Special issue: Editorial

Cognitive neuroscience goes social

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In recent years neuroscientists have begun to investigate the neural mechanisms underlying cognitive, emotional and affective processes that are core to many aspects of our social behavior. As a consequence, the neural mechanisms underlying phenomena and constructs typically considered by social psychologists have begun to be investigated. These emerging findings have facilitated the development of models attempting to bridge social cognition with neuroscience. The work has tapped a wide variety of issues within social cognition — to name but a few: empathy, moral decision making, imitation/social contagion, mimicry, cooperative joint action, racial prejudice, stereotypes, self-other in social context, etc. — and we believe the research has now reached a critical level of reliability and sophistication. With this special issue we wish to reflect new waves of interdisciplinary research, highlighting the interaction between individuals (healthy human infants and adults, brain damaged patients, and macaque monkeys) in social actions, imitation, mimicry, and self-other construal. Reflecting the emerging research field, an impressive variety of techniques are brought together here, covering kinematic recoding, electroencephalography (EEG), transcranial magnetic stimulation (TMS), functional magnetic resonance imaging (fMRI), and functional near-infrared spectroscopy (fNIRS). Both the overlap of similar issues and the converging evidence from the different techniques illustrates the depth of the analyses now taking place.

1. Joint action

The first question the special issue deals with concerns the emergence of social communication in evolution. Are humans the only primates who perform cooperative actions or is this ability already existent in non-human primates? To answer these questions, Visco-Comandini et al. (2015) analyzed the behavior of three pairs of macaque monkeys engaged in solo and joint-actions. The results showed that, when acting together, monkeys reciprocally adapt their behavior to maximize their common performance. Interestingly, the authors also speculated that the emergence in evolution of primates' extraordinary flexibility, required for co-operative joint actions, was likely to have been made possible by the development of fronto-parietal networks in the primate brain. Action co-operation was also the topic of the study by Eskenazi, Rueshemeyer, de Lange, Knoblich, and Sebanz (2015) who used fMRI to assess the neural network associated with the *observation* of joint actions. The authors reported the involvement of several brain regions when joint actions are observed: the temporal poles and the precuneus, linked by the authors to mental state reasoning and the retrieval of memories associated with social scripts, and the ventral striatum associated with a hedonistic response to observed shared intentional relations, when mental states are shared with others.

The processes that play a central role in joint task performance seem to be modulated by the neuropeptide oxytocin. Ruissen and Ellen de Bruijn (2015) observed an enhanced Simon effect in a joint action context after oxytocin administration, compared to placebo. Moreover, the administration of oxytocin affected the N2 component of the evoked response, thought to reflect response conflict elicited by simultaneously activated but conflicting response tendencies. Alongside this, the amplitude of the P3 component, taken as an index of response inhibition, was larger when performance was undertaken in a social rather than an individual context, though oxytocin was not responsible for this effect. Taken together the behavioral and the N2 results suggest that oxytocin makes participants more prone to represent and attend to a co-actor's task. Furthermore, by promoting higher similarity between actor and co-actor, oxytocin may also enhance self-other integration.

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Joint interactions are clearly important in human development. Lloyd-Fox, Széplaki-Köllőd, Yin, and Csibra (2015) used fNIRS to demonstrate that only the combination of ostensive signals, such as infant-directed speech and direct gaze, modulated the brain responses of 6-month-old infants to speech and gestures in an ecologically valid setting. Interestingly infants' responses were localized in regions known to be involved in processing auditory and visual aspects of social communication.

2. Action imitation and learning

Humans are primarily social beings and therefore it is not surprising that many of their actions are directed at communicating and interacting with others. Factors that may provide the building blocks of such interactions are action imitation and learning through the operation of a fronto-parietal system (e.g., Rumiati et al., 2005) which may operate very early in human development (Meltzoff & Moore, 1977). The mechanisms of action imitation and learning are the subject of several papers in the current issue. First Bardi, Bundt, Notebaert, and Brass (2015) measured activity in the putative mirror system while participants passively watched finger movements, without having the opportunity to execute the task. The authors showed that the mere instruction to form a counter-imitative mapping changed mirror responses as indexed by enhancement of motor evoked potentials (MEPs) induced by TMS. Thus the implementation of task instructions activates stimulus-response associations that can overwrite mirror representations. In another TMS study, Sartori, Betti, Chinellato, and Castiello (2015) had participants observe a soccer player performing a penalty kick in various conditions that emphasized different components of the action. All participants observed a soccer player carrying out a penalty kick a) running straight towards them and then coming to a full stop, b) running straight towards them and then continuing to run, and c) running to the side and then continuing to run. The results showed a modulation of the observer's corticospinal excitability, assessed through the motor response evoked by the application of TMS to motor cortex. In particular, there was modulation of output to quadriceps femoris, when the kick in the first part of the action was observed, activation of the lower limb muscle associated with watching the soccer player before performing the run and activation of the flexor carpi ulnaris in the final phase of the viewed action. The results point to predictive coding in the motor system (shown in motor activity prior to the player performing the run) as well as direct responses to seem actions (e.g., when a kick was observed).

Imitation may also be critical in modulating emotional responses to our social environment. Rauchbauer, Majdandžić, Hummer, Windischberger, and Lamm (2015) study here clarified that mimicry in response to happy and to out-group faces is driven by distinct affiliative goals, and that mimicry regulation to attain these goals is mediated by distinct neuro-cognitive processes. In particular, higher mimicry in response to happy faces seems to denote reciprocation of an affiliative signal, while higher mimicry in response to out-group faces reflects an appeasement attempt

towards an interaction partner perceived as threatening. These effects may also be modulated by gender. In their paper Korb et al. (2015) used repetitive TMS to examine the neural basis of mimicry to faces expressing different emotions. They found that rTMS to primary motor cortex and to primary somatosensory cortex disrupted facial mimicry in females but not males. Intriguingly the data suggest that the neural basis of facial mimicry may vary across males and females.

3. Action in a social context

In their paper in the special issue, Straulino, Scaravilli, and Castiello (2015) investigated the role of the dopaminergic system in actions performed in a social context. They studied patients with Parkinson's Disease (PD) when they received the dopamine replacement therapy (Levodopa) or when they were off therapy. Participants were told to reach for and grasp an object with the aim being either to hand it to another person (social condition) or to place it on a concave frame (individual condition). This latter task was performed also in a passive-observer condition in the presence of an onlooker who simply observed the scene. Straulino et al. (2015) found that, unlike PD patients in the therapy-off condition, the kinematics of PD patients in the therapy-on condition, like controls, differed depending on the condition in which the task was performed. Specifically, participants took longer to initiate the social relative to the individual action, and showed longer movement durations, lower peak velocities, amplitudes and longer deceleration times. Moreover, in the social condition, the on-medication patients also anticipated maximum grip aperture time. This study clearly demonstrates that the social context can influence low-level features of our motor behavior.

The processes involved in coding and classifying social groups was examined by Quadflieg, Gentile, and Rossion (2015) and by Piretti et al. (2015). Quadflieg et al. (2015) had participants in the scanner view a series of person dyads, comprising two people of the same or different sex, interacting in a plausible (congruent) or implausible (incongruent) manner, or not interacting at all. Participants were required to judge whether the depicted agents matched with regards to sex. The authors found that, compared with congruent person scenes, incongruent scenes led to an enhanced activation in higher-level visual areas dedicated to face and body processing and in the posterior middle temporal gyrus. Moreover, congruent and incongruent person scenes were also found to be successfully differentiated by a linear multivariate pattern classifier in the right fusiform body area and left extrastriate body area. Interestingly, increases in congruency in person scenes were associated with a bilateral increased activation of the posterior insula. These data provide strong evidence that changes in the relations between agents affect their representation in category-selective regions of the visual cortex and beyond. Using a different approach, Piretti et al. (2015) evaluated the performance of brain lesioned patients when naming and matching images of living things, non-living things and social groups. They found that damage to left frontal and temporal cortices could selectively affect access to semantic and name information about social groups. They

suggest that our stored representations of social groups may be distinct from our representations of other types of stimulus. Social groups may, in some way, be special (see also Rumiati, Carnaghi, Improta, Diez, & Silveri, 2014).

4.   Individual difference modulators of social interaction

Cacioppo, Balogh, and Cacioppo (2015) using high density EEG demonstrated for the first time that negative social stimuli are differentiated from negative nonsocial stimuli more quickly in the brains of lonely relative to non-lonely individuals. As the primary task did not require explicit judgements about whether the social stimuli were negative, the effects appear to arise implicitly. Source density analysis suggested that the effects are generated by neural circuits reminiscent of orienting and executive control aspects of attention.

Alongside loneliness, social anxiety also varies across individuals (how much we fear social embarrassment and negative evaluation by others). Schmid, Kleiman, and Amodio (2015) tested participants varying in their degree of trait social anxiety in a response conflict task — a version of the Eriksen flanker task — while EEG was recorded. Their working hypotheses were derived from a model combining the contributions of (i) reactive control [supposedly driven by conflict-related dorsal anterior cingulate cortex (dACC) and indexed by left prefrontal EEG activity (inverse alpha)], and (ii) proactive control [supposedly associated with top-down regulation and activity of the dorsolateral prefrontal cortex (dlPFC) and indexed by the N2r component of the event-related potential]. Schmid et al. (2015) found that individuals with high social anxiety relied more strongly on the reactive control pattern, driven by conflict-related dACC activity, while low social anxiety individuals engaged a more proactive control pattern, driven primarily by dlPFC activity. The data support a model of control that involves different patterns of interplay between proactive and reactive strategies as a function of the level of social anxiety experienced by individuals.

One factor particularly important for achieving successful social interactions is the ability to understand other peoples' point of view. This is particularly challenging in situations where the other person's viewpoint conflicts with our own; under such circumstances executive control processes may be required in order to limit interference from our own perspective. One important question is how domain-general these executive processes are. Samson, Houthuys, and Humphreys (2015) reported the performance of two pairs of brain-damaged patients with prefrontal cortex lesions and aspects of dysexecutive syndrome. The patients performed a card game in which they either won or lost money according to whether, when a third card was turned over, it matched the card held by the patient or an opponent. The patients were asked to decide whether they wanted the third card to be turned over or whether their opponent wanted the third card to be turned. When making a judgement concerning the opponent, the patients had to resist interference from their own desire. They also had to decide about whether to make an 'approach' response (when the trial would give a winning reward) or an 'avoid' response (when the trial would end in a

loss). The two pairs of patients showed a classic double dissociation, with one pair showing a deficit in resisting interference from their own perspective but they could avoid making an approach response, from the ascription of an approach motivation, while the other pair showed the opposite profile and found it difficult to make an avoidance judgement for their own choice. In a different study with brain damaged patients, Sui, Enock, Ralph, and Humphreys (2015) investigated whether high- and low-level tasks (e.g., for memory or for perceptual judgements) showing biases to favour self-related information over information related to other people, tap the same types of self representation. The authors concluded that the ventromedial prefrontal cortex (vmPFC) is critical for access to a core self-representation, so that damage to this brain region affects high- and low-level tasks alike. In contrast, damage to the temporo-parietal junction can reduce top-down control of attention to salient stimuli and exaggerates the effects of strong (self-related) attentional signals. Problems in dealing with strong self-related signals may contribute to some of the difficulties patients can have in taking the perspective of other people.

5.   Perspective taking and empathy

In an fMRI study on the taking of other's perspectives, Corradi-Dell'Acqua, Turri, Kaufmann, Clément, and Schwartz (2015) had participants view photographs of unknown characters associated with of descriptions of rules and desires. For each photograph participants were asked to predict whether the character would behave consistently with the description provided. Participants had no other way to formulate accurate predictions but slowly learned the behavioral profile of each character in the course of the experiment. This procedure gave the authors the opportunity to identify the brain regions associated with the updating of participants' impressions, with the dorsal mPFC being progressively more involved in predicting behavior in relation to the desires of the characters, and the medial orbitofrontal cortex and the amygdala being progressively more recruited in predicting rule-based behavior. The ventral involvement of the mPFC in self-reference and of more dorsal mPFC in reference to others has been noted previously (see Decety & Sommerville, 2013) and may reflect an important division in processing relating to the self and to other people.

One particular aspect of taking another person's perspective involves the sharing of affective states — a critical factor in empathy. Two fMRI studies in this issue examined this issue. First, Silani, Lamm, and Singer (2015) reported that empathy is subserved by distinct neural networks, with regions recruited in the first-hand experience of positive or negative affective states also being specifically recruited when empathizing with these respective states in others. Second, Cao, Contreras-Huerta, McFadyen, and Cunnington (2015) demonstrated that racial bias in neural responses to others' pain, as a neural marker of empathy, changes with experience in new immigrants at least within 5 years of arrival in the new society. Crucially this related to the level of contact with people of the other race in every-day life contexts, indicating the plasticity of such effects in the brain.

Taken together, the reports in this special issue illustrate the breadth of research now being undertaken in social cognitive neuroscience and the important converging results that are emerging about the different functional and brain mechanisms that enable us to operate successfully in a social world. We believe that the interaction between the different research social and cognitive strands and the various types of expertise provides added value to the field of neuroscience. Notably, the convergence of the different approaches raises new questions that enhance both our understanding of social behavior and our understanding of the neural mechanisms of cognitive control − one example being the study of Ruissen and Ellen de Bruijn (2015) here, which illustrates the role of neurotransmitters such as oxytocin in social behavior and the modulation of cognitive control by the social context in which actions are undertaken. This convergence is also being complemented by recent attempts to develop theories that link cognition and neural function to social drivers of behavior (e.g., Humphreys & Sui, 2015; Martin, 2015). We look to the increasing influence of such theories in the future, taking us beyond individual experimental examples to provide a more over-arching integration of the field.

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