When drawn from many studies, however, reverse inferences can provide insight into functional dissociations between brain regions.

We utilized the meta-analytic resource Neurosynth (neurosynth.org, [51], ~4000 total studies) to identify brain regions where activation is very likely to have been produced by social function (Figure 1). Although these results are corrected for the whole-brain volume, we describe only those in the greater TPJ region – focusing particularly on the right TPJ, where evidence for social function has been considered particularly strong, although similar arguments can be made for left TPJ.

Across many studies, there is considerable evidence that activation in TPJ and surrounding regions is selectively related to the perception and evaluation of social stimuli (Figure 1). Two regions on the lateral surface of the occipital cortex are selectively active for biological stimuli [52]; one representing faces (the lateral occipital face area [53,54]), and the other representing other parts of the body ('EBA' and 'Body', [55]). Regions overlapping with the inferior portion of the TPJ are linked to more complex social functions like biological motion ('Biological', [56–58]), gaze detection ('Gaze', reviewed in [59]), and identification of facial expressions ('Expression', [57,60,61]). And, activation in the angular gyrus, in particular, predicts complex social functions like mentalizing ('Mentalizing'), intention

('Intention') and theory of mind ('Theory of Mind'). While these reverse-inference maps provide an unbiased representation of the sampled literature, there remains the possibility of publication bias; i.e., that studies observing these relationships would be more likely to enter the literature in the first place. Even with this caveat, the evidence seems strong enough to conclude that if a study finds activation in the angular gyrus (especially the inferior angular gyrus) the brain was likely engaged in some form of social processing.

Collectively, these results point toward a topography of social processing along the lateral surface of the posterior cortex, beginning with face-sensitive regions that border retinotopic visual areas and continuing to regions representing social context in the angular gyrus (Figure 2). This configuration evokes one of the organizing principles of neural systems in the brain: that more abstracted stimulus representations are constructed from simpler inputs [62,63]. Here, static social stimuli are first transformed into moving agents and then placed in a context where their actions can be interpreted. The potential existence of a social processing stream was recognized in some of the earliest fMRI studies [47], was a motivating factor behind the labeling of the TPJ as playing a role in social processing [11], and has implications for clinical cognitive neuroscience including the links between TPJ and autism [64,65].

The idea that TPJ integrates information to construct a social context is consistent with the more narrow interpretations of social activation in the TPJ [66]. But, it stands in opposition to alternative explanations of social context activation in the TPJ, including arguments for effects specific to attention [25,67], memory [68], and language [69,70]. Next, we consider the most prominent such argument, which reinterprets TPJ activation during social interaction as a reorienting of attention to an external source.

## Broader Explanations for TPJ's role in Social Cognition

A key challenge for theories positing a social function for TPJ has been the consistent link between lateral temporal and parietal cortex and aspects of attention (see [71] for review). Patients with lesions near the TPJ region in the right hemisphere often display a striking inability to attend to stimuli that are presented in the left visual field (i.e. neglect, [23,24]). Moreover, tasks that involve the reorienting of attention to an external cue (e.g., in the Posner cuing task) reliably evoke activation in TPJ (see the meta-analysis in [67] as well as the Neurosynth summary in Figure 3). Reorienting attention to important unexpected targets (e.g., invalidly signaled targets), but not to expected events (e.g., validly signaled targets), has been interpreted as a mechanism for external objects to pull attention away from internally driven processes. With this role in reorienting in mind, it was proposed that previous evidence of social function in the TPJ could be reinterpreted as the orientation of attention to a particular class of important external stimuli [25].

Externally directing attention may indeed be critical for adaptive social cognition. One hypothesized mechanism for representing and responding to social stimuli is to simulate another person's perceptions, thoughts, and actions using the same systems that support those processes for self [72–74]. Doing so, in principle, introduces the problem of differentiating one's own perceptions and behaviors from those of an individual one isobserving. If the TPJ's role in social function were one of externally orienting attention, it could serve exactly this role by signaling that simulated social processes originate from an external source. Consistent with the idea that a similar region is implicated in externally reorienting attention and in social cognition, both meta-analyses [67] and direct comparisons of attention reorienting and theory-of-mind tasks [26,75] find overlapping brain activation for both processing domains in the TPJ.

Though both within the TPJ, social cognition and attentional processes do evince some spatial heterogeneity: activation peaks associated with theory of mind fall largely in the inferior angular gyrus (AG) and peaks associated with reorienting activation fall within the supramarginal gyrus (SMG) (Figure 3). This spatial bias is also present in the original work proposing overlapping functions (e.g., contrasting the activation for theory of mind with the reorienting of attention, [67]) and in previous anatomical segmentations of the TPJ [76,77]. An alternative interpretation of this correspondence, therefore, is that social cognition shares some processing with attentional reorienting – but also contains dissociable elements. In particular, building a social context depends on information that cannot readily be extracted from ongoing perception, but instead arises from internal goals, memory, and semantic abstraction. Thus, social cognition may not be subsumed by attention, but instead may integrate information derived from attention with that derived from other processing streams – using that integrated information to construct a social context.

## A *Nexus Model* for TPJ Function

Incorporating social input into decision making requires more than the recognition of another person or agent. A gesture from that agent might be interpreted in very different ways depending on other available information (e.g., past experience or the agent's description of their intentions). Ambiguity associated with the perceptual stimulus (so that perception can be mapped to the appropriate action) can be resolved through the construction of a social context.

To construct such a context, the brain must engage processing associated with nominally disparate domains: perception (especially of biological stimuli), attention, memory, and language/semantics. The functional organization of the posterior lateral surface of the cerebral cortex hints at the integration of these domains in TPJ (Figure 4). As described previously (see Figure 2), processing associated with perception of social agents falls along a topography that begins with the identification of faces and bodies in the lateral occipital cortex and builds in abstraction dorsally into the TPJ where a context for the social agent can be recalled and prioritized to support inferential processes like mentalizing.

Attention and memory processing streams converge in the TPJ, as well. Studies employing the term *attention* are very likely to report activation in two distinct attentional pathways, reminiscent of the *action* and *perception* pathways proposed by Goodale and Milner [78]. Studies of *memory* reliably report activation in parallel neighboring dorsal and ventral clusters. These two regions have been proposed to follow a similar action-perception dichotomy; i.e., endogenous, indirect, or goal-directed recall is distinct from exogenous, direct, or stimulus-driven recall [2,68]. The clusters of activation likely to be found in attention and memory studies nearly surround the TPJ. The supramarginal gyrus (SMG), within the TPJ, is perfectly situated to allow the convergence of the dorsal and ventral attention/memory streams. Consistent with a nexus model of TPJ function, crosstalk between the two streams in the SMG could support a new, otherwise unavailable function; allowing a goal to be interrupted in order to reorient attention to a salient stimulus (as proposed for the TPJ by Corbetta and colleagues [25]).

Finally, studies employing the term *language* evoke activation along the superior temporal sulcus (Figure 4). Along the poster portion of the superior temporal sulcus social and language processing streams converge and we find activations (Figure 2) commonly evoked by studies of eye gaze, facial expressions, and the perception of agency in non-biological objects. The social, attention, memory, and language processing streams evince partially overlapping activation within TPJ, consistent with the idea their output is integrated to create a social context. In these and other cases, the spatial juxtaposition of more basic processes may allow neighboring groups of neurons to interact in a way that produces more complex and otherwise unavailable functions.

We propose that TPJ activation signals not just the presence of another social agent but the convergence of multiple functions in the TPJ nexus in order to establish a social context; i.e., a decision situation that involves another agent whose goals or actions can influence one's own behavior. As examples, self-reported altruism has been linked to changes in TPJ activation associated with observing another agent [16], pro-social behavior in economic games has been linked to TPJ structure and function [22], and vmPFC value signals associated with charitable giving have been shown to be modulated by activation in TPJ [79]. Two recent studies indicate that TPJ can be modulated by the perceived relevance of another's actions for one's own behavior. Participants who engaged in strategic deception within a bargaining game showed activation in TPJ that was greatest on high-value trials (i.e., those where the deception leads to large rewards); no such effect of value was observed in participants who engaged in systematic deception across all trials [80]. And, it has been recently shown that the TPJ contains unique information predictive of bluffing behavior in an interactive poker game, but only when participants are competing against a human opponent who is seen as a credible opponent (Box 3). The importance of context to social function has a parallel in experiments using oxytocin, which amplifies social behavior when administered to members of a group but has reduced effects in a non-social or out-group context [42,81]. Collectively, this evidence indicates that TPJ contributes to decision making specifically when there is a social context relevant for current behavior.

**Box 3**

### Construction of Social Context in Decision Making

A recent study investigated decision making in social and non-social contexts, as fMRI participants played a simplified poker game against human and computer opponents [83]. The game was a variant of von Neumann's one-card poker [90], in which a player was dealt a single high or low card and must decide whether to bet or fold. The authors used combinatoric multivariate pattern analysis (cMVPA) to predict bluffing decisions – whether someone bets when dealt a low card – from patterns of activation in anatomically defined regions. For each brain region, the authors computed the degree to which its predictive power was independent of that of other regions. Consistent with prior studies, most regions typically associated with social cognition (e.g., frontal pole, precuneus) carried independent information that predicted participants' eventual bluffing decisions against both human and computer opponents (Figure 5A). For most such regions, however, the results were consistent with an overall increase in information when playing against the human opponent. Information content in the TPJ, in contrast, was selective for the social context (Figure 5B). Moreover, the selectivity of TPJ was eliminated in those participants who judged the computer to be the more competent opponent, consistent with research on dehumanization [91,92].

These results support the conception that social decision making engages processes that would also be engaged in non-social contexts, at least for regions like the medial prefrontal cortex and precuneus. But, they also argue that TPJ contributes to decisions only when those decisions are embedded in a social context; that is, when interacting with another agent whose internal states can be modeled and whose actions are relevant for one's own behavior.

## Conclusions and Predictions

The perspective proffered here points to a reconciliation of the ongoing debate on the contributions of TPJ to social cognition. So far, that debate has revolved around the generally accepted evidence that TPJ is active during tasks involving social cognition, with one perspective arguing for a specifically social function (e.g., mentalizing) and another arguing for a general, non-social function (e.g., selective attention). Impeding resolution of the debate has been imprecision in the functional description of TPJ; as shown in Figure 3, meta-analytic evidence supports the view that multiple functions produce spatially differentiable (but overlapping) activations within the TPJ. Based on that evidence – and on the specific conditions under which TPJ activation is elicited in decision making – we argue that within the TPJ the angular gyrus supports the construction of a social context for behavior based on integrated information from converging processing streams.

Several predictions – some tested, some testable – follow from this proposal. First, changing from a non-social to a social context should increase activation within the TPJ and its functional connectivity with other task-relevant regions (e.g., [82]). Should the TPJ indeed be critical for *establishment* of that social context, then its activation should be observed earlier than that of other regions implicated in social processing. And, when social information becomes irrelevant for behavior, the TPJ should be disengaged even if a social agent is still present [83].

Second, there should be spatial biases of processing within the TPJ (and neighboring regions) that mirror the anatomical organization of the contributing processing streams. That is, the topography within TPJ should be derived from the functional properties of surrounding regions. For example, recent quantitative analyses have linked the incidence of spatial neglect specifically to lesions of anterior TPJ, specifically the posterior superior temporal gyrus (pSTG), and not to more posterior regions of parietal cortex [44]. That result is consistent with a convergence of attentional and semantic streams in pSTG. Convergence of other pairs of processing streams will contribute to different higher-order processes (e.g., social and memory processing to contribute to autobiographical memory).

Third, the neural machinery used to construct a social context can be co-opted for use in non-social contexts. Under some conditions, stimuli that are not intrinsically social may be best processed through the introduction of social context – even if one would not exist, otherwise. This phenomenon is well documented within the domain of social cognition. As examples, TPJ shows robust activation to simple visual displays where the movements of shapes fit a social narrative [84] or where the change in the display implies the action of another agent [16]. But, similar effects should be possible within decision making, particularly when individuals can improve decisions by simulating others' perspectives [85].

As a concluding note, we emphasize that heterogeneity within TPJ is still consistent with a role for that region in social decision making. Under the perspective advocated, the contributions of TPJ to social cognition arise *because* it is a heterogeneous region – it sits at the nexus of several distinct processing streams, each of which carries information relevant to social cognition. When the information in those streams becomes relevant for a particular decision, the TPJ helps establish a social context for decision making –shaping processing elsewhere in the brain.

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**Box 2**

## Meta-analyses: Advantages and Limitations

Neurosynth ([51], neurosynth.org) and other meta-analytic efforts like BrainmapWeb ([86], brainmap.org), SumsDB ([87], http://sumsdb.wustl.edu/), and Talairach Daemon ([88], talairach.org) seek to leverage the explosive growth in neuroimaging over the last decade to produce a reliable functional brain map. These efforts have become powerful tools, allowing robust specification of regions of interest and quantitative descriptions of functional specificity. They can even provide information about the practice of research by mapping language use and providing pointers to open research questions [89]. With this promise, meta-analytic tools also bring new pitfalls. Meta-analyses act as a sort of popularity contest that can produce either positive or negative consequences. For example, a finding that was incorrect but influential might enter into meta-analyses, and thus persist long after it had been corrected by a single crucial study. The fragmentation of cognitive neuroscience has allowed some correction in this arena to take place by allowing multiple fields to label the function of a single region. And, even for a large database like Neurosynth (~4000 studies by early 2013) the sample of studies may not be sufficient to make strong conclusions about particular terms or concepts, nor does it necessarily represent the literature as a whole. How to optimize meta-analytic approaches to neuroscience has become an active area of research – one that holds promise for undisturbed and open evaluations of commonalities across an expansive literature.

**Box 4**

## Outstanding Questions

- What computations are supported by regions within the parietal cortex where attention and memory processing streams overlap, compared to the processing within each stream independently?
- Are there common topographic features that predict processing stream convergence in other areas of the brain?
- What is the relationship between number processing and attention in the dorsal parietal cortex?
- How does information in the TPJ shape processing in regions involved with value computations?
- Can meta-analytic descriptions of function (like Neurosynth) be used to improve the prediction of behavioral deficits from lesion mapping data?
- What is the appropriate spatial resolution for description of neuroimaging results, given evidence for overlapping functions?
- How might hemispheric asymmetries in TPJ function interact with distinct sorts of social contexts?

## Highlights

1. The TPJ supports novel functions synthesized from convergent processes.
2. Attention, language, memory and social processing streams intersect in the TPJ.
3. Convergent processing in TPJ establishes a social context for behavior.

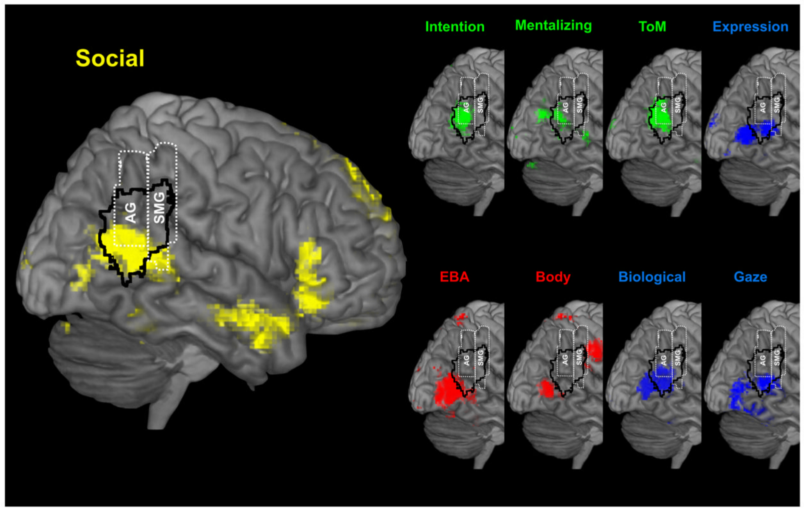


**Figure 1. Meta-analytic evidence of social function encoding in the greater TPJ**

Reverse-inference maps from Neurosynth.org, rendered on the right lateral surface of a single brain, illustrate the location of activations that are likely associated with social cognition. Within the sampled studies (~4000 included), activation in the colored region was significantly predictive of the displayed phrase. The reverse-inference map for the term 'TPJ' is displayed as a black outline for reference and includes portions of the angular gyrus (AG, white dotted line [93]), supramarginal gyrus (SMG, white dotted line [93]), and superior temporal gyrus/sulcus. Activation within the lower portion of the TPJ, along the superior temporal sulcus, is significantly associated with studies using the term 'Social'. Within the TPJ, in the angular gyrus, reverse inferences are statistically valid for terms that reflect the process of thinking about another person's mental processes ('Intention', 'Mentalizing', 'ToM' – theory of mind), as well as terms reflecting the interpretation of physical actions of social agents like eye-gaze ('Gaze'), biological motion ('Biological'), and facial expressions ('Expression'). Immediately inferior to the TPJ, significant reverse inferences clusters are present for the representation of social stimuli like bodies ('Body' and 'EBA' – extrastriate body area). The displayed statistical maps, downloaded in the fall of 2012, are whole-brain corrected for multiple comparisons [51].

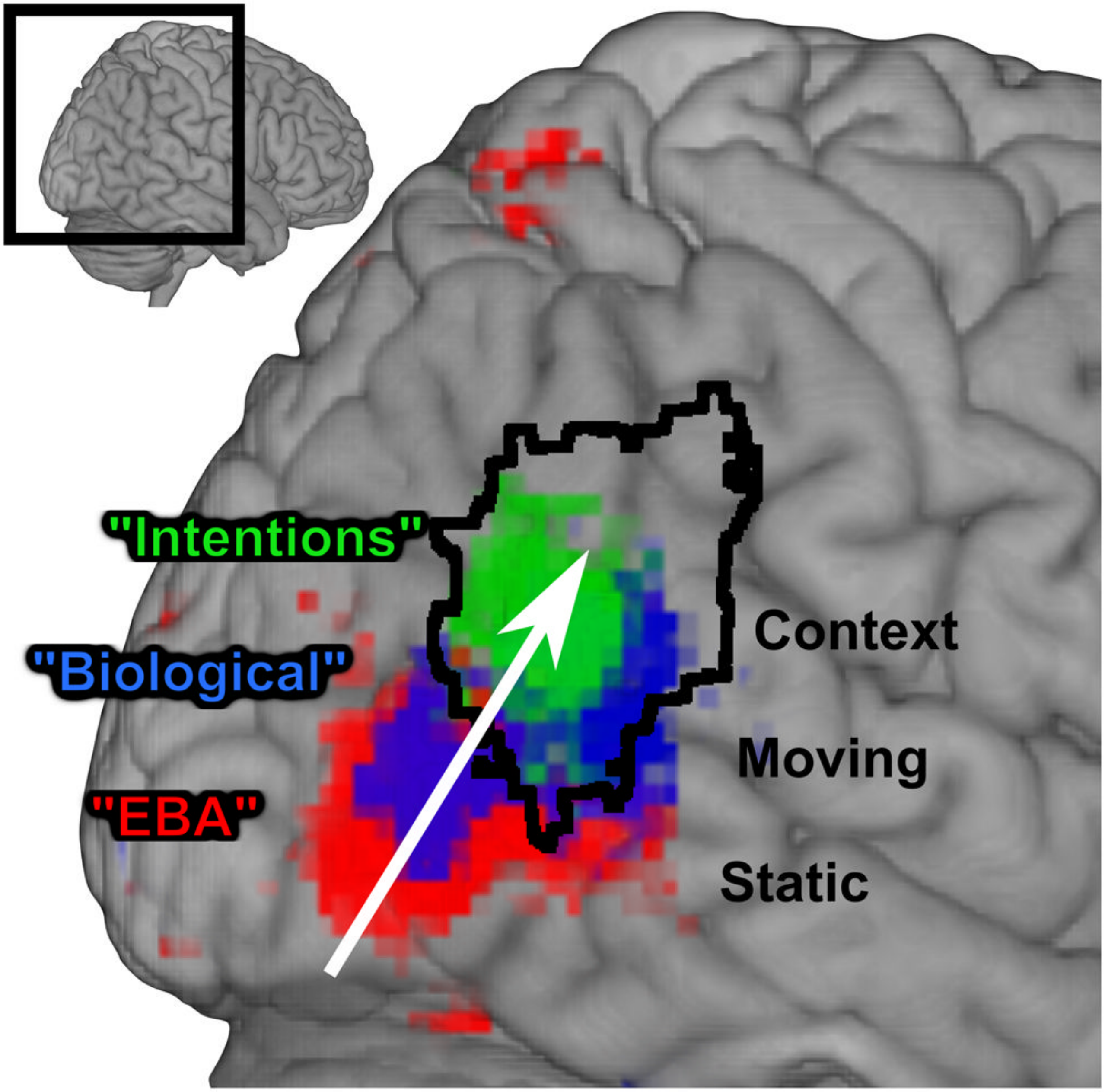


**Figure 2. Social context is constructed from information represented immediately inferior to the TPJ**

Social context construction is proposed to begin with the neural representation of static social images ('EBA' – extrastriate body area) in the extrastriate cortex. These static images could then be used to construct representations of moving social entities ('Biological' – biological motion). Representations of moving individuals could then be incorporated in a context for interpreting intentions ('Intention'). As in Figure 1, the black outline represents the extent of the reverse-inference map for the term 'TPJ'. The angular gyrus (AG, white dotted line [93]) and supramarginal gyrus (SMG, white dotted line [93]) are also displayed for reference. Reverse inference maps were downloaded from Neurosynth.org in the fall of 2012, are rendered on the right lateral surface of a single brain, and are whole-brain corrected for multiple comparisons [51] using false discovery rate correction at $p<0.05$.

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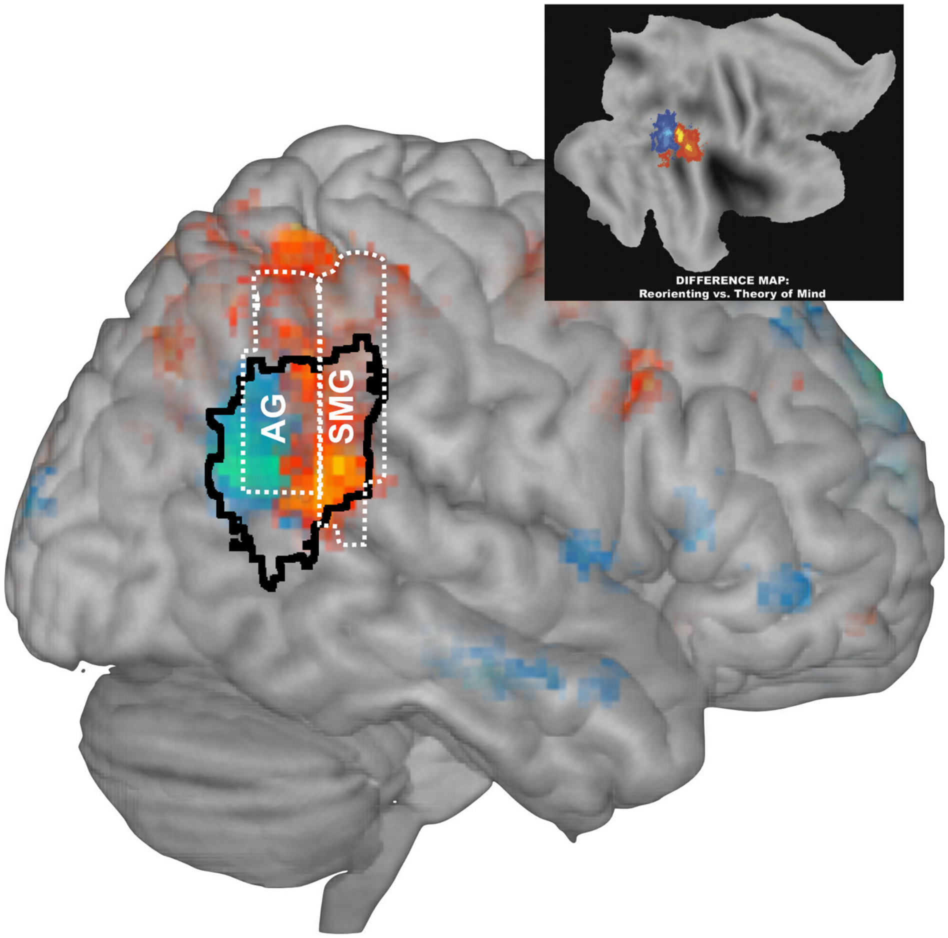


**Figure 3. Attention and social cognition evoke overlapping but separable statistical maps within the TPJ**

Spatial differentiation between activations produced by attention-reorienting (orange, ‘Corbetta’ – one of the primary researchers of attention-reorienting) and theory-of-mind (blue, ‘ToM’ – theory of mind) tasks. This spatial bias in activation peaks is consistent with that found when activations were compared for the two functions in a meta-analysis by Decety and Lamm (inset; reproduced, with permission, from [67]) and comparison of the two tasks in the same experiment [26,75]. The black outline represents the extent of the significant reverse-inference map cluster for the term ‘TPJ’. The angular gyrus (AG, white dotted line [93]) and supramarginal gyrus (SMG, white dotted line [93]) are also displayed for reference. Reverse inference maps were downloaded from Neurosynth.org in the fall of 2012, are rendered on the right lateral surface of a single brain, and are whole-brain corrected for multiple comparisons [51] using a false discovery rate of p<0.05.

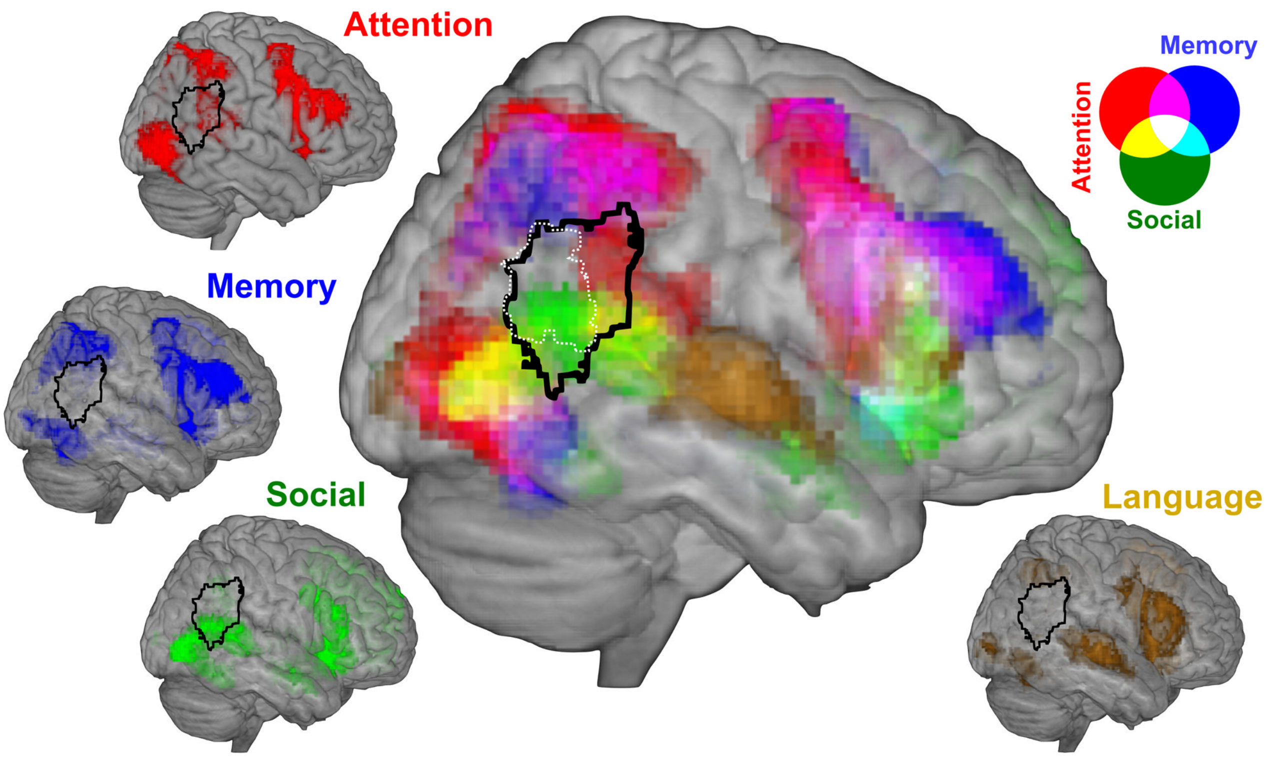


**Figure 4. The TPJ is anatomically positioned at the nexus of the social, attention, memory, and language processing streams**

Regions of the brain where activations are likely to be found for studies using the terms ‘social’ (green), ‘attention’ (red), ‘memory’ (blue), and ‘language’ (gold). Processing streams associated with these terms converge on the TPJ where novel functions are produced from combinations of neighboring processes. One such novel function that requires both the representation of social stimuli and the context provided by attention, memory, and language is theory of mind (‘ToM’ reverse inference map, white dotted line). Statistical maps were downloaded from Neurosynth.org in the fall of 2012, are rendered on the right lateral surface of a single brain, and are whole-brain corrected for multiple comparisons [51].

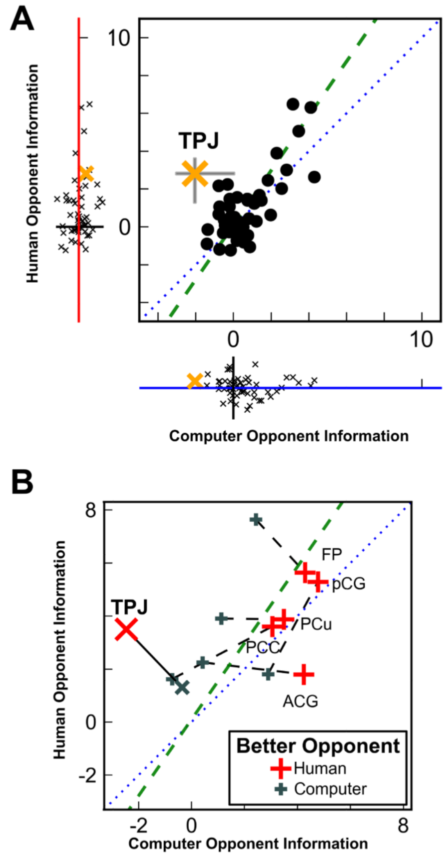


**Figure 5. A distinct role for the TPJ in social cognition**

Recent work has shown that the TPJ contained unique information that predicted bluffing against a social but not a non-social opponent (Adapted from [83]). (A) Multivariate pattern analysis was used to measure the independent information contained within each region toward predicting poker bluffs against a human opponent (y-axis) and poker bluffs against a computer opponent (x-axis). Orthogonal distance regression was used to identify a pattern of greater information content in the social context, consistent with perspectives that assume a single processes that is more engaged when interacting with other humans (dashed line). (B) One region, the TPJ, stood out as an outlier: it was one of the regions that most predicted decisions against the human opponent, but the least predictive regions against the computer opponent. This effect was modulated by the participant's opinion of their opponent. If the computer was considered to be a better opponent than the human, the TPJ was no longer predictive.