Organizational Cognitive Neuroscience: A new frontier for Magnetoencephalography

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Abstract

Organizational cognitive neuroscience is a rapidly developing field of research aimed at the neuroscientific study of human behavior in organizations. The purpose of this chapter is to provide a brief overview of the field and to elaborate on the role magnetoencephalography can play within this new area of research given its inherent advantages of non-invasively measuring macroscopic brain dynamics. Moreover, this chapter aims at elucidating some of the broader conceptual challenges as well as ethical considerations that have been raised by recent neuroscience-based approaches to the study of economically relevant behaviors, as such considerations will be relevant to neuroscientists as well as management scholars alike.

Keywords: Organizational cognitive neuroscience, neuroeconomics, neuromarketing, magnetoencephalography, decision making, gender differences, endogenous brain activity

1. Introduction

Organizational cognitive neuroscience is a rapidly developing and highly interdisciplinary area of research that explores the implications of brain science for workplace behavior. The approach builds on key theories and methods of behavioral, cognitive, and social psychology and attempts to incorporate advances in neuroscience that have yet failed to reach organizational or business research. The broad aim is a better understanding, explanation and prediction of human behavior in organizationally relevant situations, which might ultimately provide evidence-based recommendations for practice. It is hoped that neuroscience methodology will help to push organizational research in exciting new directions such as how and why managers make appropriate decisions or how serial entrepreneurs might perceive and act upon risk differently than others (Becker et al. 2011; Senior et al. 2011; Lee et al. 2012a).

As an area of research, organizational cognitive neuroscience is distinct from but nevertheless related to two established subfields of neuroscience, namely neuroeconomics and neuromarketing. The former combines neuroscience, psychology and economics for the study of how people evaluate gains, losses and rewards in economic decision making (Camerer 2008). The latter appears in practice to primarily adopt imaging tools to investigate customer choices for marketing purposes such as TV commercials (Ariely and Berns 2010; see also Breiter et al. 2015, and Lee et al. 2018 for a broader perspective). Both organizational science and neuroscience are vast domains on their own, thus making it mandatory to consider a special field known as organizational cognitive neuroscience, or ONC for short, which emphasizes the role of cognitive processes over and above processes at the cellular level. A formal definition of ONC is provided in Fig. 1, which also shows the main contributing disciplines.

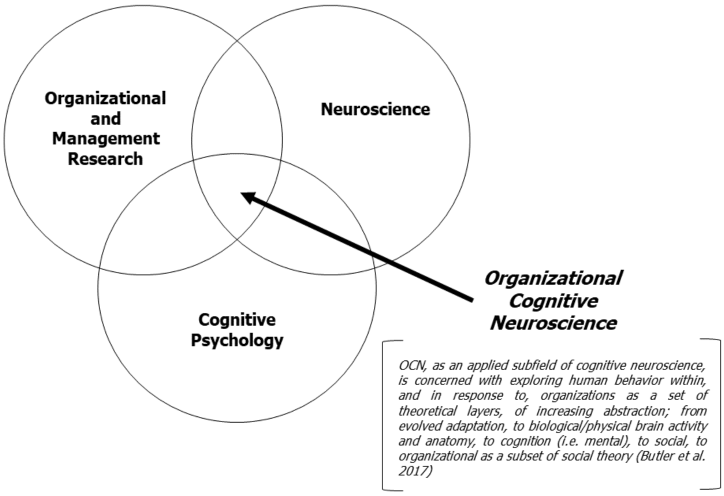

Figure 1 Disciplines contributing to organizational cognitive neuroscience.

2. The need for a cognitive approach to organizational neuroscience

In light of the significant complexity of behavior that readily manifests itself within organizations, one could easily argue that the application of an advanced neuroimaging procedure could bring additional complexity to our understanding of an already difficult to tackle problem. Yet, it is argued here that neuroimaging procedures will not only help us to understand the mechanistic processes that may sub-serve such complex social behaviors but also help identify how human interactions within organizations are best aligned to our natural social behavior.

It would be hard to argue that 'natural' behaviors such as altruism, friendliness, or cooperation should be discouraged in the modern-day workplace. Indeed, in the popular business press one can often now find stories of how companies such as Google look to construct their work environments and practices to fit employees' natural social behaviors (Coy 2006; Gallo 2006). Academic researchers have also shown significant interest in how an understanding of evolved human social behaviors can facilitate a greater understanding of effective management (e.g. Wu et al. 2016). Even more important is the fundamental notion that it may be possible to identify social behaviors within our evolutionary past that also reside at the very heart of contemporary theories of effective leadership and workplace design (e.g. Bastardoz and Van Vugt, 2018)

However, it is not being advocated here that the application of organizational cognitive neuroscience should be carried out to merely reduce the complexity of organizational behavior to simple images of brain activity, and thus discarding any wider social context. Far from it indeed; for renewed clarity, the core and perhaps the defining principal of OCN could be restated: '*the organizational cognitive neuroscientist is interested in understanding the molecular logic of organic knowledge systems only when placed in their natural social ecology*' (Lee et al. 2012b). Thus, scholars who wish to truly adopt OCN in their work should acknowledge the symbiosis between theories and embrace multiple layers of analysis. Only then will we see the emergence of genuinely novel theories and the consequent development of new testable hypotheses (Lee et al. 2012b; Senior et al. 2011; Bagozzi and Lee 2017).

3. A Role for MEG

From a neurophysiological perspective, the interest of organizational researchers should be excited by the superior temporal resolution of MEG when compared to fMRI, which, in conjunction with powerful source estimation approaches, allows the detailed, time-resolved mapping of brain activity associated with complex cognitive processes. In particular, the rapid responses that occur at the boundary between perception and cognition are deemed powerful markers in the quest for better models of decision-making and judgment under uncertainty (Senior et al. 2011). Although MEG is a well-established neuroscience research and clinical tool, it has had a limited impact on organizational neuroscience, where functional magnetic resonance imaging is almost always the method of choice.

However, MEG has been employed in a small number of neuroeconomics and neuromarketing studies, providing examples of how this technology might be able to further the debate. Moreover, EEG is recently gaining momentum in organizational fields of study, which should further encourage researchers to design and carry out relevant MEG studies in the future. Specifically, MEG has already, or is highly likely to, contribute to four areas interrelated with organizational research.

3.1 *Decision making*

The neuronal mechanisms supporting the cognitive processes of selecting a belief or a course of action among several alternative possibilities have been of interest to neuroimaging researchers for a long time. Obviously, a deep understanding of decision-making is of great importance to organizational research at all levels, from the strategic, to the tactical, to the personal. Here, MEG has relevant insights to offer, which to date primarily come from the area of neuroeconomics. As a first example, MEG was used in a study with real-life content in order to record the neuronal signals associated with purchasing decisions that have potentially long-term consequences (Hedgcock et al. 2010).

In a real-estate scenario, the subjects were given the choice to buy an expensive apartment (high monthly mortgage) located in a safe neighborhood or to buy a cheap apartment located in a less safe area with a modest crime rate. The authors found that neural responses over frontal and parietal cortices correlated with the trial outcome as early as a 500 ms after the presentation of choice options, and several seconds before the buying decision was communicated. The significance of such early neuronal activity is currently unresolved, as to what processes may be occurring during the time between the divergence of neuronal response and the decision.

These neuronal responses, however, appear to reflect higher-order cognitive processes outside awareness, raising the possibility that economically relevant behavior is, to some extent, decided upon long before it becomes manifest. If so, a deeper understanding of these neuronal systems might yield insight into why individuals often seem unaware of the relative importance of different choice attributes that affect their perceptions regarding the attractiveness of their choice options (Dhar and Simonson 2003; Braeutigam 2012).

More recently, MEG was used to study neuronal responses in adult subjects performing a kind of lottery task. On each trial, the participants were required to choose between accepting a fixed amount of money or electing to play a lottery with four potential monetary outcomes represented as four segments of a pie-chart, where the angle subtended by each segment indicated the probability of the associated outcome (Symmonds et al. 2013). The monetary outcomes and their respective probabilities were pre-defined in order to control for risk (or outcome spread) and skewness, i.e. the relative probabilities of poor outcomes and returns well-above average. The authors employed general linear modelling in order to correlate MEG source-space signal power with uncertainty, skewness, and choice (fixed amount vs. gamble).

Initially, induced broad-band (4 – 48Hz; region-of-interest approach) power correlated with variance in left posterior parietal cortices in the first 500ms after onset of the choice-inducing stimulus. Subsequently, power correlated with skewness in bilateral dorsomedial prefrontal cortices between about 250 and 750ms after stimulus onset. Finally, power correlated with choice in bilateral brain regions posterior to the central sulcus, where effects started at about 250 ms but were strongest for latencies spanning 750–1000ms. These observations are relevant as they provide robust evidence that neuronal activity tracks specific and possibly independent components of risk. It should be noted that the authors only manipulated risk (probability of a winning or losing outcome) but not uncertainty (ambiguous and/or unknown information about outcomes), which is an essential part of any real-world decision making. However, a better understanding of the spatio–temporal neuronal mechanisms supporting choice and decision making has great potential to inform strategies aimed at dealing efficiently with organizational risks, such as investment, management and safety.

3.2 *Dynamic aspects of cognitive processes*

Organizational neuroscience has so far been entirely based on a view of the human brain as an essentially reactive system driven by the demands of the environment. According to such a view, sensory input causes neuronal activity, which in turn results in some important responses such as a motor activity, or higher-level cognitive or affective processes. This view has its roots in the work of Sherrington (1906) which has influenced a large proportion of existing neuroscience work, undeniably leading to important advances in our understanding of brain operation and functional organization. The reactive view, however, is limited. It has been shown on many occasions that the behavioral response can be highly variable given a constant set of stimulus parameters, and this variability is not easily explainable by factors such as fatigue or trial history.

Commonly, such variability is considered noise, explainable to a certain degree by theories of stochastic neuronal networks and usually taken out of consideration through averaging or other statistical manipulation of the neurophysiological data. This approach is unfortunate. First, there is reason to assume that response variability is important to free a being from predictable behavioral patterns, in order to adaptively respond to changes in the environment (see, e.g., Bompas et al. 2015). Second, this approach ignores the possibility that the apparent fluctuations in behavior are related to, and perhaps even caused by the endogenous (or spontaneous) brain activity present at all times. The latter possibility constitutes an intrinsic view of cognitive processes, which is essentially based on Hebbian reasoning, expressed many years ago: “It is therefore impossible that the consequence of a sensory event should often be uninfluenced by the existing activity” (Hebb 1949, cited in Sporns 2011, p. 149).

Ever since, a substantial body of evidence has been accumulated which corroborates the notion that dynamic brain states internally reflect environmental conditions in order to anticipate sensory input in the service of optimizing subsequent action (Qian and Di 2011). Such evidence has recently prompted the present authors to introduce the intrinsic view of brain activity to organizational cognitive research, arguing conceptually that including the study of endogenous brain activity in management and organizational theory and empirical research has the potential to substantially advance our understanding of human choice and behavior in organizations (Braeutigam et al. 2017).

In particular, leadership research is an attractive first target. It is commonly agreed that leaders often face situations characterized by a complex mix of fluid social networks, and internal environments and nonnegotiable facts, which can create tension as well as unpredictability in a temporally dynamic fashion that the leader needs to handle to be successful (Hannah et al. 2015). Here, the intrinsic approach to brain activity could help clarify the extent to which the brain is a predictive inference engine. In other words, spontaneous activity might facilitate the prediction of future demands and stimuli from the environment, thereby helping the brain to anticipate and respond most effectively to what may occur in the future (e.g., Knill and Pouget 2004). Thus, one might gain better insight into the momentarily present guesses and priors about the environment or situation, which are then updated by the actual experience.

MEG is particularly well-suited to capture the intricate dynamics of endogenous activity because of its high temporal resolution and excellent signal quality compared to other non-invasive neuroimaging technologies, facilitating complex analyses and model calculations. This has been demonstrated in a wealth of so-called pre-stimulus studies, which directly investigate the relationship between the ubiquitous spontaneous activity and event-related activity elicited by experimental stimuli. For example, MEG was used to record the neuronal response in adult subjects performing a shopping task. The subjects were invited on a virtual supermarket trip including real footage and static images of common grocery items (Braeutigam 2007). On each trial (image), the subjects had to choose one item out of three items belonging the same product category (e.g., soft drinks), or opt not to buy an item. The pre-stimulus data (immediately before onset of choice inducing stimuli) were analyzed in order to extract a non-linear measure of the determinism of the brain signal, with the sample split into high and low determinism trials.

Critically, the authors observed a significant difference across the two trial groups, with those choices made when the subject exhibited a high deterministic brain state making significantly quicker choices, and also choosing significantly less-familiar items than those in the low determinism state (the main findings are illustrated in Fig. 2). These findings relate strongly to theories on consumer preference construction, which is an area of research that is almost entirely behavioral in nature. Accordingly, highly deterministic states may signify some kind expectation or anticipation of a decision-task, where the individual could be considered as more prepared to choose unfamiliar outcomes, and then to evaluate the costs of those choices. In other words, they are better prepared for what could be seen as some form of dynamic learning process. Conversely, low deterministic states are less capable of doing this, and tend toward the familiar, which has no novel learning opportunity.

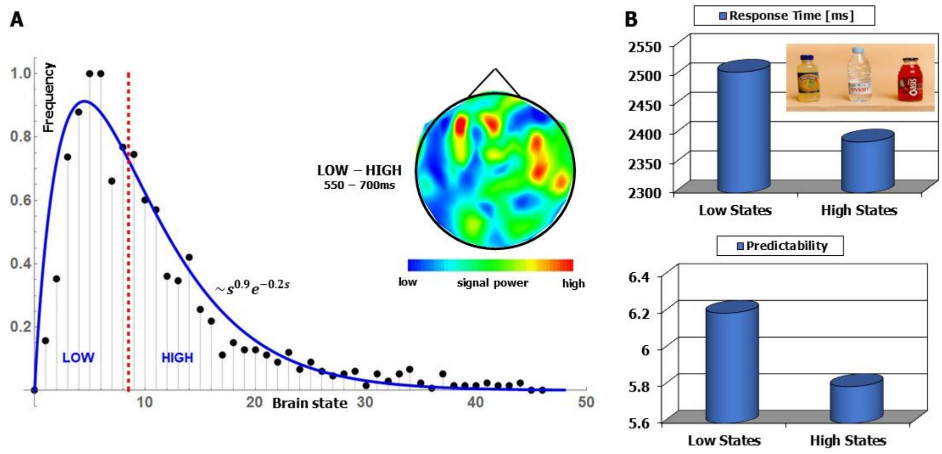

Figure 2 (A) Deterministic pre-stimulus brain states follow closely a statistical gamma-distribution. Here, determinism implies that the dynamic behavior (the totality of electrophysiological processes observed macroscopically) of a neural system is ordered and stable to some extent. Note the state measure (x-axis) is logarithmic in nature. On average, post-stimulus evoked power is higher over prefrontal and right temporal regions in trials following low compared to high deterministic states. (B) Choice making is significantly slower and the item chosen significantly more familiar (predictable choice) when the choice inducing stimulus (inset) is presented during a LOW compared to a HIGH state (defined as a median split of states; red line in A). All graphs are based on Braeutigam 2007.

The question of which neuronal processes support expectation is still far from answered, however, a recent MEG study suggests that certain pre-stimulus expectation templates are measurable and, at least to some extent, are controllable through experimental manipulation (Kok et al. 2017). The authors employed a simple perceptual discrimination task, where each trial consisted of an auditory cue followed by two consecutive Gabor grating stimuli. The cue consisted of either a low- or high-frequency tone predicting the orientation of the first grating with 75% validity. After display of the second grating, the subjects had to judge whether it was either rotated or had a different contrast with respect to the first grating.

Using a decoder algorithm trained to associate evoked responses with grating orientation (data obtained from a separate localizer task), the authors observed significant differences in decoder performance between valid and invalid (orientation not as predicted by cue) in the pre-stimulus interval before onset of the first grating. Thus, this study provides some evidence that the auditory cues evoked orientation-specific signals which were similar to sensory signals evoked by the corresponding actual gratings. It should be noted that such putative expectation templates were inconsequential to overall task performance, where the subjects detected changes in orientation and contrast with the same accuracy and speed irrespective of whether the cued (first) grating had the expected or the unexpected orientation.

Despite the absence of clear behavioral effects, however, the results show that expectations can indeed induce the pre-activation of stimulus templates, which in turn may influence the processing and integration of bottom-up sensory inputs. Clearly, external auditory cues were used in this case, but it is conceivable that templates might be generated endogenously and dynamically without direct input from the external environment.

Although such studies are not directly applicable to organizational research, they suggest that significant insight into human preference and decision making can be gained from a better understanding of the complexities of brain dynamics, which could clarify the extent to which human learning and response capabilities are dynamic and context-dependent qualities, rather than person-specific traits. Ultimately, this could help one to better understand, for example, the dynamics of business decisions over and above statically categorizing individuals as either high- or low-risk entrepreneurs.

3.3 *Leadership and management*

Leadership theory and the study of leadership styles, as already alluded to above, assume prominent roles in organizational research, have been investigated scientifically for many decades. An early and highly influential study distinguishes leadership styles mainly in terms of three different communication styles: laissez-faire, democratic and autocratic (Lewin et al. 1939). The laissez-faire style, or delegating leadership, refers to leaders who are hands-off allowing group members to act mainly on their own decision making. Although there are certain situations where this style might be the most befitting, it is generally agreed that the laissez-faire style often leads to the lowest productivity among group members.

The democratic, or transformational, style requires that the leader remains ultimately responsible for the choices, however, important decisions are usually taken with the participation of the group. In this way the leader creates some form of social climate facilitating expression of mutual confidence and motivation. Typically, a democratic style constitutes a good balance between satisfaction and productivity among group members. Finally, the autocratic style requires centralized communications allowing for good productivity in general (Bass 1985). This style is usually characterized by strong reliance on leaders and can entail forms of aggression among poorly motivated group members.

Theories positing a biological basis for the different leadership styles and their effectiveness are not new, however, there is still very little neuroscience-based evidence available in this area of research (Venturella et al. 2017).

A seminal paper, published a few years ago as part as a collection of articles on organizational neuroscience, argues that the brain's resting-state networks, as measured by fMRI, can be used to differentiate and perhaps even explain different leadership styles and roles (Boyatzis et al. 2014). In particular, the authors posit that the task-positive-network (TPN), which facilitates problem-solving and analytic work, is antagonistic with the default-mode-network (DMN), which facilitates social engagement and openness to new ideas. This antagonism at the neuronal level, so goes the argument, raises questions as to how leaders can effectively fulfill both task- and relationship-oriented roles. These issues, however, are still far from being resolved. Here, MEG can complement and extend resting-state fMRI by providing relevant data for analyzing the electrophysiological correlates of metabolism-based connectivity, its time-frequency content, and high temporal resolution interactions.

Most recently, EEG was used to measure simultaneously the neuronal responses in two individuals engaging in leader–employee interactions. Specifically, the participants had to conduct role-play interviews in which the leader had to evaluate an employee's performance. The interviews were recorded and subsequently segmented by independent referees using a technique known as conversational semantic mapping in order to identify salient discourse topics, for example, the company mission or efficiency of team work from the leader's point of view (Venturella et al. 2017). Factors such as leadership and communication styles were not tightly controlled, and the authors analyzed frontal delta and theta power as a function of role (leader vs. employee) and semantic category.

Interestingly, both delta and theta power were generally higher in leaders than employees, except at times when employees communicated their views of team work and group cohesion. Although the data do not permit a strong conclusion, the study results do suggest that neuroscience-based approaches might yield a better understanding of the neuronal processes facilitating complex leader–employee interactions. MEG harbors great potential to further this debate, as it is well documented that MEG can unravel the intricacies of brain oscillatory dynamics (da Silva 2013). More specifically, there is recent evidence suggesting that MEG can detect neuronal gamma-oscillations supporting task-switching and cognitive flexibility (Proskovec et al. 2019). The relevance to leadership theory is unresolved, but one might hope that such insight can help to clarify the behaviors associated with at least some leadership styles (e.g., the task-oriented style which is closely related to autocratic leadership).

Moreover, MEG has been shown to be a powerful tool to reliably quantify contextual effects at the level of neuronal processes with the help of well-known marker signals such as the N400 response. This response is observed at about 400 ms after stimulus onset and can be elicited by a broad range of meaningful stimuli, including but not restricted to auditory and visual words, pictures, sign language, faces and environmental sounds (Kutas and Federmeier 2011). It is generally assumed that the N400 indexes neuronal processes related to semantic memory, and there is some evidence that neuronal responses at 400ms reflect gender-specific cognitive strategies in choice making in real-life situations (Braeutigam et al. 2004).

Thus, it is conceivable that MEG-based approaches could help build towards a better understanding of how the human brain responds to and utilizes contextual information within an organizational setting. One may justifiably hope that semantic marker signals detected with MEG can give new insights into leader–group interactions and perhaps inform management training programs, an area of particular interest to organizational cognitive neuroscience. Clearly, no claim is being made that such complex interactions can be completely reduced to individual brains and neurons, however, MEG might be able to shed some light on how, for example, a leader can successfully negotiate complex situations.

3.4 *Gender differences*

Gender differences in human brain structure and function are arguably one of the most controversial issues in science at the current time. Many, probably of the order of tens of thousands, neuroscience-based studies provide clear evidence that men's and women's brains differ in subtle and less subtle ways, and these differences are most likely established at the earliest stages of neural development during gestation, due to the interactive effects of genes and sex hormones. In contrast to reproductive capacity, gender differences in human brain function appear largely a matter of degree (Vanston and Strother 2017), however, the science of such differences is still very much open to debate. According to some, behavioral differences between men and women are mostly due to cultural and societal influences, while others see biology as the main factor determining differences. Likely, the situation is complex, involving several partially interrelated and as well as independent factors that are all too easy to conflate (Halpern 2012). For this reason, our exposition, like that of many other works, does not rigorously distinguish between differences associated with sex and those shaped by gender. Operationally, we will refer to gender and gender differences, and use the words men and women in order to differentiate subject groups.

It goes without saying that gender-related differences are of great importance to organizational research for a variety of reasons. Perhaps the most significant observation is that despite greater presence of women in the workforce, their organizational and work-life experiences remain generally different from men's (Case and Oetama-Paul 2015). Most commonly, explanations for such differences are founded on the interrelated concepts of cultural socialization and patriarchal dominance (Heifetz 2007). It is, however, increasingly being recognized that gender differences at the level of neuronal systems need to be taken into account for organizations to be able to develop scalable strategies in order to efficiently and fairly accommodate differences. Essentially, it may be that organizations are too intricate to rely on one set of rules and behaviors applied to both men and women.

This, it is argued, would be of particular importance in the domain of gendered discourse styles. Echoing sex differences in the bias of their brains, women might gravitate towards discourse and work with predominantly fulfilling and personal dimensions. In contrast, men might be more interested in things and perhaps power, where discourse is a means to those ends (Case and Oetama-Paul 2015). Irrespective of the somewhat fluid differences, organizations will have to leverage and build on differences in gendered discourse in order to successfully compete in the global market-place, given the ever-increasing levels of workforce diversity and social change. Currently, there are no studies in neuroscience, management and organizational behavior that investigate biology-based gender differences at a level needed to draw strong and specific conclusions. It appears, however, that MEG has sufficiently matured towards providing relevant insight based on experiments with a real-life content. Two examples should suffice here.

Using the same shopping experiment as described above (Section 3.2), it was observed that the evoked responses of women and men differed markedly at latencies typically associated with the N2 and P2 components. In women, strong activity was found over left posterior brain regions, broadly consistent with the category-specific knowledge activity typically observed in language studies. In contrast, right temporal components were observed in men over areas commonly associated with the processing of spatial memories (Braeutigam et al. 2004). Interestingly, this difference in neuronal responses was also found when subjects had only to judge the height of products without making a shopping choice, suggesting that women and men might employ different cognitive strategies at this stage of processing.

Specifically, these differences in strategy appeared rather inflexible, which might underlie gender dimorphic patterns of task behavior and performance. Thus, a tendency to use spatial processing is likely to be advantageous in a situation where geometric information (e.g. height) has to be extracted, whereas a tendency to adopt a processing strategy that emphasizes category-specific knowledge is a disadvantage when only geometry matters (note men judged height faster and more accurately than women). Conversely, when making actual choices, women appeared to gain from category-specific knowledge, leading to faster choice times.

More recently, MEG was used to study the neuronal response in adults asked to rate the emotional valence of auditory (music), visual (film) and audiovisual (combined music and film) material along the dimensions of peacefulness and fearfulness (Yang and Lin 2017). Men and women experienced broadly the same feelings, where both genders respond with higher ratings to the audiovisual modality compared to unimodal stimuli, consistent with models predicting stronger perception and/or feelings in the presence of multimodality. In addition, women rated the fearful material higher than men did, which, the authors argued, might indicate a biologically-based, enhanced sensitivity and vulnerability of women to adverse and possibly stressful events.

The behavioral findings were accompanied by magnetoencephalographic observations that pointed to subtle, gender dimorphic interactions of the low-frequency beta phase and the high-frequency gamma amplitude. Men exhibited strongest phase–amplitude coupling following stimuli perceived as peaceful, whereas women showed the strongest coupling to material perceived as fearful. Interestingly, gender-related differences became apparent by analyzing cross-frequency coupling rather than considering specific frequency bands in isolation, suggesting that MEG can inform, at least to some extent, about complex neuronal networks facilitating gender-specific responses to stimuli with varied emotional valence.

4. Challenges

Important challenges have been posed regarding the validity and generalizability of the insight gained from neuroscience-based approaches such as neuroeconomics and neuromarketing. It is likely that organizational neuroscientists, as time progresses, will have to face similar conceptual issues, but will also be able to draw on accepted methods in order to overcome limitations. Specifically, a criticism has been made that all that neuroeconomic research has been able to identify so far has been the brain regions that appear to be activated in response to certain decisions and choices, or responses to reward stimuli. Accordingly, the evidence is only of correlation, making the interpretation of causality difficult, if not impossible (Harrison 2008; Birnberg and Granguly 2012).

Clearly, these are important points of criticism, however, one has to appreciate that OCN does not disregard any singular level of analysis. Rather, the theoretical plurality in the OCN approach ensures that it is ideally suited to address fundamental questions like this. As noted earlier, the adoption of an OCN approach would necessitate the explicit recognition of the relationship between different layers of theory that will lead to a greater understanding of the problem stated above. But this is not to say that the approach disregards neurophysiological basics. Indeed, it has been argued previously that an understanding of brain anatomy and brain function is actually an essential requirement for effective application of OCN (Lee et al 2012b), and other scholars have provided recommendations to ensure that such a foundation is not in any way a hindrance to examining such questions (Waldman et al. 2016).

Importantly, in building towards a more holistic understanding of the matter at hand, a central point is that theories at one level must at the very least not directly contradict existing knowledge that resides within other theoretical layers (Senior et al. 2011). This is most clearly seen when describing higher-level (e.g., social) theories that take into account knowledge about lower-level (e.g., cognitive or neural) systems, but the relation can work in both directions, with the study of higher-level processes used to examine lower level theories as well. The strictest form of this relationship would be classed as entailment, where a theory at one level is a logical consequence of one at another (Laudan and Leplin, 1991). However, the lower bound is non-contradiction, where theories (and hypotheses) at one level do not explicitly contradict that which is already known to be correct at another level. For example, high-level theories of leadership in organizations do not necessarily have to directly be entailed by knowledge that is already established, based on lower level neurobiological or evolutionary theories of social dominance, indeed, such direct logical links may often be very difficult to draw. However, higher-level leadership theories certainly should not make claims that would be directly contradicted by established knowledge at these lower-levels of theory. That said, knowledge generated from tests of higher-level theories can help confirm theories at lower levels, especially when there are competing lower-level theories which make contrasting higher-level predictions (Alai, 2018).

Without empirical replication, however, these are deeply fundamental, or even philosophical issues, which are unlikely to be resolved fully in the near future (Bagozzi and Lee 2019). Fortunately, there are now a number of developments that can maximize the insight gained from individual neuroimaging studies, two of which are highlighted here. First, advances in Bayesian algorithms can be exploited to support reverse inference, i.e., inferring the likelihood of a cognitive process from a pattern of brain activity (Poldrack 2011; Braeutigam 2012), assuming one has a large number of correlations at hand. An example often cited in the neuroeconomics literature is the probability that a reward process is present given nucleus accumbens activation.

The nucleus accumbens is part of the ventral striatum implicated in the processing of reward, novelty, and salience. Using meta-analytical techniques based on over a thousand studies in conjunction with Bayesian inference, it can be shown that there is moderate, almost strong, evidence to infer reward-related processes when observing nucleus accumbens activation. However, that activation is not necessarily observed in studies utilizing a reward task (Poldrack 2011). In general, Bayesian approaches are strong, meaning that, under suitable conditions, unknown or difficult-to-estimate quantities become irrelevant and final inferences robust. This is important as, for example, there is a plethora of N400 studies (many using MEG) that could potentially be exploited for the leadership studies indicated above.

Second, advances in virtual-reality and other technologies can be exploited to build towards experimental paradigms with a broader real-life content in order to address the issue of ecological validity. This is important because, invariably, most neuroimaging results will be produced under controlled laboratory conditions, making it difficult to extrapolate insights to a genetically and culturally diverse population, in a variety of organizational situations (see, e.g., Kagan 2017 for a broader aspect of the relationship between brain activity and psychological processes). Here, organizational cognitive neuroscience can follow recent trends in neuroeconomics and neuromarketing in order to boost generalizability of the insight gained from MEG studies. Of particular interest are approaches addressing the issue of drawing conclusions about real decisions based on hypothetical reports of intended behavior, as often utilized in experiments where implementing real choice is considered impractical or unethical.

A relevant example is a functional magnetic resonance imaging study that required the subjects to make hypothetical (trial did not count) and real (trial would be implemented as real) purchasing decisions (Jeong-Kang et al. 2011). Interestingly, the authors observed neuronal activity in the orbitofrontal cortex and the ventral striatum that correlated with behavioral measures of the stimulus value of the consumer goods in both types of decision. Despite apparent differences in other regions, the substantial overlap in neural activity between the two conditions suggests that conclusions about neural circuitry drawn from a hypothetical choice might generalize to a real choice when making purchasing decisions.

5. Ethical considerations

It is important to note that existing neuromarketing and, to a lesser degree neuroeconomics research, has been subject to considerable controversy within the scientific press, as evidenced by editorials in high-impact journals such as Lancet Neurology (2004, 3:71) and Nature Neuroscience (2004, 7:683). There is no doubt that brain-imaging technology will increasingly be used in commercial, organizational and governmental settings raising concerns that neuroscience methodologies might be used in ways that infringe on personal privacy to an unacceptable degree. Perhaps not surprisingly, consumer free will is one of the most discussed topics in neuro-ethics, and philosophy is an important component of this debate. Free will implies moral responsibility, and it is argued that individuals should be responsible for their actions only when free will is involved. In this sense, the consumer's mind should not be altered so as to prefer one option over the other, but it must be the underlying concept and features of the 'product' that are designed in a way that consumers tend to relate to.

In response, researchers have begun to outline guidelines and recommendations aimed at the protection of individual autonomy, averting harm and exploitation caused by the research and maintaining public trust in neuroscience. Moreover, there are now associations, such as the Neuromarketing Science & Business Association and The European Society for Opinion and Market Research, as well as many authors interested in neuro-ethics and the implications of neuromarketing research, who provide platforms to share knowledge and to protect social interests (see Olteanu 2015 for a review). So far, the emphasis is on neuromarketing, which is a strongly growing industry where many hundreds, if not thousands of companies world-wide offer neuroscience-based services related to advertisement and marketing. However, many of the emerging guideline principles, such as the call for transparency and objectivity of research, will be applicable to organizational research (and practice) as well.

Clearly, the ethical issues at hand are non-trivial, however, it has been argued that there is currently little if any evidence that neuroscience-based technologies permit the types of insights and subsequent manipulations that critics envisage. Ultimately, one has to observe and consider the implications that such a development might have and by which means it might be sensibly managed or regulated (Murphy et al. 2008; Fisher et al. 2010).

6. Conclusion

Despite challenges, the potential role MEG can play in new applications aimed at the level of groups, organizations or even societies, appears huge. Organizational cognitive neuroscience is still in its early stages, but it is likely to gain momentum rapidly offering an excellent opportunity for MEG researchers to be at the forefront of charting a new territory. Importantly, neuroeconomics and, to a lesser degree neuromarketing are increasingly recognized by clinicians as potentially powerful frameworks for investigating, amongst others, mental disorders, addiction and ageing (Javor et al., 2013; Brown and Ridderinkhof 2009; Hasler 2012). Assuming this trend continues, embarking on the organizational research venture is likely to strengthen the standing of MEG in many areas of science.

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