Williams, David M. and Happe, Francesca (2009) *Pre-conceptual aspects of self-awareness in autism spectrum disorder: The case of action-monitoring.* Journal of Autism and Developmental Disorders, 39 (2). pp. 251-259. ISSN 0162-3257.

Williams, D., & Happé, F. (2009b). Pre-conceptual aspects of self-awareness in autism spectrum disorder: The case of action monitoring. *Journal of Autism and Developmental Disorders, 39*, 251-259.

Pre-conceptual aspects of self-awareness in autism spectrum disorder: The case of action-monitoring

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Abstract

Two experiments were conducted to explore the extent to which individuals with autism experience difficulties in monitoring their own actions, both online and in memory. Participants with autism performed similarly in terms of levels and, importantly, *patterns* of performance to IQ-matched comparison participants. Each group found it easier to monitor their own actions/agency than to monitor the agency of the experimenter in a computerized task requiring individuals to distinguish person-caused from computer-caused changes in phenomenology. Both groups also showed a typical ‘self-reference effect’, recalling their own actions better than those of the experimenter. Both tasks appear to be reliable markers of underlying action monitoring ability, performance on the ‘Self’ conditions of each task being significantly associated, independent of verbal ability.

Keywords: Autism, Self-Awareness, Action Monitoring, Agency, Source Memory

Pre-conceptual aspects of self-awareness in autism spectrum disorder: the case of action-monitoring

According to some theorists (e.g., Pacherie, 1997; Russell, 1996), Autism Spectrum Disorder (ASD) involves a deficit in a basic form of non-reflexive, ‘ecological’ self-awareness – the ability to monitor one’s own basic actions. Russell and Hill (2001, p.317) define action monitoring as, “the mechanisms that ensure that agents know, without self-observation, (a) for which changes in perceptual input they are responsible and (b) what they are currently engaged in doing”. Effective action monitoring therefore allows an individual to distinguish between ‘self-caused’ and ‘world-caused’ changes in experience and hence, in Russell’s theory, gives rise to an experience of agency. According to the monitoring deficit view, individuals with ASD have a diminished feeling of responsibility for, or ownership of, their own actions ‘from the inside’, so-to-speak. This position is similar to that which Searle (1983) suggested an individual experiences when their ‘intentions-in-action’ fail to become conscious (for instance, when automatically changing the gears of a car). Pacherie (1997) extended Searle’s analysis to suggest that children with ASD are unable to generate ‘motor images’, a form of conscious motor representation deriving from motor intentions for action (Jeannerod, 1994). It is these motor images which Pacherie (p.234) suggests provide “the organism with an awareness of what is intended and with a grasp of his body as a generator of active forces”. According to Pacherie’s theory, therefore, difficulties in generating motor images results in action monitoring impairments in ASD.

Impairments in action monitoring in ASD have been inferred from findings of a reduced ability to discriminate between the actions of self and other in tests of source memory. Hala et al. (2005), for example, found children with ASD less able than typically developing (TD) comparison participants, matched for verbal mental age (VMA), to recall whether a series of words had been spoken by themselves or by an experimenter. More strikingly, studies by Russell and Jarrold (1999) and Millward et al. (2000) found an unusual pattern of memory performance in participants with ASD. In each of these studies, participants with ASD were better able to recall the actions of the experimenter than they were to recall their own actions. This 'observer effect' contrasted with comparison participants who recalled their own actions significantly better than those of the experimenter. The 'self-reference effect' shown by comparison participants in these studies is characteristic of typical adult memory performance (e.g., Conway, 2001). On the other hand, the 'observer effect' shown by participants with ASD is more characteristic of the memory profile of typically developing children below 6 years of age (Roberts & Blades, 1998). Difficulties in self-other source memory in ASD have not been found in other studies, however (Farrant et al., 1998; Hill & Russell, 2002), leaving a question mark over the reliability of the results of Hala et al., Millward et al., and Russell and Jarrold.

The most direct method for assessing action monitoring abilities, according to Russell and Jarrold (1999), is to implement tasks which require the online (rather than memorial) discrimination of one's own actions from those of an external agent. Russell and Hill (2001) implemented such a task and found, contrary to their predictions, that children with ASD were as capable as comparison participants at judging which one of several coloured dots on a computer screen was under their intentional control (through movements of the mouse) and which ‘distractor’ dots were under the control of the computer.

In light of their results, Russell and Hill (2001) partially withdrew from Russell’s (1996) theory that ASD involves primary deficits in basic action-monitoring. However, one difficulty with drawing conclusions from Russell and Hill’s study is that their experimental task may not have been sensitive enough to detect group differences, had they really existed. An analysis of their results (see Tables 2 and 3 of their 2001 study, p.320) reveals that only 5 out of 28 participants with ASD showed any variation in levels of performance, with the remaining 23 participants performing either at ceiling (n = 13) or at floor (n = 10) on the task.

In order to provide a more sensitive measure of action monitoring in ASD, therefore, the first experiment reported in this paper implemented a new action monitoring task, based on Russell and Hill’s (2001) task, but designed to produce more variation in performance. First, in order to avoid floor/ceiling effects, this ‘Squares task’ was more incremental in terms of difficulty than the task implemented by Russell and Hill. This was achieved by incorporating more distractor squares (up to 24, compared to 6 in Russell & Hill’s study) and by manipulating the degree to which the movements of the distractor squares could deviate from the movements of the target square (see below for full details).

The Squares task also differed from the task used by Russell and Hill in including an Other-person condition in which the experimenter moved the mouse, held by the participant. This Other-person condition was completed by each participant in addition to the Self condition in order to provide a more specific test of the action monitoring deficit hypothesis. In the Other person condition, where there is no internal agency (i.e., motor intention) for the participant to experience, the only strategy available for success was to match the actual movements – felt by the participant, although instigated by the experimenter – with the corresponding visual information on the screen. Here the participant was limited to monitoring the *effects* of another's agency. The Self condition was different: here the participant had the opportunity to monitor, or experience, their own agency, directly.

For an individual with an inadequate experience of their own agency, these two conditions would appear to offer the same challenges, namely to match the felt actions (instigated by self or other) with visual information. For the typical individual, who has a well developed (but still non-conceptual) experience of their agentic self, the Other-person condition should be significantly more difficult than the Self condition because in the Other condition the participant acts without access to their own motor intentions.

Experiment 1, therefore, provides a specific test of action monitoring abilities in ASD. If individuals with ASD have an impaired experience of their own agency then they should find the Self and Other conditions equally difficult, because in both cases they might be considered as 'dispassionate' proprioceivers of their hand movements. Comparison participants, by contrast, should find the Self condition significantly easier than the Other-person condition because only in the former can they use their experience of willing and acting to their advantage. The performance of participants with ASD should, therefore, be poorer than that of comparison participants in the Self condition only, if they have an impaired sense of their own agency.

The second experiment reported in this paper represented an attempt to replicate the findings of Russell and Jarrold (1999) that children with ASD a) are less able than individuals who do not have ASD to distinguish the actions of self and other in memory and; b) that they show a bias toward recalling the actions of others more reliably than their own actions. A modified version of Russell and Jarrold's 'picture lotto' card-placement task was implemented, in which participants laid cards onto a corresponding picture board, either on their own behalf or on the behalf of a doll partner who they were 'playing for'. Participants also witnessed the experimenter placing cards either on their own behalf or on behalf of the experimenter's doll partner. Participants were then given an unexpected memory test, requiring them to return the cards to the players who had placed them (child, child's doll partner, experimenter, experimenter's doll partner).

If participants with ASD do not encode, in memory, actions performed by themselves as strongly as do comparison participants, then they should be less accurate, overall, in terms of the number of items correctly returned to each player. Also, unlike comparison participants, they should not display a self-reference effect by recalling more accurately the cards laid by themselves (on their own behalf) than those laid by the experimenter (on his own behalf). Indeed, participants with ASD may be expected to show the opposite pattern of recall (the observer effect), as Russell and Jarrold (1999) found.

One further aspect of the task, relevant to self-awareness but not explicitly considered by Russell and Jarrold, relates to the relative accuracy of recall for cards laid by the participant on their own behalf and those cards also laid by them but on behalf of their doll partner. In terms of the motoric components of action, there is no difference between laying cards on your own behalf and laying them on behalf of somebody else – both actions are self-performed. However, only if one encodes experiences *in relation to* oneself, specifically, should one recall one's own cards better than those cards that 'belong' to someone else, even though they were laid by oneself.

Experiment 1

Method

Participants. Ethical approval for this research was obtained from the joint South London and Maudsley NHS Trust/Institute of Psychiatry Research Ethics Committee. Sixteen children with ASD and 16 comparison children participated in Experiment 1, after parents/guardians had given written, informed consent for their children to be included. The participants in the ASD group had received formal diagnoses, by a trained psychiatrist or pediatrician, of autistic disorder (n = 14), Asperger's disorder (n = 1) or pervasive developmental disorder not otherwise specified (PDD-NOS; n = 1) according to established criteria (American Psychiatric Association, 2000). All participants in this group attended specialist autism schools, which required a diagnosis of autism, Asperger's syndrome or PDD-NOS for entry into the school. The comparison group consisted of children with intellectual disability of unknown origin, who attended specialist schools for pupils with learning difficulties.

Baseline verbal and non-verbal abilities were assessed by an appropriate measure for the developmental level of each participant. The verbal abilities of 13 (out of 16) children with ASD and 11 (out of 16) comparison children were assessed by performance on the Vocabulary and Information subtests of the Wechsler Intelligence Scale for Children – Third Edition UK (WISC-III; Wechsler, 1991). The verbal IQ estimate gained from this short form has high reliability (Sattler, 1992). Because the lowest test age-equivalent offered by the WISC-III is 6 years and 2 months, the VMA of any participant who fell below this level on either of the verbal subtests could not be calculated. Under these circumstances, participants were administered the British Picture Vocabulary Scale – Second Edition (BPVS; Dunn et al., 1997), which offers test age-equivalents down to 2 years and 11 months. In this instance, the verbal abilities of three (out of 16) children with ASD and 3 (out of 16) comparison children were assessed with the BPVS.

The non-verbal abilities of all participants were assessed by the Block Design and Picture Completion subtests of the WISC-III. The performance IQ estimate gained from this short form has high reliability (Sattler, 1992). Participant characteristics for the total sample of ASD and comparison participants are presented in Table 1.

(Table 1 about here)

Given that some ASD and comparison participants received the WISC-III (Wechsler, 1991), whilst others received the BPVS (Dunn et al., 1997), statistical analyses were conducted on each sub-sample to ensure adequacy of matching in each case. Independent *t*-tests comparing ASD and comparison participants who received the WISC-III revealed that participants were well matched on all variables (all *ts* < 0.70, all *ps* $> .44$). Given the small number of participants who received the BPVS, Mann-Whitney *U* tests were used. ASD and comparison participants who received the BPVS were also matched on all variables (all *U*s > 1.00, all *p*s $> .24$).

Design and procedures. In the Squares task, a series of different coloured squares moved around the screen whenever the mouse was moved. One of the squares (the target square) moved exactly consistently with the movements of the mouse (i.e., was under the control of the participant), whilst all the other (distractor) squares moved in a random fashion (controlled by the computer). All the squares began moving when the mouse was moved and all squares stopped moving when the mouse stopped moving. Figure 1 illustrates the task stimuli. In the left window, the squares are in their starting position, before the mouse has been moved, whilst in the right window the squares have been activated by movement of the mouse.

In both Self and Other conditions, the mouse was located inside a cardboard box, with both ends open so that the mouse could be accessed from each end. This box obscured vision of the hand, so as to ensure that the target could not be identified through a strategy of matching observed hand movements with the movements of the squares on the screen.

The task was presented as a series of up to 12 levels, graded in difficulty, with five 30 second trials at each level. To move up a level, the participant had to complete more trials than would be expected by chance. So, for instance, on level one there were a total of four squares on screen, one target and three distractors. By chance, an individual would be expected to correctly identify the target on one in every four trials. Therefore, to pass on to level two, a participant must have successfully identified the target on at least two of the five trials on level one. On level two there were 8 distractors, going up to 15 distractors on level three and then, finally, 24 distractors on level four.

Another way in which the difficulty of the task was manipulated, in addition to the increasing number of distractors, was by varying the degree of similarity in the movements of the distractor squares relative to the target square. The vector movements of the distractors could be varied, relative to the target square, on an arc of anything between 0 and 360 degrees. At 0 degrees, the distractors would move identically to the target square making the target impossible to identify. At a movement arc of 360 degrees, the distractors could move in any direction relative to the target square, providing the maximum differentiation between the movements of the target and the distractors. If participants successfully completed level four then they moved onto level five which involved the same number of distractor squares (3) as did level one, but this time the distractors were restricted to a movement arc of 180 degrees. Levels, six, seven and eight involved the same numbers of distractors as levels two, three and four, respectively, except at this restricted movement arc of 180 degrees. If participants successfully completed level eight then they moved onto level nine which involved the same number of distractor squares as did level one, but this time the distractors were restricted to a movement arc of 90 degrees. Levels, ten, eleven and twelve involved the same numbers of distractors as levels two, three and four, respectively, except at this restricted movement arc of 90 degrees. Table 2 characterises each level of the task in terms of the number of distractor squares, number of trials required to pass and the movement arc of the distractor squares.

(Table 2 about here)

In the Self condition, participants were free to move the mouse as they wished and when they believed they had identified the target they pressed the space bar. At this point, the screen and all the squares on it froze and a cursor appeared. The participant then moved the cursor over the square which they believed to be the target and clicked the left mouse button. Their choice of square was recorded automatically by the computer and the next trial began immediately after their choice had been made. Before participants began the experimental trials, the experimenter demonstrated the task, completing two trials on level one, commenting to the participant, “Ok, I think I’m controlling the (say) red one (whilst pointing to the hypothesised target), so I press the space bar and then I choose that one by clicking on it”. The child was then given two practice trials on level one before beginning the experiment.

Once the Self condition had been completed, the participant took a short break before completing the Other-person condition. In this condition, the participant again placed their hand on the mouse, inside the box. The experimenter placed their own hand inside the box through the opposite end to the participant and took hold of the end of the mouse, using his index finger and thumb. The experimenter proceeded to repeatedly move the mouse up, then down, then left and then right. This series of movements was standardised across all participants. Once the participant believed they had identified the target square under the experimenter’s control they pressed the space bar and, as before, moved the cursor over the square they believed the target to be and clicked the left mouse button. The experimenter demonstrated the procedure again, under these new conditions, before allowing the participant to undertake two practice trials on level one, to familiarise themselves with the procedure.

The key variables on the Squares task, therefore, were the number of levels (and trials) successfully completed in each of the Self and Other conditions, by each participant group.

(Figure 1 about here)

Results

Table 3 shows the mean number of levels and trials completed in the Self and Other conditions of the Squares task, by ASD and comparison participants. Data were analysed in the first instance using a 2 × 2 repeated-measures ANOVA, with diagnostic group (ASD/comparison) as the between-participants factor and with number of levels completed in each task condition (Self/Other) as the within-participants variables.

(Table 3 about here)

The ANOVA indicated that the main effect of condition was significant, reflecting the superior performance of participants in the Self condition than in the Other-person condition, $F(1, 30) = 13.28$, $p = .001$, $r = .55$. The main effect of diagnostic group was not significant, however, indicating that participants with ASD showed the same level of performance, across conditions, as comparison participants, $F(1, 30) = 0.78$, $p = .38$, $r = .16$. Finally, the interaction between diagnostic group and condition was not significant, indicating that participants with ASD showed the same pattern of performance, across conditions, as comparison participants, $F(1, 30) = 0.29$, $p = .60$, $r = .10$. Figures 2 and 3 show the numbers of participants in each diagnostic group successfully completing each level in the Self and Other conditions of the Squares task, respectively.

A second ANOVA, with number of trials (rather than levels) completed in each task condition as the within-participants variables, produced an identical pattern of results: main effect of condition, $F(1, 30) = 22.61$, $p < .001$, $r = .66$; main effect of diagnostic group, $F(1, 30) = 0.42$, $p = .52$, $r = .12$; interaction between diagnostic group and condition, $F(1, 30) = 0.39$, $p = .54$, $r = .11$.

(Figures 2 & 3 about here)

Discussion

The results of Experiment 1 do not support the claim that individuals with ASD are impaired in their ability to monitor their own basic actions, online. There were no differences between the groups in terms of levels or patterns of performance. Each group found it easier to identify the target square when they were in control of its movements (in the Self condition), than when the experimenter was in control of its movements (in the Other-person condition). If individuals with ASD did not experience their own agency, then it should not matter who was in control of the mouse movements. In either case, they would be merely 'dispassionate observers' of perceived consequences of actions. Instead, it appears that, like comparison participants, they were able to benefit from access to their own motor intentions in the Self condition.

Whilst individuals with ASD clearly experienced their own agency in Experiment 1, the question of whether these experiences are encoded at a deeper level, in memory, is an unresolved question. Experiment 2, explored the recall performance of children and adolescents with ASD for their own actions, compared to their recall of the actions of another person.

Experiment 2

Method

Participants. Sixteen children with ASD and 16 comparison children completed the experimental task. The comparison group consisted of children with intellectual disability. The verbal abilities of 13 (out of 16) children with ASD and 11 (out of 16) comparison children were assessed by performance on the Vocabulary and Information subtests of the WISC-III (Wechsler, 1991). The verbal abilities of the remaining 3 participants with ASD and 5 comparison participants were assessed by performance on the BPVS (Dunn et al., 1997). Non-verbal abilities were assessed by the Block Design and Picture Completion subtests of the WISC-III. Due to limited child availability, the non-verbal ability of one (comparison) participant was not assessed. ASD and comparison participants who received the WISC-III were matched on all variables (all *t*s < 1, all *p*s $> .35$), as were ASD and comparison participants who received the BPVS (all *t*s < 1.70, all *p*s $> .13$). Participant characteristics for the total sample of ASD and comparison participants are presented in Table 4.

(Table 4 about here)

Design and procedure. A baby animal picture lotto game, similar to that used by Russell and Jarrold (1999), was used for this task. The game consisted of a board with 36 pictures in a 6 x 6 array and 36 corresponding picture-cards. For the purposes of this task it was decided to exclude 4 picture cards, leaving a total of 32, because they depicted animals which were very similar to other animals on the board. For instance, there were pictures of both a pig and a boar. These were deemed visually and semantically similar enough that they might become confused in participants' memories. The aim of the game was to place each card on its corresponding picture on the board. There were four 'players' in this game: the experimenter, the participant and two dolls - one a Doctor, the other a Fireman - who would, respectively, be 'partners' for the experimenter and the participant. The experimenter always sat to the left of the participant at the bottom left corner of the board, with the participant at the bottom right corner. The Doctor was opposite the experimenter, in the top left corner, and the Fireman was in the top right corner, opposite the participant.

One notable modification to the design implemented by Russell and Jarrold (1999) is in the number of stimulus items used. Whereas they used a total of 24 cards (6 cards for each player), this study implemented a total of 32 cards (8 cards for each player) in order to avoid potential ceiling effects in the current sample of participants who were developmentally more able, with VMAs approximately 17 months higher and VIQs approximately 20 points higher, than the sample of participants in Russell and Jarrold's study.

Each player had a pile of eight cards laid face down beside them, the corresponding board positions of which were evenly distributed. Players took it in turn to place the cards down on the board. The experimenter laid the first of his cards and then laid a card on behalf of his doll partner, the Doctor. The participant then laid a card on behalf of the Fireman before laying one of their own cards. The game proceeded like this, moving in a clockwise fashion.

It was explained to the participant that the experimenter would ‘play for the Doctor and put her cards down for her’ and that they (the participant) would ‘play for the Fireman and put his cards down for him’. The participant was told, at this point, that each player had eight cards. The participant was encouraged to label the pictures as they laid them down, whether on their own behalf or on behalf of their doll partner, and the experimenter labelled the pictures he laid down in a similar fashion. As the game proceeded, the experimenter provided a commentary, emphasising the different origins of the cards, saying, “I’ve got a (names and lays own card). Let’s see what the Doctor has got (experimenter names and lays the Doctor’s card). What has the Fireman got? (participant names and lays the Fireman’s card) And, what have you got? (participant names and lays his/her own card)”.

After all of the cards had been laid, the experimenter removed the board, leaving the picture cards, and introduced the memory test. The participant was instructed: ‘Ok, now you have to remember who each of the cards belonged to. So, give the cards that I had back to me, the cards the Doctor had back to her, the cards the Fireman had back to him and the cards that you had back to you’. The participant was reminded, at this point, that each player had started with eight cards and so should have eight cards at the end of the game. If, during the recall phase, the participant returned more than eight cards to any particular player, they were reminded about this fact and encouraged to redistribute some of the cards (e.g., “The Doctor’s got 10 cards now, but she only started out with 8 cards, so 2 must belong to another player"). No clues were given, however, as to which player to redistribute the excess cards.

Results

Table 5 shows the mean number of cards correctly returned to each player by ASD and comparison participants. Data were analysed using a 2 × 4 repeated-measures ANOVA, with diagnostic group (ASD/comparison) as the between-participants factor and card origin (participant/experimenter/Doctor/Fireman) as the within-participants variables. Given that these data violated the assumption of sphericity, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. The ANOVA indicated that the main effect of card origin was significant, showing that participants' recall performance was reliably affected, overall, by the source of the items, $F(1.91, 52.22) = 3.49$, $p = .04$, $r = .25$. The main effect of diagnostic group was not significant, indicating that participants with ASD showed the same level of recall performance, overall, as did comparison participants, $F(1, 30) = 0.10$, $p = .75$, $r = .06$.

The significant main effect of card origin was clarified through a series of simple contrasts, comparing the number of cards correctly returned to the child themselves to the number correctly returned to each of the other three players/origins. These contrasts revealed that participants correctly returned significantly more cards to themselves than to their own doll (the Fireman), $F(1, 30) = 14.88$, $p = .001$, $r = .58$. Participants also correctly returned more cards to themselves than to the experimenter, although this difference only approached significance, $F(1, 30) = 3.67$, $p = .07$, $r = .33$. Participants' recall of their own cards was not significantly different to their recall of the Experimenter's doll's (the Doctor) cards, $F(1, 30) = 2.18$, $p = .15$, $r = .26$.

Finally, there was no significant interaction between card origin and diagnostic group, indicating that participants with ASD showed the same pattern of recall performance as did comparison participants, $F(1.91, 52.22) = 0.70$, $p = .55$, $r = .12$.

(Table 5 about here)

Relationship between performance on the source memory task and performance on the Squares task

Of the 32 participants (16 ASD and 16 comparison) who received the Squares task, 26 (14 ASD and 12 comparison) also received the source memory task. A Self condition of the source memory task was created by combining the number of cards correctly returned by participants to themselves and to their doll partner. Also, an Other-person condition was created by combining the number of cards correctly returned by participants to the experimenter and to the experimenter's doll partner. A series of exploratory correlation analyses were then conducted, comparing the performance of participants across each condition of the Squares and source memory tasks. Given the small number of participants who received both experimental tasks and given that there were no between-group differences on either measure, it was decided to collapse the diagnostic groups to increase the power of the analysis. The following bivariate correlations were significant: Squares *Self* × Source Memory *Self* ($r = .45$, $p = .02$), Squares *Self* × Source Memory

Other (r = .50, p = .009), Squares *Other* × Source Memory *Other* (r = .40, p = .04). The bivariate correlation between Squares *Other* × Source Memory *Self* was not significant (r = .13, p = .51). In order to ensure that the above significant correlations were not confounded by general verbal ability, a series of partial correlations, controlling VMA, were conducted. When VMA was controlled, only the correlation between Squares *Self* × Source Memory *Self* remained significant (r = .39, p = .05).

Discussion

This study failed to replicate Russell and Jarrold's (1999) findings of a source monitoring impairment in children with ASD. Participants with ASD showed almost identical levels of recall performance to comparison participants. Furthermore, they also showed very similar patterns of performance on the experimental task, each group finding their own cards the easiest to recall. Both groups recalled fewer of the experimenter's cards than their own cards and this self-reference effect was very nearly significant, with a moderate effect size (r = .33). Both groups of participants also recalled their own cards significantly more reliably than their doll partner's cards. These findings suggest that individuals with ASD are typical in encoding information in memory in self-relevant ways.

It is potentially important that when both diagnostic groups were collapsed, performance on the Self condition (own cards + own doll partner's cards correctly returned) of the source memory task was significantly associated with performance on the Self condition of the Squares task from Experiment 1, independently of the effects of

VMA. Given the hypothesis that the Self conditions on each task are similar in involving the monitoring of one’s own intentions-in-action, this pattern of association is exactly what would be expected. Despite superficially different demands, then, the Squares task and the source memory task appear to be similar in tapping an underlying ability to monitor one’s own basic actions.

General Discussion

The findings from Experiments 1 and 2 do not support the notion that ASD involves a deficit in action monitoring. In Experiment 1, participants with ASD were as able as comparison participants to distinguish the changes in visual phenomenology caused by their own intentional movements from those computer-generated changes, in an online action monitoring (‘Squares’) task. The finding that both diagnostic groups found it significantly easier to distinguish such changes when they, as opposed to the experimenter, were in control of the target’s movement, shows that, contra Russell and Jarrold (1998), individuals with ASD not only *generate* a visual copy of a motor intention but also that they accurately *monitor* this generated copy (possibly unlike individuals with schizophrenia; Frith & Done, 1989).

The findings from Experiment 2 show that the ability of individuals with ASD to monitor their actions online extends to the ability to recall self-performed actions from memory. The results of Experiment 2 clearly contrast with the findings of Russell and Jarrold (1999) who used a very similar source memory task to that implemented here. Whilst participants with ASD in Russell and Jarrold’s (1999) study showed an atypical profile of memory performance – recalling the actions they saw another person perform more reliably than those performed by themselves – participants with ASD in the current sample were typical in showing a ‘self-reference effect’.

Importantly, participants with ASD were also like comparison participants in recalling significantly more of the cards they laid on their own behalf than the cards they laid on behalf of their doll partner (the Fireman). Whilst the ‘self-*enactment* effect’

(Engelkamp, 1998) – a retrieval advantage for the actions performed by oneself rather than by another – is associated with the influence of motoric components resulting from one's active agency, the 'self-*reference* effect' is thought to reflect the processing of information in self-relevant ways, independent of action/motoric mechanisms (Rogers, Kuiper & Kirker, 1977). The fact that the motoric components involved in the experimental task were the same for the participant whether they were laying cards on their own behalf or on behalf of their doll partner, suggests that it is not merely the process of acting which scaffolded memory performance in these participants. Rather, it appears that the cards laid by participants with ASD on their own behalf were (implicitly) encoded as 'belonging'/relative to them and hence were processed at deeper levels.

One potential reason for the discrepancy between our results and those of Russell and Jarrold (1999) could be the employment of a developmentally more able group of participants with ASD in the current study. It may be less able individuals with ASD have an atypical, immature pattern of recall performance in such tasks, reflecting a difficulty in action monitoring. However, the fact that other studies of self-other source memory in ASD, employing relatively less able individuals with ASD (e.g., Hala et al., 2005; Hill & Russell, 2002), have failed to find abnormalities in patterns of memory performance speaks somewhat against this idea.

One speculative idea is that the memory performance of children with ASD in the current study was scaffolded by the ongoing verbal commentary, strongly encouraged by the experimenter. It may be that such commentary was not (so) encouraged in those studies of source memory that have found atypical patterns of recall performance in individuals with ASD (although Russell and Jarrold report that their participants were engaged in commentary). Our reasoning is that engaging in verbal commentary may lead to events being encoded as *self*-experienced and, hence, recalled more accurately from memory. Comparison participants in previous studies might have naturally engaged in a form of (internal) commentary, regardless of whether or not they were instructed to do so, and hence displayed a self-reference effect. Individuals with ASD, however, may have a reduced propensity for the use of certain forms of inner speech (e.g., Whitehouse, Maybery & Durkin, 2007; but see Williams, Happé & Jarrold, 2008 for alternative findings), leading to the observer effects demonstrated in other studies. The 'outer speech' used by participants with autism in the current study may have provided the same function that inner speech does in individuals who do not have autism, and resulted in their displaying a typical self-reference effect.

Such an idea remains speculative although testable by comparing the memory performance of groups of children with and without ASD who are engaged in self-commentary with matched individuals with and without ASD who are not engaged. If participants with ASD do not naturally use inner speech then those who are not actively engaged in overt verbal commentary should show an observer effect whereas those who are engaged should show a self-reference effect. In contrast, participants without ASD who, hypothetically, naturally use inner speech should be relatively unaffected by engagement in overt verbalisation.

Regardless of the validity of the above speculation, it is clear that the samples of children with ASD in the experiments reported here showed no evidence of action monitoring impairments, either in terms of online monitoring or in recall from memory.

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This study was supported by a Medical Research Council Studentship, awarded to the first author. The manuscript was prepared during an Economic and Social Research Council Fellowship awarded to the first author. Our thanks go to Stuart Newman for his assistance with programming the task used in Experiment 1.

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Table 1: Participant characteristics for Experiment 1: Means and (standard deviations)

	ASD	Comparison	*t*	*p*	Effect size (*r*)
N	16	16			
CA: years	13.38 (1.24)	13.03 (1.74)	0.66	.52	.12
VMA: years	9.05 (2.17)	8.76 (2.02)	0.39	.70	.07
VIQ	72.00 (13.77)	69.88 (13.48)	0.44	.66	.08
PIQ	72.25 (14.33)	69.33 (20.30)	0.46	.65	.09

Table 2: Stimulus characteristics of each level of the Squares task

Level	No. of distractor squares	Min. no. of trials required to pass (out of 5)	Distractor movement arc (degrees)
1	3	2	360
2	8	1	
3	15	1	
4	24	1	
5	3	2	180
6	8	1	
7	15	1	
8	24	1	
9	3	2	90
10	8	1	
11	15	1	
12	24	1	

Table 3: Mean (SD) number of levels and trials completed in the Self and Other conditions of the Squares task, by ASD and comparison participants.

		Condition	
Diagnostic group	Dependent measure	Self	Other
ASD	Levels completed	4.69 (3.88)	2.25 (2.41)
	Trials completed	12.75 (8.66)	5.75 (6.87)
Comparison	Levels completed	3.62 (3.10)	1.81 (1.87)
	Trials completed	10.50 (8.25)	5.13 (4.56)

Table 4: Participant characteristics for Experiment 2: Means and (standard deviations)

	ASD	Comparison	*t*-value	*p*	Effect size (*r*)
N	16	16			
CA: years	12.44 (2.29)	12.24 (2.19)	0.24	.81	.04
VMA: years	8.44 (2.04)	7.65 (2.12)	0.83	.29	.15
VIQ	73.50 (12.29)	67.44 (13.59)	1.32	.20	.23
PIQ	68.94 (18.90)	63.80 (17.37) [a]	0.79	.44	.16

a Due to limited child availability, PIQ data was collected for $n = 15$ (out of 16) comparison participants.

Table 5: Mean (SD) number of cards correctly returned to each player by ASD and comparison participants.

	Player			
Group	Child	Child's doll	Experimenter	Experimenter's doll
ASD	4.44 (2.00)	3.69 (1.54)	3.50 (1.75)	3.94 (1.39)
Comparison	4.50 (1.37)	3.56 (1.50)	4.13 (2.13)	4.00 (1.63)

Figure captions

Figure 1: Example of experimental materials from the Squares task.

Figure 2: Number of participants in each group successfully completing each level in the Self condition of the Squares task

Figure 3: Number of participants in each group successfully completing each level in the Other condition of the Squares task

Figure 1 top

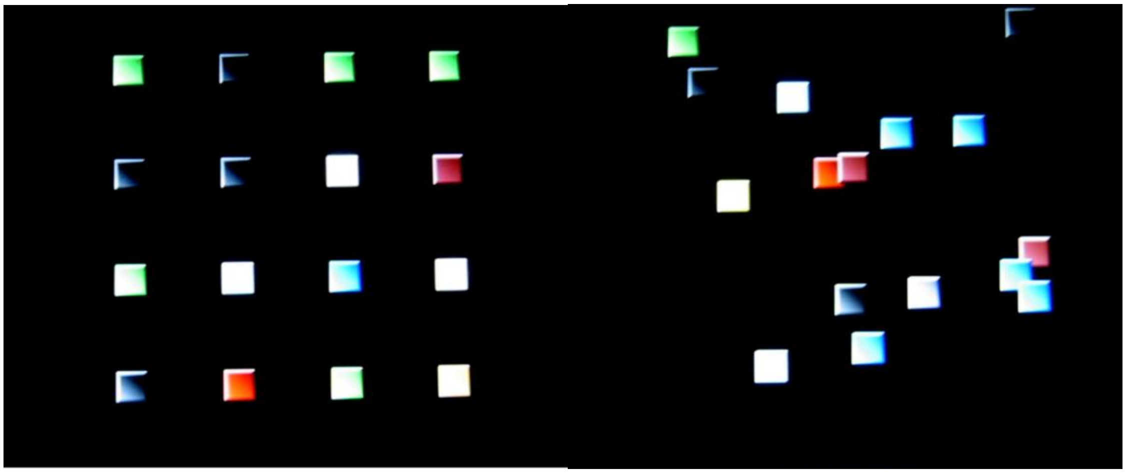


Figure 2 top

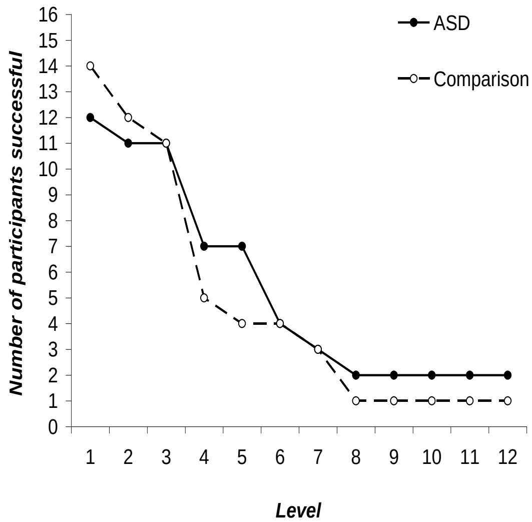
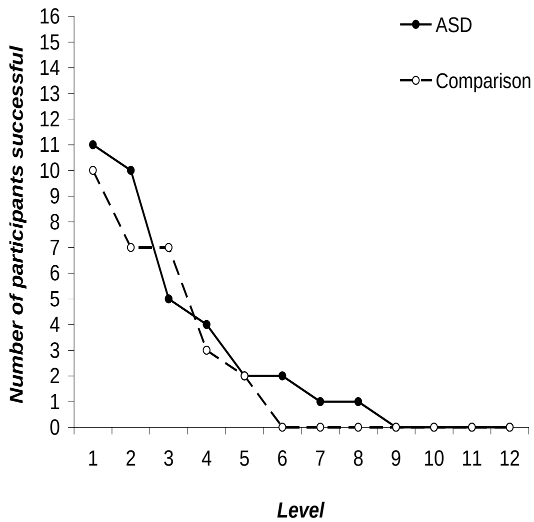

ASD
Comparison
Number of participants successful
Level
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Figure 3 top


ASD
Comparison
Number of participants successful
Level
0
1
2
3
4
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16