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EEG mu rhythm and imitation impairments in individuals with autism spectrum disorder

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Abstract

Imitation ability has consistently been shown to be impaired in individuals with autism. A dysfunctional execution/observation matching system has been proposed to account for this impairment. The EEG mu rhythm is believed to reflect an underlying execution/observation matching system. This study investigated evidence of differential mu rhythm attenuation during the observation, execution, and imitation of movements and examined its relation to behaviorally assessed imitation abilities. Fourteen high-functioning adults with autism spectrum disorder (ASD) and 15 IQ- and age-matched typical adults participated. On the behavioral imitation task, adults with ASD demonstrated significantly poorer performance compared to typical adults in all domains of imitation ability. On the EEG task, both groups demonstrated significant attenuation of the mu rhythm when executing an action. However, when observing movement, the individuals with ASD showed significantly reduced attenuation of the mu wave. Behaviorally assessed imitation skills were correlated with degree of mu wave attenuation during observation of movement. These findings suggest that there is execution/observation matching system dysfunction in individuals with autism and that this matching system is related to degree of impairment in imitation abilities.

Keywords: Autism; Imitation; EEG; Mu rhythm; Mirror neurons

1. Introduction

Imitative deficits in individuals with autism have consistently been observed (Williams, Whiten, & Singh, 2004). In fact, several researchers have suggested that imitation deficits are one of the core impairments of autism spectrum disorders (ASD; Dawson & Adams, 1984; Dawson & Lewy, 1989; Rogers & Pennington, 1991; Williams, Whiten, Suddendorf, & Perrett, 2001). Imitation impairments in autism were first reported by DeMyer and colleagues (DeMeyer et al., 1972) and in the thirty years since this initial report, over twenty studies have examined varying aspects of imitation in ASD. Most of these studies have focused on imitation impairments in children with ASD. Children with autism under 6 years of age show impaired imitation skills compared to children with mental retardation, developmental delay, and communication disorders as well as compared to typically developing children (Aldridge, Stone, Sweeney, & Bower, 2000; Charman et al., 1997; Charman et al., 1998; Dawson, Meltzoff, Osterling, & Rinaldi, 1998; Rogers, Hepburn, Stackhouse, & Wehner, 2003; Sigman & Ungerer, 1984; Stone, Lemanek, Fishel, Fernandez, & Altemeier, 1990; Stone, Ousley, & Littleford, 1997). School age children with autism also show imitation deficits (Green et al., 2002; Hammes & Langdell, 1981;

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Jones & Prior, 1985; Ohta, 1987; Smith & Bryson, 1998). Such impairments persist into adolescence and adulthood although there are fewer studies that have examined this age group (Avikainen, Wohlschlager, Liuhanen, Hanninen, & Hari, 2003; Hobson & Lee, 1999; Rogers, Bennetto, McEvoy, & Pennington, 1996). Hobson and Lee (1999) found that teens with autism were able to imitate goal directed actions but failed to imitate the style in which the examiner performed the task with greater frequency than the control group. Further, during the imitative acts, the subjects with autism made considerable reversal errors, errors in which the imitator replicates the gestures but in the perspective of how the gesture was observed. Similarly, Avikainen et al. (2003) examined imitation in adults through a task in which participants imitated the experimenter's actions using either the same hand or opposite hand. They found that while typical adults used the mirror image of the experimenter's actions to increase response speed and accuracy, the individuals with Asperger syndrome and high functioning autism failed to capitalize on the mirror image.

It has been proposed that a deficit in self other mapping is the most parsimonious explanation for the imitation impairments found in ASD (Williams et al., 2004). The self-other mapping deficit hypothesis, which posits that a biological dysfunction of cross modal processes prevents the individual with autism from forming and coordinating representations of the self and others, was earlier presented by Meltzoff and Gopnik (1993) and Rogers and Pennington (1991). Evidence from infant imitation work suggests that cross modal processes necessitate an execution/observation matching system (Meltzoff & Decety, 2003; Meltzoff & Moore, 1997). That is, in order for an infant to imitate faces, the infant must cross modally map an observed facial expression with his or her own motor execution of that expression. But the infant cannot see his or her face and so must have a supramodal internal representation that enables a match between the observed and executed expression.

1.1. Mu activity and the execution/observation system

The first neurophysiological evidence of an execution/observation matching system in humans comes from EEG work conducted in the 1950s which focused on the mu rhythm band oscillations. The EEG mu rhythm band falls between 8 and 13 Hz and is recorded from scalp electrodes over the sensorimotor cortex. Attenuation of resting EEG mu rhythm reflects desynchronization of the underlying cell assemblies, which suggests an increased load on those cells (Pfurtscheller, Neuper, Andrew, & Edlinger, 1997). Attenuation of the resting EEG mu rhythm was observed in adult subjects in response to the execution of actions, both passive or reflex movements (Chatrian, Petersen, & Lazarte, 1959). Attenuation was also observed in adults who were watching others' movements (boxing) on film (Gastaut & Bert, 1954). More recently, the finding of mu wave attenuation when observing and executing actions has been replicated in both adults (Arroyo et al., 1993; Babiloni et al., 2002; Babiloni et al., 1999; Babiloni et al., 2003; Cochin, Barthelemy, Lejeune, Roux, & Martineau, 1998; Cochin, Barthelemy, Roux, & Martineau, 1999; Muthukumaraswamy, Johnson, & McNair, 2004; Muthukumaraswamy & Johnson, 2004; Pfurtscheller et al., 1997) and children (Cochin, Barthelemy, Rous, & Martineau, 2001; Lepage & Theoret, 2006; Martineau & Cochin, 2003; Stroganova, Orekhova, & Posikera, 1999). Mu wave attenuation during observation of action is strictly a central phenomenon. That is, movement in the body does not account for the mu wave attenuation when observing other's actions. In two studies of typical adults, Muthukumaraswamy and colleagues determined that subtle activity in the hand did not account for the reduced attenuation when observing human movement (Muthukumaraswamy & Johnson, 2004; Muthukumaraswamy et al., 2004). Further, imagining movement is sufficient to attenuate the mu rhythm (Pfurtscheller, Brunner, Schlogl, & Lopes de Silva, 2006). In adults mu wave attenuation was found during the imagining of left and right hand motor movements. These consistent findings of attenuation of the mu wave during the observation or imagining of human movement, as well as during the execution of movement, suggest that the mu wave reflects an execution/observation matching system (Pineda, 2005).

In a study of 10 individuals with autism and typical individuals (6–47 years of age), Oberman and colleagues (2005) reported attenuation of the mu rhythm in the 8–13 Hz band during the execution and observation conditions for the typical group, whereas the autism group showed attenuation only during the execution condition. They concluded that the results were consistent with execution/observation system dysfunction in individuals with autism.

Although individuals with autism appear to fail to show attenuation of mu activation during observation and clearly show behavioral impairments in imitation, the relation between these to findings is unclear. This study aims to further explore the imitation deficits in a sample of high functioning adults with autism including the relation between behaviorally assessed imitative skills and the EEG index of the execution/observation matching system. It is hypothesized that adults with autism will demonstrate imitation impairments as well as reduced mu wave attenuation when observing biological movement. We further propose that degree of EEG mu wave attenuation will be correlated with level of imitative ability.

2. Methods

2.1. Participants

The original sample of participants included 17 adult males with an idiopathic autism spectrum disorder (ASD) and 16 neuropsychiatrically and medically healthy male