Topical Review: Unique Contributions of Magnetic Resonance Imaging to Pediatric Psychology Research

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Abstract

Objective This review aims to provide a brief introduction of the utility of magnetic resonance imaging (MRI) methods in pediatric psychology research, describe several exemplar studies that highlight the unique benefits of MRI techniques for pediatric psychology research, and detail methods for addressing several challenges inherent to pediatric MRI research.

Methods Literature review.

Results Numerous useful applications of MRI research in pediatric psychology have been illustrated in published research. MRI methods yield information that cannot be obtained using neuropsychological or behavioral measures.

Conclusions Using MRI in pediatric psychology research may facilitate examination of neural structures and processes that underlie health behaviors. Challenges inherent to conducting MRI research with pediatric research participants (e.g., head movement) may be addressed using evidence-based strategies. We encourage pediatric psychology researchers to consider adopting MRI techniques to answer research questions relevant to pediatric health and illness.

Key words: chronic illness; developmental perspectives; neuropsychology.

Magnetic resonance imaging (MRI) technology has significantly increased our understanding of brain structures and processes relevant to health behaviors. The use of MRI technology has increased dramatically over the past decade (Taylor, Donner, & Pang, 2012), and neuroimaging has become a prevalent method for understanding cognitive processes related to health and disease in adult health psychology (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). Furthermore, MRI studies in pediatric psychology have become more frequent (Etkin, 2010), and several authors have described the unique benefits and challenges of MRI research methods for specific pediatric conditions, including pain (Sava et al., 2009) and anxiety (Pine, Guyer, & Leibenluft, 2008). Unique information regarding brain growth and cognitive development that occurs during childhood and adolescence can be obtained using MRI methods, which has engendered increased interest in using MRI methods in pediatric research (Etkin, 2010; Taylor et al., 2012). However, neuroimaging is used less frequently in pediatric psychology research than in clinical child (e.g., autism, anxiety disorders) and adult literature (Etkin, 2010). MRI research holds promise in advancing pediatric psychology research, particularly given the large body of evidence indicating that pediatric health behaviors are highly influenced by neurocognitive processes (Pokhrel et al., 2013).

The purpose of this topical review is to (1) briefly describe several aspects of MRI research methods that may advance pediatric psychology research using exemplar studies that illustrate the merits of these methods, and (2) discuss several salient challenges to conducting MRI research with pediatric populations.
Utility of MRI for Pediatric Psychology Research

Structural MRI and functional MRI (fMRI) studies offer important insights into brain development and can be used more frequently in pediatric psychology research to localize cognitive functioning and examine differences in brain structures and processes, allowing researchers to examine the underpinnings of neural development. In addition, although current MRI methods may not be able to definitively establish how brain processes underpin health behavior outcomes, neuroimaging allows us to examine developmental changes in the brain that relate to behavior (e.g., executive functioning) and observe how brain changes associated with chronic illnesses develop over time (Etkin, 2010; Taylor et al., 2012). These noninvasive techniques provide information never before accessible to pediatric scientists to analyze the development of typical and atypical behavior (Voos & Pelphrey, 2013). The studies outlined below demonstrate the unique benefits of MRI methods in pediatric psychology research (see Table 1 for a comprehensive list of key articles).

Structural MRI

Findings obtained from structural MRI research can elucidate long-term health consequences of chronic illness. For example, structural MRI studies have increased our understanding of brain structure differences in children with type 1 diabetes mellitus (T1DM). Specifically, Aye and colleagues (2011) found that children aged 3–10 years with T1DM did not demonstrate typical increases in white matter volume compared with children without T1DM. Aye and colleagues’ use of MRI methods allowed them to elucidate a potential mechanism by which cognitive impairment in children with T1DM may occur (i.e., impaired white matter development) and demonstrated the feasibility of using MRI technology to examine the development of diseases in early childhood.

Additionally, structural MRI methods have been used to examine neural correlates of hypo- and hyperglycemic events in pediatric diabetes. Hershey and colleagues (2010) used structural MRI to examine associations between hippocampal volumes and self-reported hypo- and hyperglycemia events in children with T1DM. Interestingly, they reported that an increase in severe hypoglycemic events was associated with larger hippocampal volumes, contradicting previous findings in adults (Kalimo & Olsson, 1980). The authors concluded that their results may reflect pathological reactions to severe hypoglycemia in children.

These findings highlight the utility of MRI technology in studying the progression of chronic illnesses across development, and provide evidence for differences in neural structure associated with chronic illness between children and adults.

Functional MRI

Functional MRI methods may be particularly beneficial when examining brain processes relevant to decision making, reward sensitivity, and executive functioning in children and adolescents with chronic health conditions. Although numerous self- and parent-report measures of these constructs are widely used in pediatric psychology research, these questionnaires are limited by their focus on observable behaviors without providing information about neural processing that underlies behavior. For example, fMRI research facilitates analysis of children’s fundamental sensitivity to reward without reliance on parental self-report. Batterink, Yokum, and Stice (2010) used fMRI to examine how overweight adolescent girls respond to appetizing food images compared with normal-weight peers. They found that overweight adolescents showed less activation in the frontal inhibitory regions and higher activation in food reward regions of the brain, suggesting more impulsivity when responding to appetizing food images for overweight youth. Bruce et al. (2010) reported similar findings in children, using fMRI technology to show that, when fasting, obese children show greater response to food in the prefrontal cortex compared with their normal-weight peers. The use of fMRI technology not only provides insight regarding food reward sensitivity, but also allows for examination of neural processes that have implications for health behavior.

Another health-related cognitive ability that can be assessed using MRI technologies is working memory. Although neuropsychological assessments provide rich information regarding working memory functioning, they provide limited information regarding the brain location of abnormal function related to working memory. For example, Castro-Fornieles and colleagues (2010) reported greater activation in a...
<table>
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<th>Study</th>
<th>Sample type</th>
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<th>Utility of MRI</th>
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<tr>
<td>Batterink et al. (2010)</td>
<td>Overweight adolescent females</td>
<td>Normal-weight female controls</td>
<td>29</td>
<td>M age = 15.7; SD = 0.93</td>
<td>Examine how overweight adolescent girls responded to appetizing food images using a food go/no-go task.</td>
<td>Overweight adolescents showed less activation in frontal brain regions associated with inhibitory control and higher activation in regions associated with food reward.</td>
<td>Provides insight regarding adolescent’s cognitive control and reward sensitivity in relation to food stimuli.</td>
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<td>Bruce et al. (2010)</td>
<td>Obese adolescents</td>
<td>Age-, sex-, and education-matched healthy weight controls</td>
<td>20</td>
<td>10–17 years</td>
<td>Examine brain activation in response to food stimuli in obese adolescents.</td>
<td>Obese adolescents were hyper-responsive toward food stimuli compared with healthy-weight children, even after eating.</td>
<td>Provides insight regarding adolescent’s neural sensitivity to food rewards.</td>
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<td>Castro-Fornieles et al. (2010)</td>
<td>Adolescents with anorexia nervosa (AN)</td>
<td>Age-matched controls</td>
<td>28</td>
<td>11–18 years</td>
<td>Examine brain activation during a working memory task in adolescent patients with anorexia before and after weight recovery.</td>
<td>Adolescents with AN exhibited greater activation in temporal and parietal brain regions when completing a working memory task; after treatment, there was difference in brain activation across study groups.</td>
<td>fMRI findings may provide insight into the effectiveness of interventions in adolescents.</td>
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<td>Davis et al. (2011)</td>
<td>Overweight, inactive children</td>
<td>Age- and sex-matched controls</td>
<td>20</td>
<td>7–11 years</td>
<td>Examine how an exercise intervention can alter brain activation during an executive function task.</td>
<td>The exercise group showed increased prefrontal cortex activity and decreased activity in posterior parietal cortex as compared with a no-exercise control.</td>
<td>fMRI findings may provide insight into the effectiveness of weight-loss interventions in adolescents.</td>
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<td>Hershey et al. (2010)</td>
<td>Children and adolescents with type 1 diabetes</td>
<td>Sibling controls</td>
<td>95</td>
<td>7–17 years</td>
<td>Examine whether hypo- or hyperglycemia during brain development affected hippocampal volumes.</td>
<td>Severe hypoglycemia (but not hyperglycemia) was longitudinally associated with larger hippocampal volumes.</td>
<td>Allows one to study the progression of chronic illness across development.</td>
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<td>O’Hare et al. (2009)</td>
<td>Children and adolescents with fetal alcohol spectrum disorders</td>
<td>Typically developing controls</td>
<td>40</td>
<td>7–15 years</td>
<td>Examine the neural basis of verbal working memory in children and adolescents with fetal alcohol spectrum disorders.</td>
<td>Children and adolescents with fetal alcohol spectrum disorders perform similar to peers on working memory tasks, but demonstrated increased activation in frontal, parietal, and temporal brain regions.</td>
<td>fMRI has potential to elucidate brain functioning in children and adolescents that is undetected by neuropsychological tests.</td>
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working memory task in temporal and parietal brain regions for adolescents with anorexia nervosa (AN) compared with individuals without AN, suggesting that these regions are recruited to augment working memory function when normal function is impaired. Furthermore, this study demonstrated no increased brain activation compared with controls following treatment for AN, indicating that intervention effectively restored normative working memory functioning. Research in pediatric psychology may benefit from using fMRI methods to assess brain response to intervention.

Another study that assessed neural functioning using fMRI (O’Hare et al., 2009) demonstrated that children with Fetal Alcohol Spectrum Disorders (FASD) evidenced similar working memory function to neurotypical controls as measured with neuropsychological tests, but demonstrated increased activation in frontal, parietal, and temporal regions when performing working memory tasks. Although children with FASD would not be discernable from their peers on neuropsychological working memory assessments, fMRI methods indicate that atypical brain circuitry is recruited to perform working memory tasks in children exposed to alcohol in utero, providing evidence that children with FASD recruit different brain regions to perform working memory tasks than their neurotypical peers. This finding has significant implications for neurodevelopmental research in pediatric congenital conditions. Specifically, fMRI methods can be used to examine differences in neural activation patterns among atypically developing children and provide evidence for plasticity in functional neural processes. Taken together, these findings demonstrate that fMRI methods can yield unique and incrementally valid information regarding cognitive processes and neurophysiology that is not accessible using neuropsychological assessment.

Challenges in Conducting MRI Research With Pediatric Samples

There are several challenges inherent to conducting MRI research with children and adolescents. However, many methods for managing these challenges have been developed. For example, the MRI scanner environment can be anxiety provoking for a child because it requires individuals to lie very still for up to 60 min in an enclosed space within the bore of a scanner that emits loud noises. Thirty percent of children undergoing MRI scans reported severe levels of distress after the MRI experience (Tyc, Fairclough, Fletcher, Leigh, & Mulhern, 1995). Many successful techniques have been used to reduce child stress before the scanning session. A common technique used to prepare children to undergo MRI is to simulate this experience using a mock-MRI scanner (Barnea-Goraly et al., 2014; de Amorim e Silva, Mackenzie, Hallowell, Stewart, & Ditchfield, 2006; Hallowell, Stewart, Amorim e Silva, & Ditchfield, 2008). Barnea-Goraly et al. (2014) demonstrated that a homemade mock scanner (a massage mat to simulate scanner movement and a video player to simulate the sounds of the MRI, all within a toy tunnel) was as effective in preparing the child for the MRI experience as a commercial (and significantly more costly) mock scanner. Other investigators have created games or activities for the child to participate in (such as “The Statue Game”) that encourage the child to lie still during imaging (Aye et al., 2011; Barnea-Goraly et al., 2014). Training scanner staff in child-friendly interactions to promote child comfort, in addition to allowing the scanning process to proceed at the child’s own pace, have been shown to decrease anxiety and distress (Barnea-Goraly et al., 2014; de Amorim e Silva et al., 2006; Hallowell et al., 2008).

Head movement is also a significant concern when conducting neuroimaging research with children. Several methods for correcting motion artifacts when imaging children have been developed (Brown et al., 2010; Kuperman et al., 2011). Although motion corrections can reduce image degradation resulting from head movement, no motion correction can accommodate extreme and sustained movement (Kuperman et al., 2011). Moreover, most fMRI protocols preclude sedation as an option for motion prevention. Therefore, procedures to reduce motion may be particularly beneficial with pediatric research participants. Training children to remain still in the scanner using education, systematic desensitization, and guided imagery is an evidence-based approach to reducing head motion (Woods-Frohlich, Martin, & Malisza, 2010). However, using guided imagery in fMRI research is impractical, given that functional brain changes in response to guided imagery may represent confounds to data analysis. Other alternatives for motion reduction include pillow systems (e.g., NoMoCo; http://www.nomocopillow.com) and inflatable head restraint devices (e.g., Pearltec; http://www.pearltec.ch). Using head motion minimization and statistical motion correction procedures in pediatric research will assist researchers in maximizing the validity of MRI data.

Summary and Recommendations

We argue that MRI techniques have unique utility for examining neural processes and structure with relevance across many topic areas in pediatric psychology. As detailed above, MRI methods are well suited to answer research questions that cannot be addressed using neuropsychological measures (e.g., behavioral
measures of executive functioning or working memory). Moreover, MRI is well suited to address questions regarding development of cognitive abilities across the lifespan, another aspect of MRI methods that is appealing for pediatric psychologists. Additionally, innovation in research methods is an important criterion for obtaining grant funding, and MRI methods represent innovative research technology for many areas of pediatric psychology. We recommend that pediatric psychology researchers consider including MRI techniques in their assessment of cognitive function because these methods provide fundamental assessment of neural processes that underlie health behaviors. Furthermore, research examining outcomes of pediatric health behavior interventions may benefit from using MRI methods to demonstrate neural changes associated with treatment (e.g., Davis et al., 2011). For example, recent fMRI research in pediatric oncology has demonstrated that among adolescents with a history of brain tumor, cardiorespiratory fitness was associated with more efficient neural functioning associated with working memory (frontal-parietal network), approximating that of neurotypical adolescents, compared with less fit peers (Wolfe et al., 2013). This line of research suggests a neuroprotective effect of cardiorespiratory fitness that cannot be detected using traditional working memory assessment techniques. Demonstrating changes in neural processes in response to intervention may provide additional evidence for the long-term benefits and cost-effectiveness of pediatric psychology prevention and intervention efforts.

We also recommend that pediatric psychologists establish collaborations with neuroscientists, which will facilitate state-of-the-art research designs, promote sound data analysis techniques, and provide access to emerging MRI technologies (e.g., diffusion tensor imaging), which may enhance MRI contributions to pediatric psychology research in the future. Similarly, we urge pediatric psychology researchers to avail themselves of training in neuroanatomy, biopsychology, and neuroimaging science, as gaining knowledge in these areas will facilitate development of sound hypothesis-driven research using pediatric neuroimaging methods. Because MRI research requires rigorous experimental research designs, obtaining interdisciplinary training in these methods will prepare pediatric psychologists to conduct high-quality MRI research.

Conflicts of interest: None declared.

References


