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Social Neuroscience Tasks: Employing fMRI to Understand the Social Mind

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1. Introduction

The purpose of the present chapter is to introduce and describe some fMRI-compatible tasks that social scientists can employ to study various social phenomena. fMRI (functional Magnetic Resonance Imaging) is one of the principal methods for studying *in vivo* human brain-related responses associated with cognitive functions. Given the increasing availability of brain imaging scanners, the less complicated analysis methods, and the lower costs of using fMRI, more social scientists (from e.g., social psychology, political science, business, economics, philosophy and culture science) have become interested in integrating neuroscience into their own research agenda. It is expected that this trend will continue as multidisciplinary research becomes more popular.

Crossing or mixing disciplines has always been both challenging and very rewarding. In the case of neuroscience, the unwillingness to cross disciplines is often implicated with a lack of appreciation for the potential of fMRI and neuroscience methodologies. In addition, social scientists are often overwhelmed by the complexity of neuroscience and are unsure whether it is worthwhile to invest time and energy in enriching their methodological tools with fMRI. Therefore, there is an exigency for an introductory chapter aiding non-neuroscientists (or, generally, researchers with less exposure to experimental methods of neuroscience) to understand how cognitive neuroscientists have employed fMRI in elucidating social phenomena.

As such, the general aims of this chapter are to:

i.   Offer inspiration on novel approaches for studying social phenomena using neuroscience methods

ii.   Help readers form and answer proper questions using an appropriate methodology

iii.   Understand how neuroscience epistemologically approaches various phenomena

To achieve these aims, we here present an overview of fMRI tasks that have been successfully used to study social phenomena. Note here that we focus on the *tasks* employed and not in the social neuroscience theories or neurobiology implicated in the phenomena. We believe that this is a pedagogically more efficient way for the non-expert scientist or student to be introduced to the methodology of social neuroscience, since it approaches social neuroscience from an applied, hands-on perspective. To that end, in the following paragraphs we present tasks that are related to:

- Facial expression recognition

- Perception of biological motion

- Mimicry

- Mirror neurons system

- Mentalizing and understanding mental states of others

- Empathy

- Distinguishing self from others

- Morality

- Kinship, romantic and maternal love

- Attitudes and evaluative processes

- Race and stereotypes

- Culture

- Social interactions

We note that what follows is a brief introduction of different tasks. Most, if not all, of the tasks can be used for pure behavioral research. What makes these tasks special is that they abide to some general rules that allow for the specificities imposed by the fMRI methodology:

- The need for many repetitions (trials). Because of the large measurement error, it is advisable that each condition has a good number of trials. In other words, the design should be able to measure the same variable many times. Of course, here one needs to balance design efficiency with psychological factors such as boredom, learning and memory effects.

- The need for relatively quick presentation of stimuli. For instance, it is rather rare to have a long scenario as a stimulus, especially if one is an inexperienced researcher. Because of the temporal properties of the fMRI signal, it is also advisable, with maybe some exceptions, to present stimuli quickly, whereas the participant should be able to provide behavioral responses (if any) easily without a lot of motor or attention demands.

- Isomorphic stimuli. This is quite critical, as the brain is sensitive to a wide space of stimulus differences that could override our main targeted dimension. See below at the paragraphs about face recognition for a demonstration.

- Other needs such as good randomization and general or trial-specific time constraints.

Of course, the present text cannot cover all aspects of fMRI research and methods. We therefore strongly suggest that readers do get familiar with the nuances of an fMRI experiment (e.g., fMRI experiments typically require a large number of repetitions of the same condition). A good starting point would be Huettel, Song and McCarthy (2009). In addition, readers should be familiar with the basic tenets of experimental methodology (such as employing proper controls, separating dependent and independent variables, and avoiding confounding factors) which are typically more crucial in fMRI experiments.

Yet, we would like to emphasize three important points that are often misinterpreted:

1. **Ask 'How' and not (only) 'Where'.** It is important to form research questions that are related to specific cognitive mechanisms and, ideally, aim to test alternative/competing theoretical models of behavior. "Fishing expeditions" without concrete anatomical, function (and/or computational) hypotheses and models should be avoided. It is critical to understand how modern neuroscience aids in understanding *mechanisms* (i.e., *how* the brain processes information to produce behavioral response). Therefore, cognitive and / or computational models are essential before proceeding to fMRI experiments.

2. **Avoid reverse inference.** This is a very common error, which is elegantly described in Poldrack (2006). Imagine we find a brain area X (e.g., amygdala) that demonstrates a higher response to a stimulus A (e.g., a face with fear expression) than B (a control face with a neutral expression). The, to a great extent correct, inference is that amygdala responds to face stimuli depicting expressions of fear (A → X). Assume that in another study, a researcher employs stimulus Y (e.g., the face of an outgroup member) and finds that area X (i.e., amygdala) is activated. Often the conclusion drawn (and many times published) is that Y promotes the mental state associated with A (i.e., faces of outgroup members promote fear responses). Of course, this is a *reverse inference*, and is problematic. What we established was that A →X and that Y → X but not X → A or X→ Y. Amygdala responds to many mental states in addition to fear. Therefore, researchers should be very careful when attempting to infer the *mental state* based on *brain responses*. Proper experimental design with appropriate controls can help in alleviating these issues. Moreover, instead of approaching the variables categorically, many times it might be more appropriate to seek brain-related responses as a function of different levels of input stimulus intensity. For instance, instead of examining how the brain responds to positive and negative monetary rewards (e.g. receiving $10 vs. losing $10), one could allow for larger variation (e.g. outcome -$40, -$20, -$10, $10, $20, $30) of parameters.

3. **Deal with complexity**. Another common mistake made by researchers new to neuroscience is that they often try to solve very complex problems that introduce multiple variables and/or do not have concrete, measurable responses. Neuroscience methodology is most appropriate for straightforward questions that have few variables and very

specific responses. Remember that the neurofunctional data collected will be very complex. On average, a brain image is captured every two seconds by the scanner, equating to over 100,000 data points in 20 to 30 minutes. These time-series data points are then combined across participants, thus increasing the complexity of dataset. Fortunately, there are specialized software packages that can do such processing and analysis. However, this does not negate the need for careful experimental designs that take into consideration the complexity of the data. Lack of attention to the design may make subsequent interpretation difficult, if not meaningless.

Other neurobiological methods such as psychophysiology, EEG, fNIRS, genetics, psychopharmacology will not be covered. Readers are encouraged to further explore possibilities from other sources. Yet, many tasks and principles described here might be much related to these methods.

2. Facial recognition

Facial recognition goes beyond face processing; the latter refers to the mere ability to differentiate individuals. Facial recognition includes human's ability to decipher social information embedded in facial expressions. Some studies have explored the neurobiological basis for often-unconscious responses to specific facial expressions, such as emotional expressions (e.g., Harrison, Singer, Rotshtein, Dolan, & Critchley, 2006), untrustworthiness (e.g., Engell, Haxby & Todorov, 2007) or averted eye gaze (e.g., Hoffman & Haxby, 2000). In such studies, the principal methodology has been to contrast brain responses between conditions. For example, judgment studies of another's trustworthiness obtain behavioral ratings of the trustworthiness associated with different faces. These ratings were then used to regress against neural responses in order to compare brain signals when viewing faces rated as trustworthy versus viewing those rated as untrustworthy (e.g., Engell, et al., 2007; Winston, Strange, O'Doherty, & Dolan, 2002). Using a similar methodology, Hoffman and Haxby (2000) investigated the differential blood-oxygen-level-dependent (BOLD) responses [the principal signal derived from fMRI] when participants viewed photographs of faces looking directly versus away from the camera (i.e., direct versus averted eye gaze). This was to examine whether regions associated with perception of the face identity are also involved in perception of the changeable aspects of the face. Averted eye gaze redirect one's spatial attention in social communication, and thus different neural mechanisms should be involved. To better understand the different processes involved in facial processing, Narumoto and colleagues (2001) examined the differential brain responses towards faces as a function of attention focus (i.e., focus on contours, identity or emotional expressions).

Researchers have also investigated how people recognize speech from visual perception (i.e., lip-reading). Typical methodologies used include the comparison of brain responses when participants viewed videos of facial gurning (meaningless opening and closing of mouth) versus silent mouthing of random numbers (e.g., Calvert, et al., 1997; Campbell, et al., 2001). Buccino and colleagues (2004) also examined if the brain response observed when viewing

human verbal communicative actions are generalizable to viewing of other species' communicative actions. Their stimuli included silent video sequences of a man speaking, a monkey lip-smacking and a dog barking.

3. Perceptions of biological motion

Human beings are naturally sensitive to motion. Studies on perception of motion often concentrated on biological motion. These include facial movements such as mouth or eye movements (e.g., Puce, Allison, Bentin, Gore, & McCarthy, 1998) or bodily movements (e.g., Pelphrey, Morris, Michelich, Allison, & McCarthy, 2005). Some research has also expanded into the investigation of the neuronal mechanisms involved in perception of non-human facial movements (Buccino, et al., 2004) and complex actions that are not in one's motor repertoire (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005). Another stream of research examines biological motion depicted as point-light displays; in these tasks, subjetcs have to either judge the biological plausibility of the implied motion or to discriminate between different types of biological motion (for instance moving left or right ;McKay, et al., 2012). However, more complex discrimination tasks such as agent and expression intensity recognition (Sevdalis & Keller, 2011) have not yet been adequately examined in fMRI environments.

Individuals are also capable of perceiving implied motion. Implied motions are static images that suggest there is motion involved when the image was captured. As such, while studies on perception of actual motion often use video clips as stimuli, studies on implied motion relied on static photographs (e.g., Kourtzi & Kanwisher, 2000; Senior, et al., 2000). In these studies, participants were shown photographs of an agent in action (human, animal or a natural agent such as wave). Motion was not actually present or viewed, just implied by the static images. This allows for a deeper understanding of how humans perceive motion. Results have suggested that the extrastriate cortex is not merely involved in passive perception of motion, but also critical for visual cognition that allows for interpretation of static images with implied motion.

Furthermore, Iacoboni and colleagues (1999) investigated whether the same neural substrates are responsible for perception of motion versus actual execution of the action. This is known as *direct matching hypothesis*, which suggests that observing an action stimulates the same brain regions as actually executing the action. In addition, they also looked at the neural responses of imitation, which is learning and executing an action after observing it being performed. In most of their studies, they used actions that were familiar to participants, such as simple fingers movements. Buccino and colleagues (2004) expanded this line of research into the imitation of complex hand movements that were not in participants' motor repertoire. For instance, participants who were non-guitarists observed and later executed finger movements of guitar chords.

4. Mimicry

While imitation involves a conscious 'copying' of actions, mimicry is defined as an unconscious copying of gestures, postures or mannerisms of another person. Mimicry often takes place in social interactions and has been found to facilitate social exchanges and enhance feelings of affiliation and liking. Some mimicry actions studied include contagious yawning (Nahab, Hattori, Saad, & Hallett, 2009), smiling (Wild, Erb, Eyb, Bartels, & Grodd, 2003) and even subtle social stimuli such as pupil dilation (Harrison, et al., 2006). Typically, participants either passively viewed images (e.g., smiling or yawning) or videos (e.g., social interaction or hand movements) or instructed to perform similar actions as shown in the videos.

The effects of mimicry in social affections have been widely reported in behavioral studies. Recently, Kühn and colleagues (2010) sought to better understand this social phenomenon. Using videos of dyadic interactions, participants were instructed to take the perspective of the person filmed from first-person perspective. When the interaction partner was mimicking, stronger activation were shown in the neural reward mechanisms, which researchers infer as partially supporting the liking effect during mimicry (notice that this interpretation could be a demonstration of reverse inference – see introduction). On another note, while mimicry is unconscious, it can be enhanced or inhibited by eye contact with the partner (Wang, Ramsey, & de C. Hamilton, 2011). Wang and colleagues tested this by instructing participants to imitate the hand actions of a person in the video who is either looking at or away from the camera.

5. Mirror neurons

Mirror neurons are neurons that respond to a particular action and will respond regardless if the individual is passively observing or actively executing the action (Chong, Cunnington, Williams, Kanwisher, & Mattingley, 2008; Kilner, Neal, Weiskopf, Friston, & Frith, 2009). Studies on mirror neurons often use the paradigm of *fMRI adaptation* or *repetition suppression*. fMRI adaptation is the effect of reduced BOLD responses as a result of repeated presentation of a sensory stimulus (Chong, et al., 2008). Extending this idea to mirror neurons, if mirror neurons do exist, there should be reduced neural responses when observing an action that was previously executed relative to a novel action. This effect is also known as cross-modality adaptation, as the repetition suppression effect is observed across different 'modes' of a particular action (executive versus observation).

There have been conflicting reports on the existence of brain areas that resemble the behavior of mirror neurons in humans. Using pantomimed hand actions as stimuli, Chong and colleagues (2008) found effects of cross-modality adaptation in the right inferior parietal lobe, thus suggesting the existing of the human mirror neuron system in that region. However, their studies were refuted by Lingnau and colleagues (2009) who did not find the adaptation effect when simple right-handed motor actions were first executed and subsequently observed. This null result could be due to the use of meaningless actions, as the mirror neurons may only be activated by goal-direction actions (Kilner, et al., 2009).

6. Mentalizing and understanding mental states of others (Theory of Mind)

The term Theory of Mind (ToM) refers to the ability to attribute mental states (e.g., attitudes, perceptions, attitudes, intentions) to others in order to predict and explain behavior of another person (Premack & Woodruff, 1978). In such studies, participants are often instructed to infer the mental states of a target, which can be a person (Mitchell, Banaji, & Macrae, 2005b), a dog (Mitchell, Banaji, & Macrae, 2005a) or a character in a fictional story (Vogeley, et al., 2001). Cartoons or comic strips have also been used as stimuli in some studies (Gallagher, et al., 2000; Walter, et al., 2004). Mason and collegues (2004) found that ToM mechanisms are also involved when participants evaluate whether certain motor actions can be performed by another individual.

6.1. Empathy

There are two aspects of empathy: (i) the cognitive ability to understand and predict another person's mental states, as well as (ii) the affective ability to experience an appropriate emotion in response to another person's mental state (Baron-Cohen & Wheelwright, 2004).

Studies on empathy often use emotional facial expressions as stimuli. Typically, the tasks involve either passive observation of another's emotional expression, imitate the expressions observed or to independently generate specific emotional expression (e.g., Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Wicker, et al., 2003). Findings from these studies often suggest the involvement of ToM and mimicry mechanisms in empathy. Merely instructing participants to describe the emotion of a facial expression was sufficient to engage brain areas commonly associated with ToM, thus suggesting the involvement of unconscious mimicry in empathy (Schulte-Rüther, Markowitsch, Fink, & Piekfe, 2007). Furthermore, BOLD responses of these regions have been positively correlated with self-ratings on the Balanced Emotional Empathy Scale (Lawrence, et al., 2006; Schulte-Rüther, et al., 2007).

Many studies have also looked into the neural responses associated with empathetic responses towards others' pain. In a study by Singer and colleagues (2004), they recruited couples and examined the BOLD response of the female partners when they saw their male partners being administered painful electric stimulation. Their findings suggest that only the affective region, but not the sensory regions, of the pain matrix (areas typically activated when a participant is experiencing pain) is involved in empathetic pain. Jackson and colleagues (2006) also demonstrated both common and distinct neural activations between imagining oneself versus imagining others in painful situations. Participants were shown pictures of feet and hands in some common painful situations (e.g., toes being caught under a heavy object), and tasked to evaluate the level of pain if they were in that situation (self condition) or another individual were in that situation (other condition).

Biases in empathy between ingroup versus outgroup targets are also common research directions. Cheon and colleagues (2011) examined how culture can affect empathy (for details, see below under the section 'Culture'). Cikara and Fiske (2011) hypothesized that individuals show differential empathy responses toward different outgroup members, depending on the

stereotype of the specific outgroup. To examine this phenomenon, participants saw different types of events (e.g., "had stomachache after lunch") paired with a photograph of an outgroup member (e.g., elderly person, homeless person, business person). Furthermore, they also examined empathy for positive events (e.g., "found $5 bill") instead of merely focusing on negative or emotionally painful events.

6.2. Distinguishing self from others

Being able to distinguish the self from others is fundamental for many higher-order abilities, such as directing goal-specific actions and self-reflection of one's mental or emotional states. One way we distinguish our actions from others' is through our intentions to move. This is also known as *self-agency*, which is the knowledge of being the source of causality. A common paradigm used to investigate this phenomenon is through the mismatch of sensory-action consequence. Typically, participants performed a simple task with periodic "interference" from the experimenter. Such tasks may involve pressing a button to produce a certain color (Spengler, von Cramon, & Brass, 2009) or directing a target down a path (Farrer & Frith, 2002). During the "interference", the action produced would be the opposite of what the participants had intended, thus producing incongruence (or mismatch) between their actions and the actual consequences.

Some tasks may also use temporal mismatch rather than consequential mismatch. In other words, there will be a time lag between their actions and the perception of their actions. For example, participants performed some simple hand movements while the same actions on a screen. They may be viewing either a visual feedback of their own actions with varying degree of temporal delay (Leube, et al., 2003), or similar actions performed by an actor (Macuga & Frey, 2011). For the latter paradigm, it is important that participants know whether they are watching a pre-recorded action or live feedback of their own action.

Another aspect of distinguishing the self is our ability to recognize our own faces and own mental or emotional states. Many neuroscience studies on self-face recognition showed participants photographs of either themselves, a close or familiar other and a stranger. The stimuli were digital morphs between these pictures (Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005) or simply the original facial photographs (e.g., Platek, Keenan, Gallup Jr, & Mohamed, 2004; Platek et al., 2006). In a study on self's emotional reflection, participants were shown photographs of people displaying different emotions and asked to evaluate their own emotional response to each photograph. This revealed a neural network in the prefrontal cortex that is specifically recruited for evaluation of own emotions (Ochsner et al., 2004). In another study on high-functioning individuals with autism, this ability to separate self from others has also been demonstrated; these individuals were impaired in representing their own social intention but not in distinguishing others' social actions from the self (Chiu et al., 2008).

6.3. Morality

The main focus of experimental studies of morality is the evaluation of moral judgments. Thus, participants are commonly asked to either evaluate the morality of an action (for instance,

driving away after bumping another parked car) or to decide how they themselves would respond in a moral dilemma (e.g., smothering a loud crying baby in order to save oneself and fellows from enemy soldiers). Moll and colleagues (2002) compared emotionally charged pictures that either conveyed moral violations (e.g., physical assaults) or not (e.g., accidents). In a later study (Moll et al., 2005), in order to examine neurobehavioral differences between emotion with and without moral aspect, they also contrasted pictures of pure disgust with and without indignation.

Besides identifying the neural correlates, the principal goal is often to uncover the dimensions that can account for moral judgments. Often, these are in comparison with basic emotions. For instance, recent research has compared 'utilitarian' and 'non-utilitarian' choices. A classic example is the choice of whether to adopt a new vaccine that will ensure immunity to the vast majority of people but will also introduce the disease to a small minority. Adopting the vaccine is the utilitarian choice as the decision criterion is overall welfare; non-utilitarian option is not to adopt the vaccine in order to avoid harm to innocent people. Other dimensions include personal versus impersonal dilemmas (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001); consequences, action (versus inaction) and intentionality (Borg, Hynes, Van Horn, Grafton, & Sinnott-Armstrong, 2006); and harm versus dishonesty versus disgust (Parkison et al., 2011; Haidt, 2002; Rozin, Lowery, Imada, & Haidt, 1999). A useful resource of condensed moral vignettes can be found at Knutson et al. (2010).

We would like to add two important words of caution with regards to the morality studies. Firstly, it is unlikely that participants have encountered the situations used in such experiments. This raises reasonable criticisms as to whether the moral judgments made during the experimental sessions are realistic or credible. Secondly, the experimental moral situations versus either (i) other moral situations or (ii) non-moral situations might be different on more than one dimension. For instance, the contrasted scenarios often also differ in the emotional reaction elicited, levels of social desirability or involvement of bodily harm (Heekeren, Wartenburger, Schmidt, Schwintowski & Williringer, 2003). Therefore, great care should be given in the development of proper controls.

6.4. Kinship, romantic and maternal love

The aim of this group of studies is often to examine the neuronal responses associated with positive feelings towards close others (such as romantic partners or children). The universality of both romantic and maternal love (Jankowiak & Fischer, 1992) has been associated with the involvement of a strong, evolutionary mechanism. Typically, in these studies, participants engage in passive viewing of pictures of a person they 'feel love' towards, often a romantic partner or an infant (Aron et al., 2005; Strathearn, Fonagy, Amico & Montague, 2009; Strathearn, Li, Fonagy, & Montague, 2008; Zeki, 2007). Mashek, Aron and Fisher (2000) suggested that a photograph is more effective in eliciting a positive response compared to either touch or voice of the person.

In such studies, the experimenter often has to control for familiarity. Some common controls used include pictures of familiar but emotionally neutral acquaintances, such as photographs of babies whom they have known for the same amount of time. Another important methodo-

logical issue to note is with regard to one's emotional response. Intensity of emotional response towards a pictorial stimulus often diminishes after 30 seconds of exposure (Mashek, Aron & Fisher, 2000).

7. Attitudes and evaluative processes

Two fundamental concepts in social psychology are attitudes (i.e., 'relatively stable ideas about whether something is good or bad'; Cunningham & Zelazo, 2007, pp. 97) and evaluation (i.e., temporally narrower appraisals). Theoretically, a major categorization of processes refers to implicit (mostly automatic) versus explicit (mostly controlled) processes (also known as Dual Attitude Theory; see Greenwald & Banaji, 1995). Implicit, automatic attitudes towards specific social constructs are often measured by the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998). Information gleaned from IAT is valuable in an fMRI context as it can be correlated with brain responses.

One common method used to study 'automatic/implicit' versus 'controlled/explicit' attitude-related responses is the manipulation of the duration of presentation of a stimulus. Stimuli can be presented to participants subliminally by carefully manipulating the duration of presentation such that presentation is so short that stimulus cannot be consciously perceived by participants but yet long enough for unconscious perception to take place. Cunningham and colleagues (2004) found higher amygdala response in participants when Afro-American faces, relative to Caucasian faces, were presented subliminally. This effect was not found when the stimuli were presented supraliminally. Another method of inducing automatic responses is to frame the task in an analogous way. For instance, Cunningham and colleagues (2003, 2004) asked participants to either evaluate a word (e.g., "murder") as a 'good' or 'bad' word, or to evaluate whether it is an abstract or concrete term. The former evaluation is more likely to elicit controlled (and thus socially desirable) responses from the participants.

8. Race and stereotype

The effect of controlled versus automatic responses is a major question in studies on racial stereotyping as well. Physiological measures, and in particular, neuronal responses have an advantage over traditional behavioral measures, particularly self-report, as the responses are less likely to be 'controlled' by the participants. This aids in reducing social desirability issues as well as uncovering 'hidden' temporal patterns to responses; in addition, behavioral responses can be more easily influenced by extraneous factors, such as fatigue and order effects. Thus, neuroscience is a good supplement to the more traditional behavioral methodologies. The prototypical fMRI task in such studies involves the presentation of same- and other-race face stimuli; the amygdala is often activated when out-group faces are presented (Hart et al., 2000; but see next paragraph & Phelps et al., 2000).

It is important to point out some important issues that should be taken into consideration when designing a study related to race. Firstly, neural responses to race-based stimuli might depend,

to a great extent, on the duration of the presentation itself. Differences in behavioral and brain responses are likely to be related to whether the stimulus is presented subliminally or supraliminally. Differences in neural responses to ingroup and outgroup faces disappear when the stimuli are presented for a longer duration, which allows for conscious elaboration (see Phelps et al., 2000).

Secondly, the mere exposure to outgroup faces might induce cognitive depletion effect for some participants. Richeson and colleagues (2003) found that performance in a Stroop color-naming task was more impaired after interaction with an Afro-American person; however, this effect is limited to Caucasian participants who exhibited anti-Afro-American evaluative bias.

Thirdly, researchers should take extra care in the interpretation of differences in neural responses to the different faces. Differences may also result from mere increased familiarity (even to low level characteristics such as color patterns), perception exposure or social knowledge (in contrast to biases or stereotypes; Eberhardt, 2005). For example, Golarai and colleagues (2004) found that the difference in fusiform activation when perceiving Caucasian versus Afro-American faces extend to perception of scrambled faces as well.

One should also note that it might be easier to uncover the neural responses implicated in stereotyping when implicit (rather than explicit) measurements are used. For instance, in Phelps et al. (2000), no differences were found in amygdala response when Caucasian versus Afro-American faces were presented explicitly; however, differential amygdala response emerged when implicit attitudes measures (e.g., IAT or startle responses) were used instead. Furthermore, event-related responses employing EEG have been very prolific in showing implicit racial biases and their successful or unsuccessful regulation (see Amodio & Bartholow, 2011, for a review).

9. Culture

Behavioral evidence has demonstrated that cultural experiences can influence responses at a variety of tasks. Tasks in such cultural studies look at basic mechanisms (e.g., visual processing) as well as more complex behaviors (e.g., social cognition). One of the fundamental goals of culture neuroscience is to evaluate differences in neural responses between people with different cultural backgrounds. Below are some central phenomena that have been studied.

Holistic versus analytic processing of visual information. In such studies, common stimuli used are pictures with a foreground object against a background. It has been hypothesized that Caucasians will fixate to the central object while Asians also pay equal attention to the background (Chua, Boland, & Nisbett, 2005). This is likely to be related to a more general holistic (versus analytic) processing style characterizing Asian societies (as compared with North American societies; Chiao et al., 2009). Another task that has been used to study this phenomena is the "framed-line test" (Kitayama, Kawamura, & Larsen, 2003), which sustains that perceptual comparisons mechanisms are different between Japanese and US students.

Though widely used and examined, both the framed-line task and the cultural basis of the holistic/analytic dipole in perceptual terms have been challenged as their results either contradict basic visual science findings, which offers simpler explanations (see Zhou, Gotch, Zhou & Liu, 2008) or they seem to be produced by the natural (and not the cultural environment; Ueda & Komiya, 2012).

Emotional faces recognition. Similar to the 'racial stereotypes' experiments described in the previous section, participants in these studies are presented with emotional faces from either the same or different cultures as themselves to investigate the differences in neural activations and possible mechanisms to behaviors towards members of same versus different cultures (Chiao, et al., 2008). Adams Jr and colleagues (2009) had also used another task to study the same phenomenon. They used the 'Reading the mind in the Eyes' test (Baron-Cohen, Wheel-wright, Hill, Raste, & Plumb, 2001), where participants described the mental state of a person based only on the picture of his/her eyes.

Social elements, such as responses to status and hierarchy. Freeman and colleagues (2009) examined how culture shapes individual's neural reward mechanisms. In their study, participants passively viewed pictures of body displays displaying dominate body posture or subordinate body posture. Cheon and colleagues (2011) also examined how cultural preferences for social hierarchy influence empathy for outgroup members, while further examining how these preferences interact with different cultural groups (Japanese / Korean vs. European / Americans). Participants viewed photographs of scenes that were emotionally painful or neutral. They also indicated their empathy level toward the person in the photograph through a button-press controller in the scanner.

Recent developments in culture science suggest that a valuable method will be to use individuals who have been acculturated into two different cultures (i.e., biculturals). This allows researchers to compare differential cultural responses within the same individuals, instead of comparing between groups of participants. Such differential responses can be elicited by priming these bicultural participants with different cultural images, hence activating the respective cultural frame (for more details see Hong, Morris, Chiu, & Benet-Martinez, 2000; Oyserman & Lee, 2008). This line of research demonstrated that priming biculturals with different cultural images is associated with differential behavioral and neuronal responses (for instance, priming with either Asian or Western images is associated with different responses in culturally sensitive tasks). This suggests that cultural experience influences brain function, which is at odds with the static and essentialistic interpretation of inherent cultural differences in neural responses.

It is important for researchers to be mindful of some major issues when engaging in cross-cultural research. In addition to the issues that are also present in cross-cultural behavioural research (e.g., matched samples across cultures, properly translated instructions), cross-cultural neuroimaging has additional caveats that researchers need to be aware of:

1. **Scanner compatibility**. Typically, neuroimaging data from different cultures are captured by different scanners. It is thus important that researchers should strive to collect data that are captured by the same, or not very highly similar, MRI machines with the same

sequences. Furthermore, interscanner reliability tests have to be carried out to ensure that any differences found that not due to scanner variability (see Sutton et al., 2008).

2. **Task selection**. Standardised, non-verbal visuospatial tasks are preferable to numerical tasks, as the potential for language-mediated cultural bias is higher in the latter. Hedden et al. (2002) have a list of useful neuropsychological tests that researchers may want to refer to.

3. **Brain templates**. Most brain templates used by major neuroimaging software are based on data collected from Caucasian samples. However, there is a demonstrated variability in brain structural anatomy across populations (Tang et al., 2010), which may make the existing templates inappropriate. Some possible solutions include either finding a more appropriate template or to use templates derived from the sampled population itself.

10. Social interactions

A revolutionary development in social neuroscience is the introduction of game-theoretic methods in the study of social interactions. In such experiments, participants typically play particular roles in highly-structured social exchanges (i.e., games) to stimulate real social interactions.

There are multiple advantages to this methodology. Firstly, the interactions involve real monetary outcomes, thus making available a metric of phenomena that are otherwise difficult to capture (e.g., the dilemmas involved in trust or reciprocity). In addition, incentivizing the choices participants make allows researchers to study certain social phenomena that are highly sensitive to social desirability problems. For instance, participants might self-report that they are very trusting towards other people; however, they might behave otherwise when their choices or actions have financial consequences.

Another advantage is that there is a wealth of behavioral, simulation and theoretical studies related to such social-economic games. Optimal or 'rational' behaviors (e.g., Nash equilibrium) are well-characterized and studied. The mathematical descriptions of the various choices one can make are also readily available. Furthermore, behavioral explanations and formal computational models of the different choices have also been described in sufficient details. As such, it is possible to model the underlying, hidden computations or processes that change parametrically on a trial-by-trial basis. Moreover, one can study how dynamic social interactions evolve over time. This allows social neuroscientists to move beyond mere brain mapping to the examination of brain mechanisms involved, as described in the introduction of this chapter. In other words, the research focus can thus move from social neuroscience to *social computational neuroscience*.

Social computational neuroscience should include the following steps:

1. Adopt or develop a simulated interaction (game), based on the phenomenon being studied. Ensure that the behavioral choices actually reflect the phenomenon in question.

2.   Find one or more algorithms that can describe the choices available. In dynamic environ-ments, the focus can be on how previous interactions update the representations of the self, partner and their relationship.

3.   Fit the algorithm/s to actual behaviors in order to identify the optimal values for the parameters of each model.

4.   Identify whether the computations implied by the models are actually taking place in the brain. This will ensure the biological plausibility of the model.

An excellent example of the social computational neuroscience approach is the study by Behrens, Hunt, Woolrich and Rushworth (2008). The authors wanted to study the behavioral and neuronal responses related to advice from a partner. In their game, participants had to choose between different cards offering rewards associated with different and unknown probabilities (step 1). At the same time, they received advice from a partner who may or may not be trustworthy. Thus, participants needed to update, on each trial, the probability that the advisor is reliable (or not). The authors hypothesized that the probability was updated using basic reinforcement learning algorithms (step 2). They then fitted their model to the behavior in order to identify the (otherwise hidden) probability associated with their partner's perceived reliability. The outcome was a time-series of updated values, on a trial-by-trial basis (step 3). Next, they fitted the time-series values to the BOLD responses, which thus allowed them to identify the brain areas that appeared to subserve the relevant calculations (step 4).

As illustrated, this approach allows the identification of individual or group differences of very subtle and hidden computations. Another example of its application is the differentiation of participants according to whether they update the value of social gestures in social inter-actions. This is well demonstrated in a series of studies by King-Casas and colleagues (2005, 2008). In these studies, the authors used a paradigm known as the Trust Game (see figure 1).
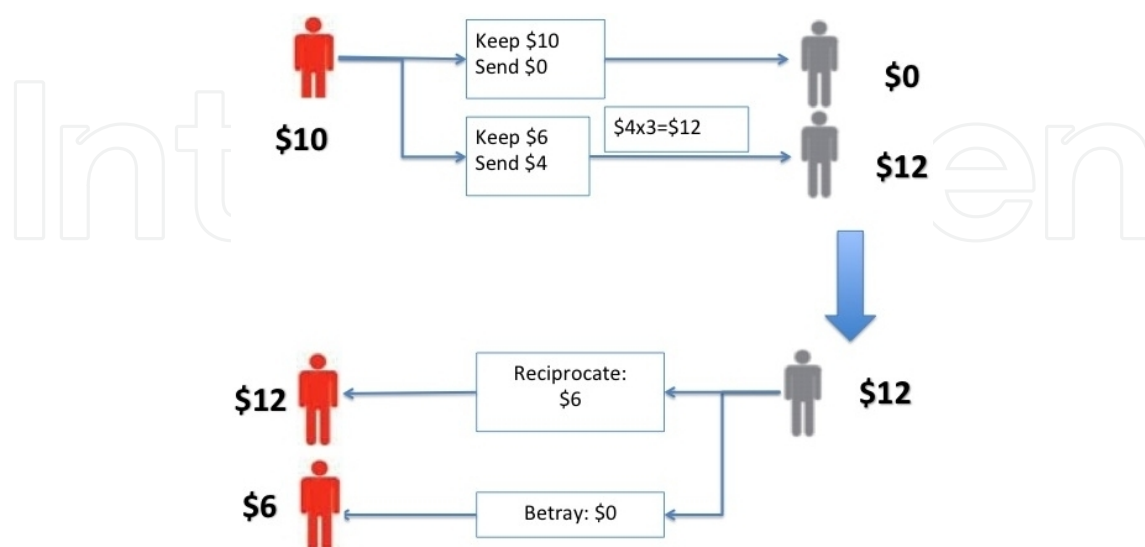

Figure 1. The Trust Game

In a typical trust game, player A (red in figure 1) is given an amount (e.g., $10). Player A has the choice to keep the amount, or to send ('invest') a portion of it to player B (gray in figure 1). The amount sent to the partner will then be tripled by the experimenter (as shown in our example, $4 was invested, and thus player B receives $12). Next, player B has to decide how much of the received amount (i.e., $12 in this case) to send back to player A as an indication reciprocity.

King-Casas and colleagues measured the BOLD responses as participants played the trust game. In the first study, they identified a neuronal response reflecting the computational learning signals that represented the intentions of the social partner. In the following study, they included participants who were diagnosed with Borderline Personality Disorder (BDP). This disorder is strongly characterized by inadequate and brief social relationships (see American Psychiatric Association, 2000, for more details). By analyzing behavior in the trust game, they found that participants with BDP cooperated less as the game progressed, thus indexing a breach of trust in the dyad. This was reflected in these participants' insula brain responses, which failed to represent the magnitude of offers received. This series of studies elegantly demonstrated how a simple simulated social interaction can be used to uncover social deficits.

Many similar games have been used to describe or simulate various social interactions. It is beyond the scope of the current chapter to elaborate on each game. Nevertheless, we present a list of relevant papers together with the major constructs they measured in Table 1.

Game / Task	Concept	References (fMRI or behavioural studies)
Prisoner's Dilemma; ultimatum game	Cooperation / Competition; unfairness	Rilling et al., (2004)
Social allocations / social value orientation / fairness	Social predisposition	Hsu, Anen & Quartz (2008) Haruno & Frith (2010) Tricomi, et al. (2010)
Ball-tossing task (Cyberball)	Social Rejection	Williams, Cheung & Choi (2000)
Trust game	Trust, reciprocation	King-Casas, et al. (2005, 2008)
Observational learning	Learning from others	Burke, et al. (2010)
Altruistic punishment	Altruistic punishment	de Quervain, et al. (2004)
Work-or-shirk	Mentalising	Hampton, et al. (2008)
Beauty contest	Depth of strategic reasoning	Coricelli & Nagel (2009) See also Bhatt & Camerer (2005)
Social comparisons, envy and Schadenfreude	Schadenfreude occurs when envied persons fall from grace	Takahashi, et al. (2009); Fliessbach et al. (2007)
Punishment games	Parochial altruism; norm enforcement	Baumgartner, et al. (2011)
Promise game	Promise keeping	Baumgartner, et al. (2009)
Bargaining Games	Bargaining/Suspicion/Strategic Deception	Bhatt, et al. (2010)

Table 1. A limited list of games employed in the study of social interactions

11. Criticisms, issues and the future

A common criticism to social neuroscience in general (and games in particular) is the lack of ecological validity as the tasks seem to fail to represent the complexity of actual social interactions. The same argument has been directed towards non-social decision-making studies in neuroeconomics (Volz & Gigerenzer, Chapter 22, this Book). There have been plenty of responses to this criticism.

Firstly, participants do appear to be sensitive to the experimental manipulations and thus display the behaviors that truly represent their social preference or even social pathology (see above for example of participants with BDP). This is illustrated in many neuroeconomic studies where participants demonstrated consistent risk aversion (Christopoulos, Tobler, Bossaerts, Dolan, & Schultz, 2009), even with small monetary rewards. In addition, these games can be the basis or building block of more realistic and sophisticated simulations of social interactions (see Wolf, Dziobej, & Heekeren, 2010). Furthermore, this approach allows for an understanding of basic or fundamental cognitions which can contribute to subsequent models of more complex behaviors.

Nevertheless, this criticism is not unfounded and has been constructive in bringing improvements to the field of social neuroscience. A number of recent studies have tried to relate neuroimaging results with real life behaviors. Kanai, Feilden, Firth and Rees (2011) used brain volumetric techniques to correlate neuroanatomical structural differences (i.e., size of specific brain structures) with the size of one's social networks (e.g., Facebook). In another study, Falk, Berkman, Whalen and Lieberman (2011) demonstrated that neural responses to health messages can predict whether the participant will reduce unhealthy behaviors (i.e., smoking in their study) over-and-above self-reported intentions.

In conclusion, social neuroscience is in its infancy. It can be expected that studies trying to understand basic mechanisms will eventually corroborate with studies that more closely investigate real life, out-of-the-lab behaviors.

Acknowledgements

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