Mimicry deficits in autism are not just storm effects

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ABSTRACT

Imitative behavior is known to be affected in Autism Spectrum Conditions. This issue has been addressed with a wide range of tasks and from many different perspectives. Here we use a version of Hamilton, Brindley, and Frith’s (2007) bar-task in a sample of individuals with ASC and matched controls, to assess spontaneous imitation of goal-oriented actions. Contrary to previous studies which relied on ambiguous instructions to explore the spontaneous tendency to copy inefficient action patterns (Jiménez, Lorda, & Méndez, 2014), we used explicit instructions centered on the material outcome, in order to reduce the social motivation to overimitate. Consistently with previous findings, results showed that individuals with ASC and their matched counterparts were equally guided by action planning, but that the former exhibit a smaller tendency to mimic the less functional actions displayed by the model. These results are discussed as showing that these mimicry deficits cannot be accounted exclusively in terms of STORM (i.e., Social, Top-down Response Modulation) effects.

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1. Introduction

Imitation is affected in Autism Spectrum Conditions (ASC). Despite a recent increase in research on this topic, it is still unclear whether such deficits can be taken as a core symptom of ASC, producing a cascade of other social and communication impairments (Rogers & Pennington, 1991; Rogers & Williams, 2006), or whether imitation difficulties should be better construed as a consequence of other primary deficits, such as abnormal motor or sensory-motor disturbances (Dziuk et al., 2007), atypical distribution of attention over social and nonsocial stimuli (Vivanti, Nadig, Ozonoff, & Rogers, 2008; Vivanti, Trembath, & Dissanayake, 2014), or specific difficulties with understanding the intentions of others (Cattaneo et al., 2007).

In an attempt to clarify this question, Hamilton (2008) proposed a dual model of imitation, distinguishing between emulation processes, defined as those involving goal-directed imitation, and mimicry processes, defined as the tendency to reproduce the low level kinematic features of any modeled action, regardless of its instrumental value. A number of studies have converged toward the conclusions that individuals with ASC show a lesser propensity to spontaneously imitate when imitation is not part of the explicit requirements of the task (Giganti & Esposito Ziello, 2009; Helt, Eigsti, Snyder, & Fein, 2010; McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006; Senju et al., 2007; Vivanti et al., 2014, but see Bird, Leighton, Press, & Heyes 2007), that they show larger difficulties to imitate actions without a clear goal, such as gestures or arbitrary movements (Wild, Poliakoff, Jerrison, & Gowen, 2012; Williams, Whiten, & Singh, 2004), and that they tend to imitate

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differently, reproducing the goals rather than the style of a demonstrated action (Hobson & Lee, 1999) and imitating the instrumental parts, rather than the less functional features of such actions (Rogers, Young, Cook, Giolzetti, & Ozonoff, 2010). These conclusions are consistent with a specific dysfunction in the mimicry route, which would lead to abnormal behavior specifically on those tasks which are more dependent on the spontaneous imitation of observed motor patterns.

In a recent study, Jiménez, Lorda, and Méndez (2014) attempted to further distinguish between emulation and mimicry deficits in ASC, by adapting an imitative bar-task in which participants were asked to reproduce the actions of a model who grasped a horizontal bar to put it vertically over one of its two extremes on a target location (Hamilton, Brindley, & Frith 2007). In Jiménez et al.’s version of the task, the salience of the goal was varied by presenting participants with either a bicolor (black and white) or a mono-color (i.e., white) bar over different trials. They predicted that those trials showing a mono-color bar would increase the difficulty of identifying the bar side that had been inserted in the container, therefore leading participants to rely more on the illustrated hand movements; in contrast, in the bicolor trials, participants could focus on the distinction between the two bar sides, and thus they could adopt an emulation strategy to reproduce the goal regardless of the particular goal and end state illustrated by the model.

In addition to goal salience, Jiménez et al. (2014) manipulated the efficiency of the action pattern illustrated by the model, including trials in which the model combined overhead or underhand grips with comfortable or uncomfortable end states (see Fig. 1). According to the literature on action planning (e.g., Rosenbaum, Chapman, Weigelt, Weiss, & van der Wel, 2012), people instructed to perform this kind of manipulative tasks would tend to choose the overhead or the underhand grip so as to yield the goal in a comfortable end state (e.g., with the hand in a thumb-up position). Therefore, imitation of the actions ending in comfortable states could be attributed both to emulation and mimicry but, crucially, reproduction of those actions ending in a non-comfortable state could only be attributed to mimicry, since the action constraints would otherwise induce the selection of the opposite pattern. In these conditions, a comparison of the imitation profiles observed in two groups of school-age individuals with typical development (TD) and ASC confirmed that both groups showed analogous tendencies to imitate comfortable rather than non-comfortable end states. Importantly, the results also showed that participants with ASC had specific problems to reproduce low salience goals, arguably because mimicry was more useful in these conditions, but it was selectively impaired in ASC. Moreover, when emulation and mimicry were specifically dissociated, by looking at those trials in which observers reproduced a goal that had been modeled by means of a suboptimal action, the results indicated that participants with TD did systematically replicate those goals by mimicking the inefficient action, whereas this tendency was reduced in participants with ASC, who reached the same goal more often by adopting the opposite, but more efficient, action.

The results of Jiménez et al. (2014) are consistent with the claim that individuals with ASC are less prone than their typical counterparts to mimic observed action patterns, but they do not allow us to unequivocally identify the determinants of such a difference. There are at least two possible accounts for this result. On the one hand, reproduction of non-functional actions might be driven by a process of automatic imitation or “motor priming” (Heyes, 2011), which could be specifically impaired in ASC (e.g., McIntosh et al., 2006; Senju et al., 2007). Alternatively, imitation of inefficient actions could also be determined by a top-down decision, based mostly on social motivational factors. As posited by the Social, ToP-down Response Modulation (STORM) account proposed by Wang and Hamilton (2012), an increased motivation to conform to social rules may have led typical observers to “overimitate”, that is, to reproduce the details of the modeled actions, whereas people with ASC may have been less affected by such social factors, and could remain more focused on the material action goals (see also Nielsen & Blank, 2011; Lyons, Damrosch, Lin, Macris, & Keil, 2011). Research on overimitation in ASC is still scarce and somewhat contradictory (Marsh, Pearson, Ropar, & Hamilton, 2013; Nielsen, Slaughter, & Dissanayake, 2013). However, given that the imitation goal had been left deliberately ambiguous in Jiménez et al., it was possible that the difference between groups could be explained in terms of a difference in the interpretation of the task purpose.

The aim of the present study was to replicate the results of Jiménez et al. (2014) in conditions that minimize the uncertainty of the task goal, and that therefore decrease the social motivation to overimitate (Flynn & Smith, 2012). If the previous difference between groups was due to a larger tendency of participants with TD to copy every action in the absence of specific instructions, then making it explicit that the task goal was not to reproduce every modeled gesture, but rather just to insert the same side of the bar in the container, should minimize that difference. In contrast, if there were still differences between groups after reducing the social factors which arguably underlie overimitation (Over & Carpenter, 2012), then we contend that those differences should be better attributed to a more basic difference between groups in their relative susceptibility to automatic imitation. Moreover, because Marsh et al. (2013) reported that overimitation was reduced when the actions involved familiar objects, we pre-trained participants with a non-imitative version of the bar task before proceeding to the imitation task. Thus, participants were first presented with a series of steady pictures of the same bar arrangement, and they were asked to put in the container the specific bar side pointed at by an arrow. After that practice phase, participants were presented with the imitation task, which was described as analogous to the previous condition but in which, instead of seeing an arrow, they were going to see an actor illustrating which side of the bar should be inserted in the container.

2. Materials and methods

Before the experimental session, all participants’ parents signed an informed consent form in which they authorized their children to participate in the study. All tests and tasks were administered individually for all children in both groups. The study was approved by the University ethical committee.
2.1. Participants

Nineteen right-handed participants with ASC (3 female) and 27 with TD (3 female) participated in the study. All children in the ASC group were members of a local association (Asperger Granada) and had received previous diagnostic of high functioning autism or Asperger’s Syndrome by external professional services. The TD group was selected from a local school. The sample of ASC was slightly older (mean age ± standard deviation: 11.8 ± 2.95) than the control group (mean age: 10.2 ± 2.75), F(1,44) = 3.95, p = .053, \( \eta_p^2 = .08 \), but their cognitive abilities were strictly comparable, as judged by their raw scores in Raven SPM (40 vs. 38), F(1,44) = 0.56; p = .46; \( \eta_p^2 = .01 \). All participants in the ASC group, and none in the TD group, scored above
the cut-off scores for their respective Autism Spectrum Quotient (AQ; Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008; Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006) for children and adolescents as appropriate for their age (76 for the AQ-child and 30 for the AQ-Adolescents).

2.2. Apparatus and materials

All participants completed a fluid intelligence test (Raven Progressive Matrices, SPM, Raven, Raven, & Court, 1995) in a session independent from the experimental procedure, and their parents completed the version of the AQ questionnaire appropriate for their age (the Child version was used for participants below 12 years old, and the Adolescent version was administered for older participants).

During the imitation task, experimental displays and video-clips were presented on a 15 in. screen, and their succession was controlled by INQUISIT 3.0.4.0 software (Milliseconds software, 2010). They consisted of a series of pictures (pre-training trials) or short video-clips (imitation trials) displaying the torso (but not the head) of an adult model sitting in front of a stand which held a wooden bar, with a metal pen holder located beside it. The wooden bar was either a mono-color (white) or a bicolor (black-and-white) dowel, 30 cm long × 3 cm wide, resting on two cradles of 20 cm high, separated from each other by a distance of 15 cm. The pen holder was a cylindrical container, 17 cm height × 7 cm wide, located 20 cm to the left of the cradles. Participants were seated at approximately 60 cm from the screen, and between them and the screen there was mounted a replica of the same objects, placed in front of them in a mirror arrangement with respect to those shown in the screen.

On the pre-training trials a yellow arrow in the picture pointed at the bar side that should be inserted in the container (see Fig. 1). The imitation trials were analogous to those arranged in Jiménez et al. (2014), showing a model who grasped the bar and inserted one of its two sides in the pen holder. After that, the message “Your turn” appeared on the screen, and participants were required to use their own material to insert the corresponding side of the bar in the container.

2.3. Design and procedure

Participants performed 16 pre-training trials followed by 32 imitation trials. They were required to keep their hands on the table until the words “Your Turn” appeared on the screen. On the pre-training trials participants were instructed to “put the bar in the container by the side indicated by the arrow”. The bar was either mono-color or bicolor in a half of the trials, and the arrow pointed equally often to the bar side located closer or farther to the container. In the bicolor trials, the black side of the bar was always located closer to the container. After every response, the experimenter removed the bar and prepared the next trial.

The imitation trials were similar to the pre-training trials, except that they showed a 5 s video-clip showing a model who actually grasped the bar and inserted one of its two sides in the container. Participants were instructed to “put the same side of the bar in the container as shown in the video-clip” after the instruction “Your turn” appeared on the screen. As in Jiménez et al. (2014), imitation trials were randomly administered, including four random repetitions of eight different types of modeling trials. These combined two Goals (inserting the closer vs. the farther side of the bar), two values of goal Salience (mono-color vs. bicolor bar), and two Modeled End States (comfortable, or thumb-up, vs. uncomfortable, or thumb-down). The overall design was a mixed 2 × 2 × 2 × 2 design with Group (ASC vs. TD) as a between-participants factor and with Goal (2), Salience (2) and Modeled End State (2) as repeated measures. Verbal encouragement was provided after every trial regardless of children’s performance. Their hand movements were continuously video-taped, and for each trial, the grip (under or overhand), the end state (comfortable or uncomfortable) and the achievement of the goal were coded offline.

3. Results

Trials in which the goal was not accomplished or in which the children grasped the bar with two hands were cataloged as errors or invalids respectively and did not enter the analysis. Pre-training performance showed no significant difference between groups in the proportion of trials that fulfilled the goal (.98 vs. .94, respectively for the TD and ASC groups, F(1, 43) = 2.09, p > .15; ηp² = .05). Both groups adopted the overhand grip more often (.73 vs. .70) than the underhand grip (.27 vs. .30), and finished the action more frequently in a comfortable (.70 vs. .75) than in a non-comfortable end state (.30 vs. .25). These proportions did not differ significantly between groups (Fs < 1), and the effect of goal Salience was not significant in these analyses.

As for the imitation task, the proportion of trials in which participants imitated the modeled end state was submitted to a mixed ANOVA with Group (TD vs. ASC) as a between-participants factor and with Modeled End State and Goal Salience as repeated measures. As expected, the results confirmed that participants imitated comfortable end states much more often than non-comfortable end states, .92 vs. .54, F(1, 44) = 61.66, p < 0001, ηp² = .58. The difference between TD and ASC groups fell below significance, .79 vs. .68, F(1, 44) = 3.79; p = .06, ηp² = .08, but there was a significant Group × Modeled End State interaction, F(1, 44) = 4.66; p < .05, ηp² = .10. indicating that such difference was absent in those trials depicting a comfortable action (.92 in both cases, F < 1), but arose specifically in those trials modeling non-comfortable end states (.65 vs. .44), F(1, 44) = 4.87, p < .05, ηp² = .10.
Finally, the analysis of the effect of mimicry, defined as the proportion of correct trials in which the observers copied a suboptimal action (cf. Jiménez et al., 2014), showed a significant main effect of Group, \( F(1, 44) = 4.84, p < .05, \eta_p^2 = .10 \). Thus, despite the explicit instructions to focus on the action goal, the TD group still tended to achieve those goals by mimicking the inefficient action pattern illustrated by the model in those particular trials (they did so as an average in 67% of those trials, see Fig. 1). In contrast, participants with ASC showed the opposite tendency to reach those goals more often by adopting the most efficient pattern, and they did only modeled those inefficient actions in 45% of the relevant trials. Neither the effect of Goal Salience nor the interaction between Group and Salience were significant in this analysis.\(^1\)

### 4. Discussion

This study was intended to distinguish between two possible accounts for the reduced effects of mimicry reported in a group of school-age participants with ASC as compared with a control group (Jiménez et al., 2014). Consistently with the previous results, we found that participants with ASC are similarly sensitive to action planning constraints as are their typically developing counterparts, but that they show a reduced tendency to reproduce those features of the modeled actions which are contrary to functional constraints.

The original study by Jiménez et al. (2014) showed the same qualitative pattern, but this was found in conditions in which the imitation goals remained deliberately vague. In those conditions, the difference between groups could be attributed to a deficit in ASC in the automatic tendency to mimic observed actions, but also to a difference in the social interpretation of the task requirements. In the present experiment, we removed this ambiguity by providing participants with explicit instructions requiring them to focus on the material outcome, and by including some practice trials which made them more familiar with that goal, in a task version devoid of any imitative requirement. The results of this study confirmed that, even in those conditions, participants with TD still mimicked the less efficient actions to a considerable extent, whereas participants with ASC were significantly less affected by the modeled actions. A comparison between the mimicry scores obtained in the present experiment and those reported by Jiménez et al. (2014) showed significant effects of Experiment, \( F(1, 82) = 17.37, p < .001, \eta_p^2 = .17 \); and Group, \( F(1, 82) = 9.77, p < .01, \eta_p^2 = .10 \); but not an interaction between them (\( F < 1 \), see Fig. 1). In sum, despite the fact that our manipulation proved to be useful to reduce the overall levels of imitation, arguably by reducing the social motivation to overimitate, both groups were still different with respect to the measure of mimicry, which reflected a persistent tendency of participants with TD to mimic even the inefficient actions performed by the model.

The results of this experiment are consistent with a specific dysfunction of mimicry in ASC, and thus it adds some relevant evidence to the debate about whether the mirror neuron system may be affected in ASC, and may play a major role in the production of some of the social-communicative impairments which are typically observed in this condition (Rogers & Williams, 2006; for a recent meta-analysis finding similar results, see Edwards, 2014). This question has been the object of an intense debate over the last few years, which has been shaped by a host of complex and partially contradictory results (for a recent review, see Vivanti & Hamilton, 2014). Indeed, the present results are still open to some possible alternative accounts. Specifically, one cannot discard the possibility that the mimicry deficits observed in this study could be caused by a perceptual, attentional, or sensory-motor impairment. Of course, if participants with ASC have specific problems to perceive others’ actions, it should come as no surprise that they fail to imitate them. These two conceptually different hypotheses may be hard to disentangle at an empirical level, because perceptual and motor processes are deeply intermingled with each other, and because the perception of others’ actions has been shown to comprise the very same mirror functions to which the observed deficits have been attributed (see Klin, Jones, Schultz, & Volkmar, 2003). In any case, we contend that the present results are informative to distinguish between the STORM hypothesis (Wang & Hamilton, 2012), which attributes those deficits to a Social, T0p-down Response Modulation of imitative behavior, and a most lower-level disturbance in the automatic processes of mimicry.

### 5. Conclusions

As it has been demonstrated through the present experiment, the difference between TD and ASC performance persists even when the social motivational factors are controlled by means of explicit instructions, thus showing that the difference between groups, rather than being completely attributable to a social, top-down response modulation, as argued by the “STORM” hypothesis, depends partly on a lower-level factor which may be better defined as a lack of transparency in the mirror processes involved in this self-other mapping. Thus, rather than dealing with fully broken mirrors, or with STORMy mirrors, it appears that individuals with ASC would need to deal with a kind of blurred, or otherwise foggy mirrors, which afford them a less immediate or automatic access to imitation.

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\(^1\) When the variable Age was included as a covariate in this analysis the effect of Group just fell below significance, \( F(1, 43) = 3.43, p = .07, \eta_p^2 = .07 \), but this trend arose together with a significant Group x Salience interaction, \( F(1, 43) = 3.43, p = .07, \eta_p^2 = .07 \), which indicated that the difference in mimicry between groups was especially observed in low salient trials, \((.67 \text{ vs. } .43), F(1, 43) = 5.15, p < .05, \eta_p^2 = .11 \).
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