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Weak imitative performance is not due to a functional 'mirroring' deficit in adults with Autism Spectrum Disorders

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Abstract

A large number of studies have demonstrated impaired performance on a range of imitation tasks among individuals with Autism Spectrum Disorders (ASD). The theory which suggests that these impairments are caused by a mirror system deficit has become increasingly prominent. Under this view, the capacity to match observed with executed actions or to 'mirror' is impaired in individuals with ASD. This study investigated the extent to which any impaired performance on imitation tasks is due to a functional mirroring deficit by comparing the performance of adults with ASD on imitative and non-imitative versions of the 'pen-and-cups' task. Participants in this task are required to observe transitive actions and to imitate them as fast as possible. Experiment 1 revealed impaired performance by high functioning adults with ASD on the imitative version of the task compared to IQ matched controls. The same participants then completed two non-imitative versions of the task in Experiment 2. The 'geometric' version of the task required participants to perform actions specified by the movement of abstract geometric shapes. The 'verbal' version of the task required participants to describe the observed actions. Adults with ASD were as impaired on each non-imitative version of the task as they were on the imitative version, suggesting that the impaired performance on the imitation task was not due to a functional mirroring deficit. Instead, more general factors contributed to the poor performance on this task. These findings add to the weight of evidence suggesting that impairments in imitation skills should not be cited as evidence consistent with a 'mirror system deficit theory' of ASD.

Keywords: Autism; Imitation; Mirror system; Pen-and-cups task

Imitation has been studied extensively in Autism Spectrum Disorders (ASD; for review see Williams, Whiten, & Singh, 2004). Despite a wealth of evidence, the literature is contradictory: although the majority of studies report an imitation impairment in ASD (e.g. Avikainen, Wohlschlager, Liuhanen, Hanninen, & Hari, 2003; Rogers, 1999; Rogers, Bennetto, McEvoy, & Pennington, 1996), others have found no evidence of such an impairment (e.g. Aldridge, Stone, Sweeney, & Bower, 2000; Beadle-Brown & Whiten, 2004; Carpenter, Pennington, & Rogers, 2001; D'Entremont & Yazbek, 2007; Hamilton, Brindley, & Frith, 2007).

Imitation is of relevance to ASD because it has been suggested that imitation typically underpins the development of social cognition, including theory of mind, empathy, and the development of language (Rogers & Pennington, 1991). Impairments in these abilities characterise individuals with ASD, which has prompted some theorists to suggest that an imitation impairment is the core deficit in ASD (Williams, Whiten, Suddendorf, & Perrett, 2001). It is therefore important to make sense of the conflicting findings in the literature and to understand fully the nature of observed imitation impairments.

Studies demonstrating impaired performance on imitation tasks are consistent with evidence of disturbed mirror system activity in ASD (e.g. Gallese, 2006; Iacoboni & Dapretto, 2006; Williams et al., 2001). In typically developing individuals, the mirror system, comprising inferior parietal cortex and frontal gyri, is active when actions are executed and when they are passively observed, and is maximally activated during imitation (Iacoboni et al., 1999). Given this profile of activation, it is plausible that the mirror system mediates one of the basic functions required for imitation—self-other mapping, or, more specifically, the capacity to match observed with executed actions

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(Brass & Heyes, 2005). If this is correct, then studies indicating disturbed mirror system activity in individuals with ASD (e.g. Gallese, 2006; Iacoboni & Dapretto, 2006; Williams et al., 2001) raise the possibility that these individuals perform poorly on tests of imitation, in part, because they are have a 'functional mirroring deficit', i.e. they are impaired in their capacity to match observed with executed actions. The present study investigates this possibility.

Even if individuals with ASD have a functional mirroring deficit, it is very unlikely that this would be sufficient to explain why they perform poorly in most imitation tests. Imitative performance typically involves a broad range of cognitive, motivational and praxic abilities, involving perceptual processing of complex stimuli, attentional control, executive function, motor control, theory of mind, language, and the comprehension of social cues (e.g. Rogers, Hepburn, Stackhouse, & Wehner, 2003; Pennington, Williams, & Rogers, 2006; Vanvuchelen, Roeyers, & De Weerdt, 2007). Impairments in all of these processes have been found in individuals with ASD (e.g. Baron-Cohen, Leslie, & Frith, 1985; Frith & Frith, 2003; Ozonoff, Pennington, & Rogers, 1991; Pennington & Ozonoff, 1996; Russell, 1997), making it likely that imitation impairments in ASD arise from impairments in a range of abilities. Therefore, the present study asks whether a problem with functional mirroring, the capacity to match observed with executed actions, is *one of* the impairments that contribute to poor imitation performance by individuals with ASD.

The capacity to match observed with executed actions is of particular interest, not only because it relates to recent research on mirror system functioning in ASD, but also because it is characteristic of imitation tasks that they require this ability. A variety of laboratory and everyday tasks require observed actions to be mapped in some way to executed actions, but only imitation tasks require the participant to *match* observed actions; to do the same thing as a model. Conversely, whereas the other abilities that contribute to imitative performance – for example, perceptual and motor processing, attentional and executive control, theory of mind – are involved in a range of non-imitative tasks, the capacity to match observed with executed actions is required only in imitation tasks. Therefore, matching observed with executed actions, or functional mirroring, may be described as an 'imitation-specific' ability, while other processes that contribute to imitative behaviour are 'non-specific' or 'task-general'.

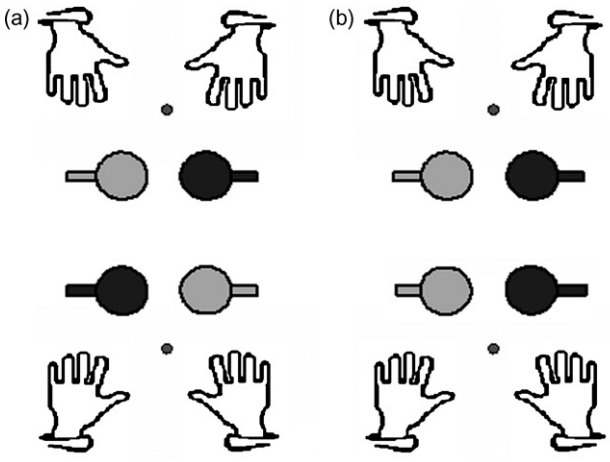

Fig. 1. Schematic diagram showing the layout of the stimuli in both the transpose (a) and mirror (b) conditions.

This study therefore sought to examine two possible explanations for the mixed findings in the ASD imitation literature. Under the first explanation, there is a functional mirroring impairment in ASD; that is, the processes that match motor outputs with perceptual inputs are in some way disturbed. Under the second explanation, there is no functional mirroring impairment in ASD. Rather, poor performance on tests of imitation is due to impairments of non-specific abilities – such as theory of mind and executive function – which are also required for successful performance on these tests. This study sought to distinguish these two possibilities by investigating whether observed impairments in imitative performance can be accounted for by more general abilities.

We investigated functional mirroring in ASD by testing the performance of a group of high-functioning adults with ASD, and a matched typically developing control group, on a test of voluntary imitation. We used the 'pen-and-cups' imitation task because it has previously been shown to produce greater errors in adults with ASD than in controls (Avikainen et al., 2003). On each trial in this speeded response procedure the participant sees a model move a centrally located pen into one of two coloured cups (object), using his right or his left hand (effector), while grasping the pen with his thumb pointing up or down (grip). Thus, the task is demanding because, in order to minimise errors, the participant needs to keep track of three dimensions of action: object selection, effector selection and grip selection (see Fig. 1).

Experiment 1 replicated the finding (Avikainen et al., 2003) that individuals with ASD make more errors in the pen-and-cups tasks. Experiment 2 sought to establish whether this finding reflects an impairment in the capacity to match observed with executed actions. In Experiment 2, participants completed two versions of the pen-and-cups task which dissociated the components of the imitative stimulus-response relationship instantiated in the original pen-and-cups task. In the original version, action responses are made to action stimuli. In Experiment 2, one task involved action responses being made to abstract geometric stimuli, while the other required participants to describe verbally the original action stimuli. Thus, the action stimulus and action response components were separately removed while all other aspects of the task were held constant. The tasks in Experiment 2 did not require matching of observed with executed actions, and therefore, if the impaired performance on the pen-and-cups task in ASD is due to a functional mirroring impairment, one would expect improved performance on these non-imitative versions of the task. Alternatively, if impaired performance on the pen-and-cups task is due solely to nonspecific mechanisms, then impaired performance would also be expected on the non-imitative versions of the task.

1. Experiment 1

The aim of Experiment 1 was to establish that the particular sample of individuals with ASD who participated in this