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The Use of Neuroimaging Methodology in Counselling Psychology Research: Promises, Pitfalls, and Recommendations
L'utilisation de la méthode de neuro-imagerie pour la recherche en psychologie du counseling : promesses, pièges et recommandations

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ABSTRACT

The use of neuroimaging has become increasingly popular among applied psychological researchers. However, when implementing a neuroimaging study in counselling psychology, several conceptual and methodological issues that may threaten internal or external validity must be considered. Although neuroimaging methods hold promise as a tool for counselling psychologists to utilize as we move toward a greater emphasis on science-based practice, important limitations must be addressed at the conceptual (e.g., the reverse inference problem, the danger of neurorealism, and lack of ecological validity) and methodological (e.g., preprocessing, design of experimental tasks, multiple comparisons correction) levels. We discuss the advantages and limitations of the application of neuroimaging to the field of counselling psychology and provide recommendations for those who wish to conduct research in this area.

RÉSUMÉ

L'utilisation de la neuro-imagerie gagne en popularité chez les chercheurs de psychologie appliquée. Toutefois, quand on met en œuvre une étude de neuro-imagerie en psychologie du counseling, il faut prendre en considération plusieurs aspect conceptuels et méthodologiques qui risquent de compromettre sa validité interne ou externe. Bien que les méthodes de neuro-imagerie soient un outil prometteur pour les psychologues du counseling à une époque où on s'oriente vers une pratique davantage fondée sur la science, certaines limites sur le plan conceptuel (p. ex. le problème de l'inférence inverse, le danger du neuroréalisme et l'absence de validité écologique) et méthodologique (p. ex. le prétraitement, la conception des tâches expérimentales, la correction des comparaisons multiples). L'article traite des avantages et limites de l'application de la neuro-imagerie en psychologie du counseling et formule des recommandations à l'intention de ceux qui souhaitent mener des recherches dans ce domaine.

Counselling psychologists have recently been called to work more closely with neuroscientists to clarify brain-behaviour relationships and derive implications regarding applications for prevention and treatment in psychotherapy (e.g., Gonçalves & Perrone-McGovern, 2014). A special section of the *Journal of Counselling Psychology* was dedicated to articles written by interdisciplinary teams of counselling psychologists and neuroscientists, who provided recommendations for future research in this area (Coutinho, Silva, & Decety, 2014; Fine & Sung, 2014; Gonçalves & Perrone-McGovern, 2014; Sampaio & Lifter, 2014; Simon-Dack & Marmarosh, 2014; Wright & Díaz, 2014). The next step is to provide a greater level of specificity regarding methodology that can be utilized by counselling psychologists in pursuing this line of research.

In this article, we discuss advantages of and limitations to the use of neuroimaging in counselling psychology research, and recommendations for researchers using this methodology in an applied field such as counselling psychology. The range of neuroimaging techniques is large, including methods as diverse as positron emission tomography (PET), *single-photon emission computed tomography (*SPECT), magnetoencephalography (MEG), and *near-infrared spectroscopy* (NIRs). However, in this article we will focus on magnetic resonance imaging (MRI) because this is one of the most commonly used methods of enuroimaging in psychological science, and it is also the one with which we are most familiar as researchers.

A broad range of topics have been addressed by neuroscience researchers in recent years, including the examination of basic psychological processes such as perception or attention, as well as complex and inherently human processes such as our capacity to reason and understand others' emotions. Neuroimaging studies, particularly structural and functional magnetic resonance imaging (fMRI), progressively emerged as the gold standard techniques for the study of psychological processes as diverse as learning (e.g., Zatorre, Fields, & Johansen-Berg, 2012), working memory (e.g., Koppel et al., 2014), emotional processing (e.g., Etkin & Schatzberg, 2011), moral judgement (e.g., Yoder & Decety, 2014), sense of free will (e.g., Chambon, Wenke, Fleming, Prinz, & Haggard, 2012), theory of mind (e.g., McCleery, Surtees, Graham, Richards, & Apperly, 2011), deception (e.g., Ganis, Rosenfeld, Meixner, Kievit, & Schendan, 2011), social interaction (e.g., Redcay et al., 2010), humour (e.g., Neely, Walter, Black, & Reiss, 2012), and introspection (e.g., Kreplin & Fairclough, 2015).

The growth of fMRI research in applied psychology is such that for most psychological processes, there are already published meta-analyses that derive from hundreds of studies previously implemented. For example, we have available meta-analysis of fMRI studies of emotional face processing (Aoki, Cortese, & Tansella, 2015), fear conditioning (Fullana et al., 2016), response inhibition (Criaud & Boulinguez, 2013), and decision making (Bartra, McGuire, & Kable, 2013), to name only a few examples.

Since the groundbreaking paper by Belliveau et al. (1991), the number of fMRI studies has increased exponentially. Belliveau et al. described the injection of a susceptibility contrast agent to map blood volume in humans. The first successful

experiments with noninvasive MRI-based techniques using endogenous functional contrast associated with localized changes in blood oxygenation during activation were conducted by Bandettini, Wong, Hinks, Tikofsky, and Hyde (1992) and Ogawa et al. (1992).

In fact, the history of neuroimaging has been a history of growth at various levels. The strength of the magnetic field has been increasing, and also increasing are the types of software available to analyze the data, the number of researchers familiar with fMRI methodology, the number of scanners available for research purposes around the world, and, consequently, the number of scanned participants and published papers.

In what follows, we draw from our experience as clinicians and neuroscientists to discuss the advantages and limitations of using neuroimaging methods in counselling research. We start by briefly reviewing the different neuroimaging measures and paradigms. Then we discuss the potentialities of disseminating the use of neuroimaging methods in counselling psychology research. Next, we discuss some conceptual and methodological limitations associated with current neuroimaging methods. Finally, we provide recommendations for counselling psychologists interested in introducing neuroimaging methods in their research programs.

Neuroimaging Measures and Research Paradigms

There are two main neuroimaging measures: structural MRI, in which we measure different markers of brain anatomy, and functional MRI, in which we measure brain function. Structural MRI is based on T1 or T2 images, which allows us to observe brain morphology—namely the volume and shape of specific structures and tissue types. MRI analytical approaches include manual-outlined and/or automatic volumetric studies (Keller, Roberts, & Hopkins, 2009), cortical thickness analyses (Nguyen et al., 2013), voxel-based morphometry (Coutinho et al., 2014), surface-based structural analysis (Fischl, Sereno, & Dale, 1999), and shape analyses (Vannucci, Barron, Lerro, Antón, & Vannucci, 2011).

Another type of structural analysis is diffusion tensor imaging (DTI). DTI is a variant of traditional MRI based on the water diffusion rate across the brain tissue (Le Bihan & Breton, 1985), which allows us to study white matter anatomy and structure (for a detailed description of DTI acquisition and analytic steps, see Soares, Marques, Alves, & Sousa, 2013).

fMRI is based on the principle that when a specific brain region is recruited, the metabolism in that area increases, leading to an increased blood flow and influx of more oxygenated hemoglobin (Ogawa, Lee, Kay, & Tank, 1990). The alteration in the balance between oxygenated and deoxygenated hemoglobin triggers a change in image contrast (captured by T2* images), the known blood-oxygen-level-dependent (BOLD) contrast mechanism.

Within fMRI, we can measure brain activation by means of block, event-related, and mixed block/event-related fMRI paradigms. These three types of fMRI paradigms can be distinguished based on the way the experimental stimuli

are presented as a function of time. In block designs, we use blocks of identical trial types to establish a task-specific condition (e.g., visual vs. auditory stimuli; negative vs. positive emotional images; Dale & Buckner, 1997). In this design, we can compare the brain activation during one stimuli condition and baseline/rest, or we can compare stimuli presented in different conditions.

Block design is the most simple task design and started to be used in the early days of fMRI. It has a number of benefits: it attains an adequate signal-to-noise ratio by collapsing across many trials (Bandettini, Jesmanowicz, Wong, & Hyde, 1993), it is suited for detecting regions of interest for particular tasks (Donaldson, 2004), and it can handle experimental tasks that do not fit into a trial-by-trial framework. However, this design cannot distinguish between trial types within a block (e.g., correct versus error trials) nor account for the transient responses at the beginning and end of task blocks, for example (Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008).

In event-related paradigms, we can measure the brain activation associated with discrete events of short duration, which are separated by an interstimulus interval. These are more complex task paradigms that allow us to detect transient variations in local hemodynamic response. There are two types of event-related designs: slow event-related designs in which the trials are spaced, allowing the hemodynamic response to resolve back to baseline prior to the next trial resulting in a trial-type specific time course (Petersen & Dubis, 2012), and rapid event-related designs in which the stimuli are closely spaced in time, resulting in the overlap of their hemodynamic response functions (Soares et al., 2016).

Finally, a mixed block/event-related design allows for the simultaneous extraction of transient activity related to trials and block transitions and sustained activity related to task-level processing. This design offers the advantages of both block- and event-related designs, although it has a poorer hemodynamic response function estimation and decreased statistical strength of sustained signal, requiring more subjects to measure statistical significant effects (Soares et al., 2016).

On the one hand, there are fMRI paradigms that measure the brain activation during a resting state condition, that is, when the participant is not asked to perform a specific task. In these studies, no specific instructions are given to the participant other than to remain still and relaxed during the acquisition, keeping their eyes closed or open while fixating on a cross. Resting state fMRI studies (Biswal, Zerrin Yetkin, Haughton, & Hyde, 1995; Damoiseaux et al., 2006; Fox & Raichle, 2007) are a growing field in fMRI. When studying resting state networks, we look at the organization of large-scale networks that connect anatomically separated brain regions. Therefore, we use measures of functional connectivity, which refers to the degree of co-activation or temporal correlation between the activation patterns of brain regions that are spatially separated (Rykhlevskaia, Gratton, & Fabiani, 2008). On the other hand, effective connectivity measures the influence that one brain region exerts over another. Effective connectivity thus constitutes an alternative method to understand how brain regions interact with each other, one that is closer to causality, requiring different analytic approaches, as we will see later in this article.

Advantages of Neuroimaging Research in Counselling Psychology Research

The use of neuroimaging methods can help move counselling psychology from an evidence-based practice to a science-based practice by identifying the pathophysiological mechanisms of psychological disorders as well as specific processes responsible for change in psychotherapy. By elucidating the neural mechanisms underlying psychological disorders, neuroimaging research contributed to the introduction of a new paradigm in counselling psychology. We are now moving from categorical to transdiagnostic models of psychopathology, in which the contributions of genetic, molecular, cellular, and brain systems converge to provide a deeper understanding of psychological processes associated with symptomatic dimensions present across disorders (Insel et al., 2010). For example, alterations in corticolimbic circuits involved in emotion regulation have been associated with symptoms of negative affect across several disorders such as schizophrenia (Rasetti et al., 2009), conduct disorder (Marsh et al., 2008), substance dependence (Upadhyay et al., 2010), and mood and anxiety disorders (Dannlowski et al., 2009; Etkin & Schatzberg, 2011).

Similarly, psychotherapy research can move from an evidence-based toward a science-based paradigm by using neuroscience research to identify the active ingredients responsible for psychotherapeutic change. Neuroimaging can be an alternative way of assessing the effects of psychotherapy and testing its efficacy in promoting healthy brain functioning. In fact, there is a burgeoning area of research examining the effects of psychotherapy on neuroplasticity (for a review, see Gonçalves & Perrone-McGovern, 2014). For example, there is evidence suggesting the specificity of psychotherapeutic interventions in terms of brain activity alteration when compared with other forms of treatment such as psychopharmacology interventions (Goldapple et al., 2004; Siegle, Carter, & Thase, 2006).

A good example of a science-based approach to psychotherapy is the recent study by Mason, Peters, Dima, Williams, and Kumari (2016) that looked at the effects of cognitive behavioural therapy (CBT) in normalizing functional connectivity in response to social threat in psychotic patients. There is now evidence that high sensitivity and problems in disengaging from social threat cues in psychotic patients is associated with alteration of functional connectivity in social threat brain networks (e.g., limbic, visual, prefrontal regions, insula regions). More specifically, a reduced connectivity between the prefrontal cortex and the amygdala may render patients more vulnerable to social threat cues.

The Mason et al. (2016) study showed that, before therapy, patients had an increased amygdala connectivity with the insula and visual areas and decreased connectivity with somatosensory areas while confronted with angry faces. After CBT, the patients not only normalized these connectivity patterns but also increased the connectivity between the amygdala and the dorsolateral prefrontal cortex (DLPFC) along with an increased connectivity between the DLPFC and other prefrontal regions. These changes were associated with symptom improvement, suggesting that the reestablishment of functional connectivity in brain regions

associated with processing of social threat could be an active mechanism of the CBT treatment with psychotic patients.

Another example of a study that demonstrated the impact of therapy using neuroimaging techniques is a study by Buchheim et al. (2012), who studied clients with major depressive disorder prior to and following 15 months of psychodynamic psychotherapy. Prior to therapy, participants with depression demonstrated a higher activation in the left anterior hippocampus/amgydala, subgenual cingulate, and medial prefrontal cortex as compared to a control group of individuals who did not have a depressive disorder. Following 15 months of therapy, however, participants with depression showed a reduction in these areas that was associated with reduced depression, whereas there was no change in these areas for the control group. Additionally, a study by Schiepek and colleagues (2013) used repeated fMRI measurements to demonstrate the effectiveness of psychotherapy for persons with obsessive-compulsive disorder in comparison to a group of matched health controls, and they found changes in the cingulate cortex, bilateral dorsolateral prefrontal cortex, bilateral insula, bilateral parietal cortex, and cuneus of the treatment group.

There are also a number of review articles that present a compilation of neuroimaging empirical evidence of the effectiveness of psychotherapy. For example, Linden (2006) provided a review of research demonstrating neuronal changes as a result of psychotherapy. A review by Barsaglini, Sartori, Benetti, Pettersson-Yeo, and Mechelli (2014) showed that psychotherapy seems to be effective in reverting patterns of brain abnormal activity in several psychological disorders and that these patterns are good predictors of therapeutic outcomes (e.g., obsessive-compulsive disorder, panic disorder, depressive disorder, posttraumatic stress disorder). More recently, Straube (2016) presented an overview of neuroimaging studies showing the effectiveness of psychotherapy for anxiety disorders.

In conclusion, we now have promising evidence that psychotherapeutic and counselling interventions can change the brain and normalize the activation pattern of brain networks in psychological disorders. We assert that neuroimaging can be a powerful tool for counselling psychology researchers to demonstrate the efficacy of psychotherapy in general, and to identify specific mechanisms responsible for change.

In the next sections, we will address the conceptual and methodological issues that should be taken into account when using neuroimaging methods in counselling psychology.

Limitations of Neuroimaging Research for Counselling Psychology

Conceptual Issues

Discrepancies between theories of the brain and theories of mind. Any scientific inquiry begins with a research question. In affective neuroscience, typically this question encompasses a compound of concepts from mind sciences (e.g., experimental psychology, counselling psychology) along with concepts from brain

sciences (e.g., biology, neurophysiology, neuroradiology, neuroengineering). Therefore, the formulation of the research question constitutes a challenge in itself. As suggested by Slaby and Choudhury (2011), this may be partially due to discrepancy between theories of the brain and theories of the mind. While theories of the brain aim to explain neural processes at the molecular, cellular, and brain circuitry level, theories of the mind try to untangle the psychological components such as perception, attention, memory, language, and emotion. Not only do the targets differ, but the terminology and concepts are also different. Thus, one of the first challenges for a researcher who wishes to use neuroimaging methodology to understand clinical phenomena is to come up with a well-defined scientific question that can be operationalized and addressed through a neuroimaging study, integrating concepts from both mind and brain sciences.

An example of the need to carefully articulate our theories of the brain and our theories of mind when formulating our research question will be presented below. It is related to the traditional nomothetic logic that pertains to most clinical research. Despite a commitment to overcome traditional psychiatric nosology by identifying objective markers of psychopathology, ironically most neuroimaging studies end up endorsing the old logic of recruiting patients diagnosed through categorical diagnostic systems. This is *not* in accordance with brain evidence suggesting that functional alterations in specific brain systems cut across several disorders. Thus, the current Research Domain Criteria (RDoC) initiative of the NIMH (Insel et al., 2010) attempted to redefine psychiatric nosology by identifying the systems-level circuits implied in neuropsychological functions that are altered in different psychological conditions. Buckholtz and Meyer-Lindenberg (2012) proposed a transdiagnostic model that specified the brain networks involved in broad domains of cognition (attention and cognitive control; affective arousal and regulation; reward and motivation and social cognition) associated with the emergence of psychopathology. Therefore, we believe that an applied researcher that intends to adopt a neuroscientific approach to better understand, define, and treat psychological disorders should follow this research strategy of looking at neuronal markers of altered psychological processes, rather than starting with specific disorders diagnosed with a categorical system.

The problem of reverse inference. In neuroimaging research, it is not uncommon for the author to infer the occurrence of a specific cognitive process (e.g., theory of mind) based on the activation of specific neural systems supposedly involved in that function (e.g., the temporal parietal junction and medial prefrontal areas) and, at the same time, rely on these data to confirm the involvement of those brain regions in that specific function. Poldrack (2006, 2011) calls this the *problem of reverse inference*, which is related to the fact that neuroimaging findings are mostly correlative, not causative.

A way of addressing this issue is to use analytic approaches that allow us to explore direct influences between different populations of neurons in the data. This is called *effective connectivity*, as opposed to *functional connectivity* (temporal correlation between distinct brain regions). A comprehensive review of the dif-

ferent connectivity analysis methods that can be used to estimate brain networks using fMRI data can be found in a paper by Smith et al. (2011). These methods range from very simple measures that consider just two nodes at a time (e.g., correlation between two nodes' timeseries) to more sophisticated approaches that estimate global network model (e.g., Bayes net models). By comparing different connectivity estimation approaches, Smith et al. found that general correlation-based approaches can be quite successful in detecting network connection on good quality fMRI data. On the other hand, methods based on higher-order statistics were shown to be less sensitive, meaning that accurate estimation of connection directionality is more difficult to achieve. Examples of two methods that can be implemented to explore the influence one brain region exerts over another are Granger causality mapping (Roebroeck, Formisano, & Goebel, 2005) and dynamic causal modelling (Stephan et al., 2010). The description of these methods is beyond the scope of this article; please see Friston (2011) for a detailed description.

Closely related to the problem of reverse inference is the problem of "double dipping" (Kriegeskorte, Simmons, Bellgowan, & Baker, 2009), a common error in the neuroimaging data analysis process. *Double dipping* refers to the use of the same dataset for selection and selective analysis. This occurs when the researcher hypothesizes that a given brain region will respond more strongly to stimulus A than to B, and thus selects voxels within this area to define a region of interest (ROI). The researcher will selectively analyze that ROI to test this hypothesis. The problem is that the analysis is circular in this case. In other words, because the selection process in dependent on our experimental design, we are violating the assumption of random sampling. One way to avoid double dipping is to use an independent dataset for the final analysis of the selected voxels or to define our ROI based on a totally independent analysis (i.e., functional localized) or based on a priori expectations from the literature. In this regard, as pointed out by Smith et al. (2011), when defining the network nodes and extracting their associated timeseries, the use of functionally inaccurate ROIs can be an important confound for network estimation.

The lack of ecological validity. Neuroscience researchers must often sacrifice ecological validity in order to keep the internal validity of their studies. This is not an easy balancing act, particularly for applied researchers who tend to use more ecological and naturalistic research paradigms. Thus, these researchers may find it difficult to foresee how the controlled experimental tasks used in fMRI can be applied to real clinical situations. An illustrative example is the case of a counselling psychologist investigating the brain mechanisms involved in depression using fMRI. This researcher will have to design a well-controlled experimental task that captures a specific dimension of depression (e.g., the ruminative nature of depressive thinking). Moreover, it is likely that this fMRI task won't be able to capture the whole complexity of ruminative thinking. For example, in a first set of experiments, rather than asking the participant to report the content of his or her ruminative thoughts, the participant would be primed with a series of negative stimuli (e.g., negative images of the International Affective Picture System or

IAPS), that are supposed to elicit rumination, and then perform an attentional task to explore the effect of rumination on task performance.

In fact, the ideal trade-off between internal and ecological validity is not easy to achieve in applied neuroscience research. We suggest that a good strategy is to start by using more controlled and simple stimuli like the ones used in the example above, even if this means sacrificing ecological validity. After replicating the results obtained with these stimuli, it is possible to move on to more ecological-based paradigms such as the one used by Cooney, Joorman, Eugène, Dennis, and Gotlib (2010). In this study, the ruminative-induced task included several rumination statements like "Think about what people notice about your personality," as opposed to a control condition such as "Think about a row of shampoo bottles on display." The researcher could also design an fMRI task using real stimuli based on real clinical situations. For example, the participants could be exposed to daily life situations that elicit rumination (e.g., through a narrative description or a video of real life episodes) and report on the content of their thoughts after the video. In this way, we could relate the content of the ruminative thoughts to the brain activation.

The technical advances in neuroimaging are bringing a whole set of possibilities that allow research tasks to be more ecological. For instance, hyperscanning (Montague et al., 2002), a method by which different subjects can interact with one another while their brains are simultaneously scanned, is a technique in which we can actually assess the brain activation during real interpersonal interactions.

Confounding structure and function. The way brain structure relates to brain function is a controversial issue in the field of neuroimaging. We would expect that structure and function would be positively related, considering that an increased volume in a specific structure, for example the amygdala, represents a bigger population of neurons and thus an increase in functional activity. However, the relationship may not be linear. DeYoung et al. (2010) discussed the relationship between personality traits and the volume of brain structures. As noted by DeYoung and colleagues, more neurons may result in more function; however, it may also be the case that a smaller volume in a given structure may indicate increased efficiency in a specific function. Evidence supporting this position comes from developmental studies demonstrating that individuals with above-average intelligence present greater reductions in cortical volume in late childhood (Shaw et al., 2006). On the other hand, evidence favouring the positive correlation between volume and structure comes from studies showing that training induces the volume increase in brain structures involved in the trained functions (Boyke, Driemeyer, Gaser, Buchel, & May, 2008; Maguire, Woollett, & Spiers, 2006).

Other examples of the nonlinear relationship between volume and function comes from studies about neurodevelopmental changes in aging. As shown in the revision by Greenwood (2007), although the brain shrinks in aging, the cortical regions that show a more pronounced age-related volume loss—the prefrontal and parietal cortices—are the same regions that show a significant increase in task-related activation for older adults. This negative relationship between corti-

cal volume and activation led authors like Van Petten (2004) to question the "bigger is better" assumption made about brain volume and cognition. In fact, different studies found that larger volumes in neocortical areas such as the PFC were related to poorer performance in tasks such as working memory (Salat, Kaye, & Janowsky, 2002). In the same line, the volumetric atrophy in these areas was associated with increased activation in several tasks, including perception (Grady et al., 1994), lexical decision-making (Madden et al., 1996), and problem-solving (Prabhakaran, Rypma, & Gabrieli, 2001) in older subjects. Whether these results can be explained by a compensatory mechanism or not, they should alert us to the need to be cautious when inferring the relationship between brain volume and activation.

Furthermore, as pointed out by authors such as Pessoa (2014), the nonlinearity of the relationship between brain structure and function is evidenced by the absence of a one-to-one relationship between a specific structure and a specific brain function. Pessoa argued that the simplistic strategy of understanding the brain in terms of individual regions must be overcome by adopting a network perspective. While a specific brain region participates in many psychological functions, many functions are carried out by more than one region. For example, the medial prefrontal cortex is involved in a wide range of cognitive and emotional processes, yet both prefrontal and parietal regions are involved in operations of executive control.

In sum, although it seems reasonable to expect that volume tends to be positively related with function, researchers should be very cautious when making predictions regarding the direction of the relationship or when interpreting their findings. In addition, it is important that researchers provide the reader with a comprehensive account of the inconsistency in the literature regarding the relationship between the volume of a specific ROI and its function, as well as the inconsistency between their results and those found in previous studies.

Methodological Issues

The need for a carefully designed fMRI paradigm. In this section, we provide some important cues for the design and planning of typical fMRI experiments in which brain activity is measured while the participant is performing a specific cognitive task (what we may call task-based studies, in contrast to resting-state studies). The experimental design here must follow the general rules of any experimental study but must also consider the specific needs of fMRI.

The physics involved in this technology and the imaging parameters interact with the experimental paradigm. Thus time is a central issue in experimental design. For example, the fact that the hemodynamic response has a delay of approximately two seconds after the stimulus presentation prevents us from using very fast stimuli like we can use in other modalities with much better temporal resolution such as EEG Event Related Potentials. In fact, the shape of the hemodynamic response function that characterizes the BOLD signal needs to be taken

into account when designing the study. This hemodynamic function is characterized by an initial dip followed by a gradual rise, peaking ~5–6s after the stimulus, followed by a return to the baseline (about 12s after the stimulus) and a small undershoot before stabilizing again, 25– 30s after (Soares et al., 2016).

Moreover, one of the first decisions the researcher must make is to choose the type of paradigm (blocked, event-related design, or mixed block/event-related design designs) to use. As we already mentioned, in block designs stimuli of the same condition are presented subsequently (e.g., food stimuli), alternating with a different condition (e.g., nonfood stimuli). The advantage of block designs is that the BOLD response is generally of higher magnitude; however, they may trigger participants' expectations, which is a serious limitation. In event-related design, each stimulus's hemodynamic response function is detected, allowing the temporal characterization of BOLD signal changes. They allow for stimulus randomization and variation in the interstimulus interval, which reduces habituation effects. This, in turn, increases attention levels thorough the experiment.

Another issue pertains to the method used to register the participant´s response. In order to assess task performance (e.g., error rate or reaction times), you should have a measurable behavioural response, such as a yes or no button-press response. As we mentioned in the first part of this article, this can compromise the ecological validity of your study but also makes it easier to record participants' responses and assure the control of the experimental conditions. An ideal tradeoff should thus be found for each specific research question. Another important guideline when designing an fMRI task to measure a specific psychological process is to change the task or the stimuli but not both. For example, if stimuli are kept identical (e.g., using faces), the task can be varied. Or if an n-back task is used, faces or words in different blocks can be used.

Sample composition. The composition of the sample is a critical issue in all types of research, and neuroimaging studies are no exception. Journal reviewers are increasingly concerned with the quality control of the data, and much of the quality control is related to the number of participants included in the study and their characteristics. The sample size is especially important in the case of fMRI studies in which we perform multiple cross comparisons, as we will explain in the next section. Thus, the authors must always perform a power analysis in order to determine if the number of subjects and scans included in their study is enough to account for both within- and between-subject variability. There are appropriate tools to calculate the adequate sample size for fMRI studies. For example, Mumford and Nichols (2008) presented an approach for calculating power for a group fMRI model that includes nonsimulation-based calculations. This allows for quick power calculations; incorporation of temporal autocorrelation, flexibility of first-level design (allowing for either block or event-related study designs); and flexibility of second-level design (i.e., beyond a simple one-sample *t*-test). Moreover, this method can easily adapt to the models of a variety of fMRI software packages such as SPM (Statistical Parametric Mapping, http://www.fil.ion.ucl.ac.uk/spm/) or FSL (FMRI Software Library, http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/).

Not only the sample size but also the inclusion criteria require careful attention when planning the study. For instance, if you plan to look at the neural basis of pathological functioning in any dimension, whether it is emotional regulation, empathic abilities, or visual perception, you must delimit the boundaries of "normal" or "abnormal." This is not always an easy task. For example, what amount of coffee or alcohol consumption could be considered normal for an adult? What is the score that allows us to distinguish individuals with low empathic abilities? Is self-report the best way to classify the participants?

A typical solution found by researchers is to use two different groups: one considered "normal" and another pathological. Again, the decision of inclusion in the control or in the clinical group can be challenging. Should someone who was clinically depressed one year ago but whose score on the Beck Depression Inventory is now in the minimal range be included in the clinical group? Should someone diagnosed with panic disorder whose symptoms are currently controlled with medication be included?

Ideally, we would be able to control every aspect of the person's state of mind and brain before and during the fMRI experiment, but this is rarely the case. Nevertheless, researchers should always be aware that the ability to compare the results from different groups or conditions and the ability to compare their results with those of other experiments, are highly dependent on how precisely they defined and considered the state of the participants. Thus, our suggestion is to invest time and effort to detect (and if possible to control) the maximum number of factors that can influence the results, such as what each participant eats or drinks before the scan, how rested or anxious the subject is, and what exactly the subject is doing during the MRI acquisition.

The Specificities of Image Preprocessing

> "We must understand our tools before we can hope to understand our results." (Perlmutter & Raichle, 1986, p. 384)

The above quote from Perlmutter and Raichle (1986) is true for all areas of scientific research. However, we argue that it is particularly true in neuroscience research, including neuroimaging, due to the technical components involved. Indeed, the technical aspects involved in neuroimaging analysis, especially in the preprocessing of the images before the statistical analysis is carried out, can be challenging and difficult to grasp for researchers who have no neuroscience training or background. Fortunately, recent efforts have been made by the neuroimaging community, namely the Committee on Best Practice in Data Analysis and Sharing (COBIDAS) created by the Organization for Human Brain Mapping, to elaborate comprehensive guidelines for the planning, acquisition, and report of fMRI studies. An example of a reference paper in which the reader can find the best practice and reporting recommendations is a recent article by Nichols and colleagues (2017) that elaborates the principles of open and reproducible research for neuroimaging using MRI, and then distill these principles to specific research practices.

In most neuroimaging studies, images will be realigned with other brain images, transformed into a normalized space, corrected for motion artifacts, and spatially smoothed. The question is "What level of knowledge is needed for a counselling psychologist researcher to begin using neuroscience methods to conduct these studies?" We recommend that a very detailed knowledge of the complex mathematical algorithms that are running beyond the analysis that you are performing can be left for the biomedical engineers who developed those methods. However, a knowledge of the menu of the software/toolbox that you are going to use to conduct fMRI analysis is not enough. In order to make informed decisions and be aware of the specific influence that each preprocessing step can have on your results, you need to know the purpose and the basic mechanisms involved in that step. As an example, you need to know that smoothing is applied in order to increase your signal-to-noise ratio by applying a Gaussian blurring kernel across your image to average part of the intensities from neighbouring voxels together.

This is especially important because most of the inconsistency of the results seen in the literature stem from different methodological options employed by the researchers. Thus, it is crucial to know the methods well enough to select those most appropriate for your research study. At the moment, there are a number of methodological papers comparing two or more different methods to perform the same type of analysis (e.g., different methods for volumetric analysis of specific brain areas; Bergouignan et al., 2009; Soares et al., 2016). These papers can be useful when selecting your methods of analysis and respective toolbox. Counselling psychology researchers may also contribute to that effort by comparing different methods using the same database.

As well as the preprocessing complexity and the number of available tools to deal with it, it is also important to mention the relevance of the quality control needed for all neuroimaging studies, and fMRI particularly. The first step to monitor the quality of the data occurs in the acquisition phase. As suggested by Soares and colleagues (2016), it is important to inspect the images to verify the appearance of the brain, to screen for brain lesions, gross head motion, and spiking, as well as important small motion. These inspections of visible artifacts can be done with general purpose viewers such as Osirix or MRIcro. Complementary quality control procedures may also be implemented using software tools specifically developed for this purpose, such as the NYU CBI Data Quality tool (http://cbi.nyu. edu/software/dataQuality.php) and the CANLAB Diagnostic Tools (http://wagerlab.colorado.edu/tools).

Statistical Inference: Type I and Type II Errors

The fundamental concept in functional imaging analysis is the statistical comparison of what is expected to happen in the hemodynamic response, as defined by a reference function or a regressor, with the data, on a voxelwise basis. The voxelwise statistical tests imply a high number of tests that are being performed on the same data. These multiple comparisons performed in the analysis lead to the inflation of type I error/false positives. The danger of false positives in fMRI

research was illustrated in a paper by Bennett, Wolford, and Miller (2009), which showed that active voxel clusters could be observed in the brain of a dead salmon when using uncorrected statistical thresholds. When any form of correction for multiple comparisons was applied to the statistical analysis, the false positives were no longer present.

In order to avoid type I errors, statistical methods of correction for multiple comparisons need to be applied to the data. Although we can easily find published papers using uncorrected statistical thresholds (normally a threshold of $p < 0.001$ with a minimum voxel clustering value of 10 voxels is used), the proportion of studies using uncorrected thresholds is decreasing (Bennett et al., 2009). Examples of methods of correction for multiple comparisons often used in neuroimaging research are Familywise Error Rate (FWE), which eliminates familywise errors (Nichols & Hayasaka, 2003); Bonferroni correction (typically seen as too conservative for functional neuroimaging as it does not take into account spatial correlation between voxels); Gaussian random field theory that adapts to spatial smoothness of the data, but was shown to be quite conservative at low levels of smoothness (Worsley, Evans, Marret & Neelin, 1992); and nonparametric permutation correction techniques, which emerged as an ideal choice for adequate correction while maintaining high sensitivity (Nichols & Holmes, 2002).

Another correction method is False Discovery Rate (FDR), which controls how pervasive false positives are in the results (Benjamini & Hochberg, 1995). Thus in FWE we control the probability that we make even a single error, whereas in FDR we control the fraction of errors we make. FWE is a more conservative strategy, but FDR still provides precise estimates of the percentage of false positives.

Finally, one of the correction methods most commonly used is the Monte Carlo correction. This method creates multiple simulated null datasets, and from them creates a distribution of cluster sizes, from which the cluster size corresponding to a desired corrected significance level can be read off. Monte Carlo simulations may be implemented in AlphaSim distributed with AFNI and with the REST toolbox.

It is important to note that the results may change significantly depending on the method and significance threshold applied to the data. This often leads to situations in which the authors confirm or reject their hypothesis depending on the correction method they used. Specifically, more conservative correction methods increase the likelihood of type II errors, that is, the failure to detect a true effect. Type II errors are particularly evident with small samples (Nichols & Hayasaka, 2003) or with subtle phenomena (such as more complex cognitive and affective processes) often associated with signals of low amplitude (Lieberman & Cunningham, 2009). Thus, when reporting results, the authors should always report the method of correction for multiple comparisons that were used.

Final Remark: The Danger of Neuroenchantment and Neurorealism

Considering all the possible conceptual and methodological pitfalls of neuroimaging methods explained above, researchers should be very careful about what

some authors call *neuroenchantment*—a fascination with brain science that leads us to overestimate the current state of scientific knowledge and real capabilities and accept tentative evidence as unquestionable fact (Racine, Bell, & Illes, 2010; Slaby & Choudhury, 2011). This phenomenon is encouraged by the media and the general public, who increasingly seek answers for societal problems in neuroscientific discoveries. Interestingly, previous evidence demonstrated that providing the information within a neuroscience context using specific terminology prompted nonexperts to rate scientific arguments more highly compared to explanations lacking neuroscientific jargon (Michael, Newman, Vuorre, Cumming, & Garry, 2013; Weisberg, Keil, Goodstein, Rawson, & Gray, 2008).

Another illustration of *neuroenchantment* was provided in an intriguing study performed by Ali, Lifshitz, and Raz (2014). Amir Raz (the third author) is a neuroscientist who, in the past, worked as a magician. The authors wanted to see whether they were able to influence the participants´ critical judgement by presenting them with a fake and very dubious mind-reading procedure based on neuroimaging. They recruited 26 participants from an advanced undergraduate course focused on the merits and shortcomings of several imaging techniques. Surprisingly, they found that despite the ridiculous setup of their scanner, which included a scrap salon hair dryer, participants were neither skeptical nor suspicious of the paradigm and accepted science fiction as neuroscientific fact. This work showed that not even participants' knowledge about neuroimaging acquired through a university course addressing the limits of neuroimaging was able to prevent them from believing in a highly implausible experience.

Closely related to neuroenchantment is *neurorealism,* which is the tendency to turn a phenomenon under study into something uncritically real and objective in the eyes of the public. This is particularly present in neuroimaging research due to the nature of the method itself, which is based on images. By suggesting the location of a specific psychological function or pathology, images are likely to convey a sense of objectivity and reality, and thus contribute to neurorealism. McCabe and Castel (2008) found that individuals tended to attribute more scientific merit to cognitive research when it presented brain scans in colourful renderings, rather than simple bar graphs or plain text. Later, Keehner, Mayberry, and Fischer (2011) found that the quality of the images of the brain, namely those that were more three-dimensional and tangible, mediated the perception of the quality of neuroscience information. If this is true for a scientific audience, it may be even truer for clients and the mass media that tend to view brain scans as incontrovertible evidence.

Press content reporting fMRI results typically convey a sense of neurorealism and neuroessentialism in the news report (Racine et al., 2010). In fact, the major strength of brain images, which is the ease of getting persuasive maps of brain activation, can also become a problem. Therefore, an important aspect that clinical researchers should care about is the need to conciliate the unique power that images can have with the exact description of the findings to prevent the overinterpretation of the results. In fact this applies as well to other types of images such

as astronomical images, tables, and graphs (Galison, 1998). The main point is that images should serve to better explain the findings and the argument presented in the article instead of becoming the end of publication in itself. Finally, the acquisition of brain scans of our patients and their interaction with the neuroimaging technology throughout the process may alter their overall experience of their own clinical condition and/or the nature of the therapeutic relationship. This is because patients may see the evidence produced by fMRI as indicating, in a deterministic manner, the physical basis of their symptoms.

conclusions and recommended guidelines

It is our hope that this article has provided useful information that can both alert and inform an increasing audience of clinical researchers such as counselling psychologists, psychotherapists, counsellors, and psychiatrists, who are starting to use neuroimaging methods. We conclude with a summary of important recommendations and guidelines presented in this article:

1) Begin with a well-defined scientific question that can be operationalized and addressed through a neuroimaging study.
2) When designing your research paradigm, in order to find a good trade-off between internal and ecological validity, start by using more controlled and simple stimuli that allows you to gain internal validity and then move on to more ecological research paradigms.
3) Try to control the maximum number of factors that can influence your results. You should carefully define the inclusion criteria for the participants that will compose your sample and administer sociodemographic and psychological measures to assess variables that you can add as covariates in your model.
4) Learn the purpose and the basic mechanisms involved on each step of image preprocessing (e.g., slice timing, realignment, normalization, smoothing). Be sure to report in detail all the methodological parameters you have used in each step of the preprocessing pipeline to allow the reproducibility of your study and the possibility of sharing your results.
5) Report the procedures of quality control that you have used to monitor the quality of your data so that your audience knows how you detected and corrected for the artifacts that may interfere with fMRI data, thus ensuring the reliability of your maps of functional activation.
6) To control for the inflation of type I error, apply a method of correction for multiple comparisons and report the method you used (FDR, FWE, Monte Carlo).
7) Resist neuroenchantment. Even when your audience (mass media or general public) accepts the results as unquestionable facts, you should not overestimate the power of the beautiful 3D images and maps of brain activation obtained in neuroimaging analysis.

8) When interpreting your findings, be very cautious in the predictions regarding the direction of the relationship between volume and function.
9) Be aware that most neuroimaging findings are mostly correlative, not causative, so you must avoid reverse inference assumptions. If you wish to look at the direction of the influence, you should use analytic approaches that allow you to look at effective connectivity.

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