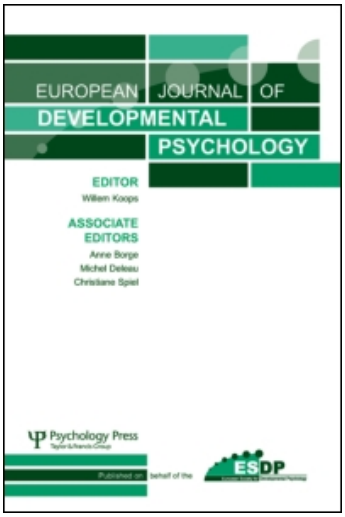

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Task-switching abilities in children with autism spectrum disorder

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Task-switching abilities in children with autism spectrum disorder

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Task-switching performance is often used as a measure of executive control functions. Various task-switching studies in children with autism spectrum disorder (ASD) found, in contrast to expectations, no impairments in cognitive flexibility. Here, we studied whether the role of memory for arbitrary task rules can explain these findings, and how studying rule memory can help to generally better understand executive control. We designed a novel task-switching paradigm to separate cognitive flexibility from demand on memory for arbitrary rules, and we compared 19 children with ASD (9 to 16 years old) with an age- and IQ-matched control group. Children with ASD had increased difficulty with task switching only when memorizing arbitrary rules was required. When no arbitrary rules needed to be memorized, they performed accurately and quickly. Nevertheless, they showed less distraction from task-irrelevant stimulus features, suggesting that they represented tasks differently from the children in the comparison group. We conclude that children with ASD have a weaker capacity of forming rule representations, which only leads to performance impairment when they need to memorize arbitrary rules. Further, executive control impairments in ASD seem more complex than hitherto hypothesized due to mutual interactions between memory demand and task representations.

Keywords: Autism spectrum disorder; Attention; Executive function; Memory; Task switching.

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Autism spectrum disorder (ASD) is a developmental disorder characterized by impaired communication, language, and social interaction, as well as by perseverative and stereotyped behaviour (Frith, 1997). The study of cognition in people with ASD has different types of purpose. On the one hand, such research helps to refine our understanding of the disorder, and to improve diagnostic tools. On the other hand, the comparison of typical and atypical cognition can contribute to understanding how cognitive functions are implemented. The current study was carried out with both purposes in mind. First of all, our study aimed to explain some of the anomalous findings in the research on executive functions in people in with ASD, and so to better our understanding of the behaviour of people with ASD. Second, we aimed to get insight into how the human cognitive system represents tasks and rules.

Executive control functions are defined by their role in the co-ordination of thought and action. Planning actions, flexibly switching between actions, suppressing certain thoughts when required, monitoring actions and their outcome, as well as short-term maintenance are all considered executive control functions (Royall et al., 2002; Stoet & Snyder, 2009). The intense study of these functions began several decades ago (Atkinson & Shiffrin, 1968; Butterfield & Belmond, 1977). Today, there is a consensus that they play an essential role in cognition, and that an abnormality in executive control is an important determinant of neuropsychiatric disorders (Royall et al., 2002), including ASD (Hill, 2004). Further, there is a strong link between executive functions and working memory (Baddeley, 1996; Postle, Berger, & Esposito, 1999), and there is a continuing discussion about the exact definition of working memory and its relationship to executive functions (see Miyake & Shah, 1999, for a recent review).

The first publication focusing on executive control functions in ASD appeared more than 15 years ago (Ozonoff, Pennington, & Rogers, 1991), and since then it has been well established that people with ASD suffer from impaired executive control functions (Hill, 2004; Russell, 1997). Various studies have demonstrated the presence of executive dysfunction in ASD in tasks that require planning (such as the Tower of Hanoi; Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Ozonoff et al., 1991), cognitive flexibility (such as the Wisconsin Card Sorting Test, WCST; Rumsey, 1985; Shu, Lung, Tien, & Chen, 2001), and inhibition of prepotent responses (such as the Go/No Go task; Ozonoff, Strayer, McMahon, & Filloux, 1994), and these impairments are stable across time (Ozonoff & McEvoy, 1994). In relation to working memory, the evidence is less clear, with studies providing evidence for both intact and impaired working memory, depending on the test used (Bennetto, Pennington, & Rogers, 1996; Geurts et al., 2004; Williams, Goldstein, & Minshew, 2006b).

We designed a novel task-switching paradigm to disentangle the contributions of mental flexibility and memory for arbitrary[1] rules in task performance. In cognitive psychology and cognitive neuroscience, task-switching paradigms are well established for the assessment of executive control functions; task-switching behaviour has been characterized in hundreds of studies with neurotypical adults (see Monsell, 2003, for a review), in people with cognitive impairments (Barton et al., 2002; Greenzang, Manoach, Goff, & Barton, 2007; Manoach, Lindgren, & Barton, 2004; Manoach et al., 2002; Meiran, Levine, Meiran, & Henik, 2000; Stoet, Markey, & López, 2007), and with non-human primates (Stoet & Snyder, 2003a, 2003b, 2004, 2006, 2007a, 2007b, 2009). In task-switching paradigms, participants perform randomly mixed trial sequences of two tasks (e.g., task A and task B), such that both task-repetition and task-switch trials occur (e.g., ABBABAAABAB, but alternative mixing schemes exist; see Monsell, 2003). Humans are known to perform more slowly and less accurately on trials in which they have to switch from performing one task to performing an alternative task than when they have to repeat the same task as in the preceding trial (even after long training; Stoet & Snyder, 2007c). This cost of slowing down and becoming less accurate when one needs to switch between tasks is known as a switch cost. This cost is typically quantified as the difference in the average response time (or error rate) in task-switch trials and the average response time (or error rate) in task-repeat trials.

Besides measuring the difficulty of switching between tasks (i.e., switch costs), the task-switching paradigm also gives insight into how well people can focus on one task whilst ignoring features of the alternative task. The executive-control function involved in ignoring or filtering out irrelevant distracting stimulus features is known as inhibition. Stimuli containing features that are irrelevant for the task at hand and having an opposite meaning in the task not currently performed are called "incongruent" stimuli. Stimuli containing features that are irrelevant for the task at hand, but have nonetheless exactly the same meaning as in the task not currently performed are called "congruent". Inhibition in task-switching paradigms is typically quantified as the cost associated with responding to incongruent stimuli. This cost can be calculated by taking the difference in response times (or error rates) in incongruent and congruent trials. In task-switching paradigms, the two executive control functions can be disentangled because task switching and the presence of irrelevant distracting stimulus features can be manipulated independently (see methods).

[1]The word *arbitrary* refers to a stimulus-response relationship which is not known to the participant before the experiment, one that is not intuitive, and one that cannot be deduced from which is on screen. The arbitrary rule will be the same throughout the experiment, and will be contrasted with a straightforward stimulus-response rule.

Task-switching paradigms have been used to study executive control functions in people with ASD. Manoach and colleagues (2004) showed that adults with Asperger's syndrome have no greater difficulty switching between tasks than typically developing adults (TDA). Further, a study by Whitehouse, Mayber, and Durkin (2006) compared performance in blocks of doing just one task to blocks of alternating between two different tasks; no task-switching abnormalities were found. In a similar vein, Bogte, Flamma, van der Meere, and van Engeland (2008) failed to find set-shifting difficulties in high-functioning adults with autism. Finally, a recent study with children with ASD detected no difference from children in a control group (Poljac et al., 2010). The findings of these studies seem to be a contrast to the general assumption that people with ASD have limited cognitive flexibility (Hughes, Russell, & Robbins, 1994), and they justify further study of cognitive flexibility in people with ASD.

One of the difficulties with interpreting the aforementioned studies, all showing no impairment in mental flexibility in people with ASD, is that they used paradigms much simpler than those typically used with adult human participants (which require memorization and application of arbitrary rules). For example, Poljac and colleagues (2010) used a paradigm in which participants switched between matching either the colour (task 1) or shape (task 2) to a reference object. We wondered whether the simplification of task-switching paradigms used in people with ASD plays a role in the lack of observed executive impairment.

The main question we aimed to answer here was whether children with ASD can generally perform task-switching tasks, or whether they are only spared at these tasks when there is a low demand on memory for arbitrary rules. There are good reasons to assume that simplified task-switching paradigms use less memory and do not require memorization of arbitrary rules. There is evidence that people with ASD tend to have difficulty using arbitrary rules in tasks that require inhibiting a prepotent response (Bíró & Russell, 2001; Hughes & Russell, 1993), and there is evidence of working-memory impairments in ASD (Bennetto et al., 1996; Williams, Goldstein, Carpenter, & Minshew, 2005; Williams, Goldstein, & Minshew, 2006a). Further, there is an ongoing debate about how factors such as task complexity are involved in executive impairment (Hill, 2004). Arguably, task-switching paradigms are often relatively complex, as they require the memorization of several arbitrary rules. That said, the exact role of rule memory remains unclear in task-switching paradigms.

Using our novel task-switching paradigm, we tested the capacity to rapidly switch between two tasks and the capacity to ignore task-irrelevant stimulus–response relationships under two memory-demand conditions. In the "low memory" condition, participants did not need to memorize arbitrary rules, whereas they did need to do so in the "high memory"

condition. We hypothesized that mental flexibility and inhibition of irrelevant information are strongly affected by whether or not these tasks required the memorization of arbitrary rules. We assumed that if children with ASD have a lack of mental flexibility, they would show larger switch costs in both low- and high-memory-demand conditions of the paradigm. Alternatively, if children with ASD have difficulty memorizing arbitrary rules, they should only have a problem with the high-memory-demand condition of the paradigm.

METHODS

Participants

Altogether 38 children participated and were studied at their school in a quiet room. Nineteen boys with ASD (age 9:0 to 16:4 years of age; $M_{\text{age}} = 13{:}1$ years, $SD = 1{:}10$) were selected from special-needs schools in England. These schools only admit children who have received a statement from the educational authorities and a formal diagnosis by an experienced clinical psychologist or psychiatrist using the guidelines of standard criteria such as DSM-III-R (American Psychiatric Association, 1987), DSM-IV (American Psychiatric Association, 1994) or ICD-10 (World Health Organization, 1993). A further selection criterion was that the children had verbal skills sufficient to participate in an intelligence test and to understand the task instructions (which was based on a judgement of the school or experimenter, and not formally tested). Our measurements of IQ using the Wechsler Abbreviated Scale of Intelligence (WASI) ranged from 55 to 139 (mean IQ score = 103.4, $SD = 20.8$). A further nineteen typically developing boys, age (9:9 to 16:6; $M_{\text{age}} = 13{:}6$, $SD = 2{:}0$) and IQ (mean IQ score = 104.5, $SD = 11.5$) matched (at group level), were selected as a control group. As intended, we could not establish a statistical difference between age, $t(36) = 0.65$, $p = .52$, or IQ levels, $t(36) = 0.20$, $p = .84$.

Apparatus

The experiment was carried out on a laptop computer running custom software. Left and right shift buttons of an external keyboard were used for response measurement. Stimuli measured 3 × 3 cm and were presented on the laptop screen.

Design and procedures

Participants performed a computer-controlled choice–reaction time experiment. The experiment had a mixed design with Task-Switching (task-switch

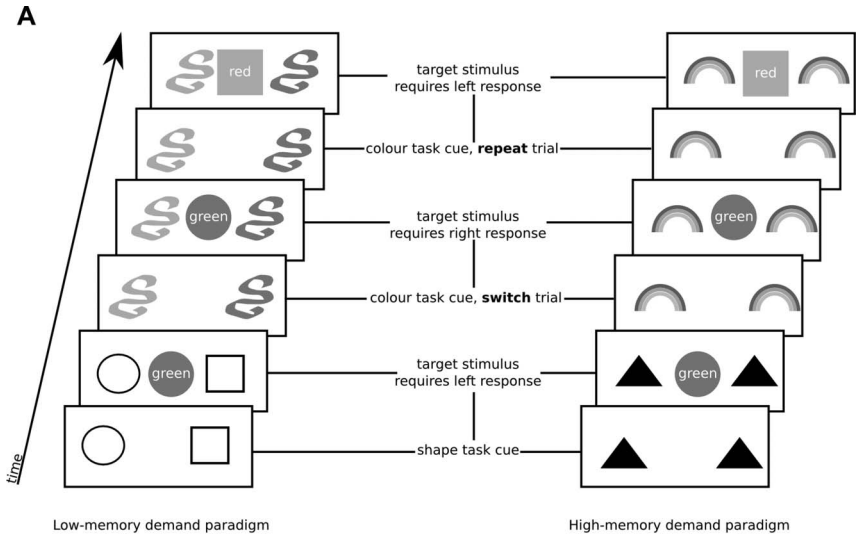
vs. task-repeat), Congruency (congruent vs. incongruent) and Memory Demand (low-memory vs. high-memory) as the within-subject factors and Group (ASD vs. control) as the between-subject factors. This design resulted in a total of eight within-subject conditions. Altogether, participants performed 76 training trials and 464 further trials. Response time (RT) and error percentage were the dependent variables.

Participants were instructed to either discriminate the colour of a stimulus (i.e., colour task) or the shape of a stimulus (i.e., shape task) depending on which task they were doing (Figure 1). The task cue was the first stimulus of each trial and informed participants which of the two tasks should be performed. The task cue was followed by an imperative stimulus (this stimulus is called "imperative" because it is the stimulus that triggered the response).

In the colour task, participants were instructed to indicate whether the imperative stimulus was either red or green with a left or right-positioned button press, respectively. In the shape task, participants were instructed to indicate whether the imperative stimulus was a circle or a square with a left or right button press, respectively. The imperative stimulus always appeared in the centre of the screen, whereas information on the left and right of this stimulus informed the participant which of the two tasks to apply. Trials of the two tasks were randomly mixed, such that participants had to switch between tasks on half of the trials (e.g., the sequence of trials could be: *colour* task trial—*colour* task trial—*colour* task trial—*shape* task trial—*colour* task trial—*shape* task trial—*shape* task trial—*colour* task trial; in this sequence there were 4 switch trials and 3 repeat trials, the first trial is considered neither, because a first trial by definition neither constitutes a switch from another task, nor a repeat of a task type).

We used four different imperative stimuli, a red circle, a green circle, a red square, or a green square (Figure 1B). One half of these stimuli were congruent, meaning that colour and shape would be associated with the same response in both tasks, and one half was incongruent, meaning that colour and shape of a stimulus were associated with different responses in the two tasks. For example, a green square is a congruent stimulus because it is always associated with a right button press, regardless of whether a participant is performing a colour or a shape task. On the other hand, a green circle is incongruent because it is associated with the left response in the shape task and with the right response in the colour task (Figure 1B).

We created two memory conditions. In the *low-memory* condition (Figure 1A, left side), the task-cue information not only informed the participant which of the two tasks to perform, but also what the stimulus–response mapping rules of the task were. For example, the colour-task cue contained a red scribble on the left side of the screen and a green scribble on the right side of the screen (Figure 1A, left side); the participant was reminded that a red



B

task cues		target stimuli			
low memory	high memory	congruent		incongruent	
		red	green	green	red
		left	right	left	right
		left	right	right	left

Figure 1. Tasks used. (A) Three example trials in the low-memory (left) and high-memory (right) conditions of the task-switching paradigm used. The example trials on the left and right are identical except for the task cues. In the low-memory condition, the cues not only convey information about the task, but also about the task-specific stimulus–response mapping. The example sequences should both be read from the bottom left to the top right. Vertical lines connect trial events task cue and imperative stimulus. The colour-name labels such as "green" in the stimuli are for black-and-white print purposes only, and indicate true stimulus colours. The black-filled triangles on white background were in the experiment white-filled triangles on black background. (B) Stimulus–response associations in the two tasks.

stimulus required a left response and a green stimulus a right response. Similarly, in the shape task, the task cue contained a white circle on the left side of the screen and a white square on the right side of the screen (Figure 1A, left side), indicating the shape-task mapping rules (Figure 1B). Pilot studies with typically developing adults showed that even though the "low memory" condition seems simple, people still showed significant switch costs.

In the *high-memory* condition (Figure 1A, right side), the task cue did not help the participants to memorize the task's stimulus–response mapping rules (and we call the rules in the high-memory task arbitrary, because of this lack of a straightforward relationship between task cue and imperative stimulus). A comparison between performance in the low-memory and high-memory conditions would allow us to find out whether memory demands for maintaining task rules affect task-switching performance.

The sequence of events within trails was as follows. Each trial started with the presentation of a task cue for 200 ms (Figure 1A). The task cue remained visible for the duration of the trial. Then, 200 ms after task-cue onset, the imperative stimulus appeared at screen centre. Depending on task and imperative stimulus, the participant was required to press the left or right button to indicate the response. As soon as the participant responded, the imperative stimulus disappeared and the trial ended. The next trial followed after 650 ms. In case of an erroneous response (or the lack of any response within 5 seconds), a 3 second delay with a blank screen followed to discourage errors and to give additional time to refocus attention on the task at hand.

In the low-memory version, the colour-task cue consisted of a red and green colour scribble (positioned left and right of the centrally presented imperative stimulus), and the shape-task cue of a white circle and square (again, positioned left and right of the centrally presented imperative stimulus, Figure 1A). In the high-memory paradigm, abstract task cues were shown left and right of the imperative stimulus. These abstract task cues were rainbows in the colour task and white (filled) triangles in the shape task.

All participants started with the low-memory version to make the high-memory version equally difficult for all participants.

Data analysis

For each participant, 464 trials were analysed. Each trial corresponded to one of eight within-subject conditions. These eight conditions resulted from the three experimental factors "memory demand" (with the levels low-memory and high-memory), "task switching" (with the levels switch and repeat), and "congruency" (with the levels congruent and incongruent). For each condition of each participant, the median RT and error percentage was calculated and subsequently analysed using a mixed-design analysis of variance (ANOVA).

When reporting a group mean, we will also report the standard error of the mean (i.e., mean $\pm$ 1 *SEM*). Switch and repeat trials were only considered as such if they followed a correctly performed trial.

RESULTS

Our first analysis focuses on error rates. We analysed error rates (Figure 2) using a repeated-measures ANOVA with the between-subject factor Group (ASD vs. control) and the within-subject factors Memory Demand (low vs. high), Task Switching (switch vs. repeat), and stimulus–response Congruency (congruent vs. incongruent). This ANOVA revealed that participants performed less accurately in switch than in repeat trials, $F(1, 36) = 53.2$, $p < .01$, less accurately in incongruent than in congruent trials, $F(1, 36) = 88.8$, $p < .01$, and these two factors interacted, $F(1, 36) = 30.0$, $p < .01$. Participants performed less accurately in high- than in low-memory trials, $F(1, 36) = 88.2$, $p < .01$. This effect interacted with Task Switching, $F(1, 36) = 48.3$, $p < .01$ and with Congruency, $F(1, 36) = 61.8$, $p < .01$. In both these interactions, the costs of switching and congruency increased in the high-memory conditions.

The between-group effects are of special interest to this study. The interaction between Group and Memory Demand shows that the negative

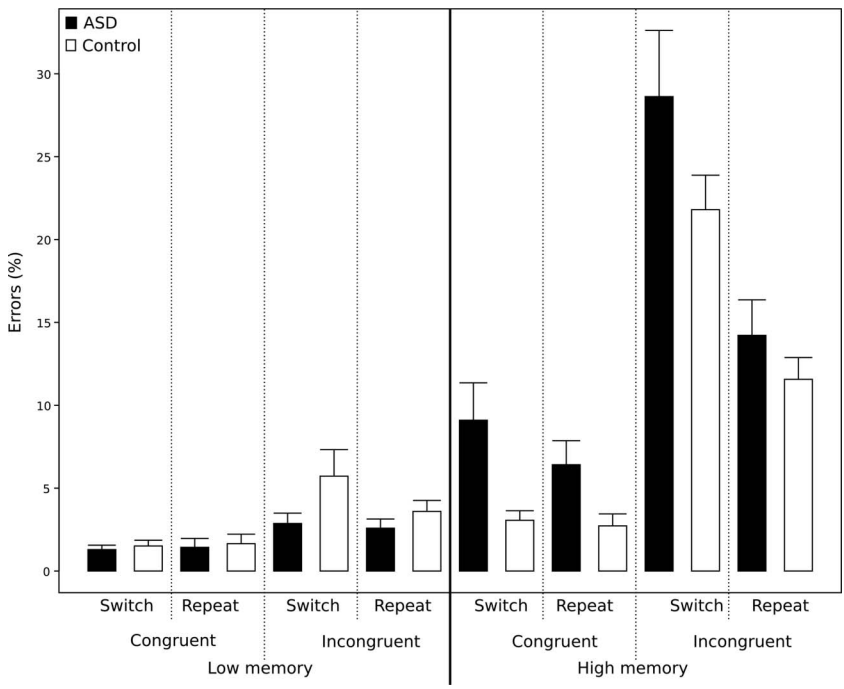


Figure 2. Error rates in eight conditions resulting from the factors memory demand (low vs. high), congruency (congruent vs. incongruent), and task-switching (switch vs. repeat). Error bars indicate 1standard error of the (group) mean.

effect of high-memory demand on accuracy was larger in the ASD group than in the control group, $F(1, 36) = 8.3$, $p < .01$. Further, the effect of higher switch costs in the high- than in the low-memory condition was more pronounced in the ASD group, $F(1, 36) = 82.9$, $p = .03$.

The ANOVA helps to determine differences in the conditions and groups, but does not in itself inform us whether the very high group-average error rates (over 20% in some conditions) implied that some participants were unable to perform the task. We performed a separate analysis to answer this question. Using binomial tests, we determined for each of the eight conditions of each participant whether performance was significantly better than chance level (Figure 3). We found that 6 out of the 19 children (31.6%) with ASD performed no better than chance level in the high-memory incongruent switch condition (Figure 3A). In the control group, we found 2 children (10.5%) performing no better than chance in that condition. The group difference of the percentage of children performing at chance level (31.6% vs. 10.5% of children performing at chance level) was not statistically significant, $\chi^2(1) = 1.43$, $p = .23$.

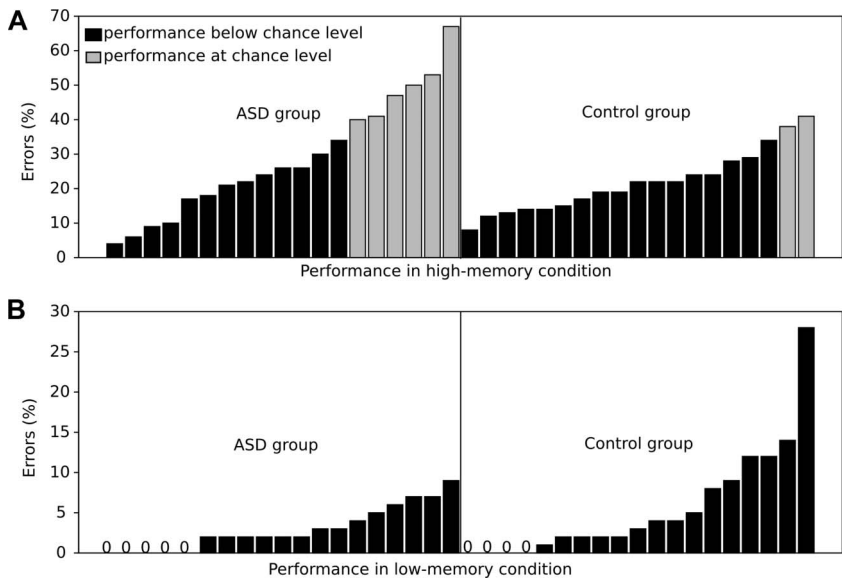


Figure 3. Accuracy of individual participants sorted from low to high. (A) Accuracy in the most difficult condition, the task-switch incongruent condition in the high-memory condition. Performance of six children in the ASD group and 2 children in the control group could not be distinguished from chance level (binomial test). (B) Same as in A, but now in the low-memory condition. Five children in the ASD group and four in the control group made no errors at all (0). The ASD group worked well, albeit that the advantage was not statistically significant.

Contrary to performance in the high-memory condition, children performed well in the low-memory condition, even in the most difficult incongruent task-switch condition (Figure 3B): Error rates in the ASD group were low, with 5 participants making no errors at all. The finding that the error rates in this group were low and not significantly different from the control group indicates how successful the children with ASD were in performing this task.

The finding of performance at chance level in the high-memory condition in a number of participants in both groups has implications for further data analysis of response times (RT). If someone works at chance level, this person's RT can, logically, not be interpreted as reflecting decision time. But if we left out participants who performed at chance level in the high-memory condition, the resulting group averages of RT would not be representative of the whole group that the participants belonged to. We chose to refrain from RT analysis in the high-memory condition because of this problem.

We analysed RT (Figure 4) of the low-memory condition using a mixed-design repeated-measures ANOVA with the within-subjects factors task switching and task interference and the same between-subject factor (Group). As expected, based on previous studies of task switching, we

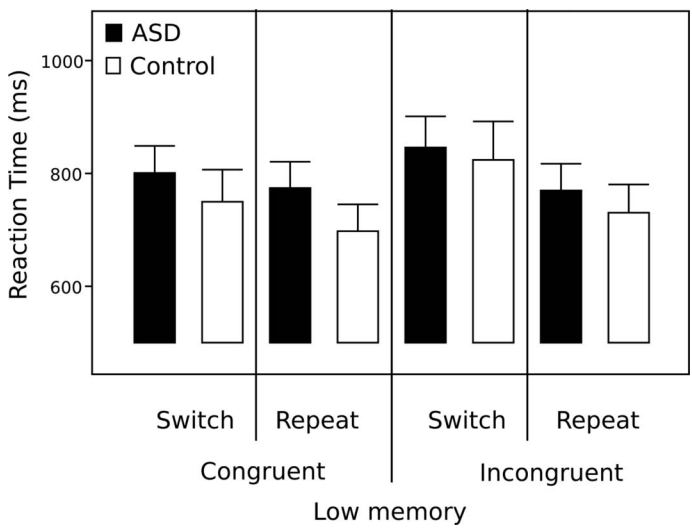


Figure 4. Reaction times (+ 1standard error of the mean) in the low-memory condition. Switch trials were performed significantly slower than repeat trials (in both groups), and incongruent trials slower than congruent trials (in both groups). Note that switch and incongruency effects were calculated as within-subject effects, and are thus not reflected by the error bars, which reflect the standard error between subjects per condition. The difficulty of responding to incongruent trials was significantly larger in the control than in the ASD group.

found that participants were slower in the task-switch than in task-repeat trials, $F(1, 36) = 37.3$, $p < .01$, that participants were slower in incongruent than in congruent trials, $F(1, 36) = 27.1$, $p < .01$, and that these two factors interacted, $F(1, 36) = 10.2$, $p < .01$. The latter interaction showed larger switch costs in the incongruent condition.

The factors Group and Congruency interacted, $F(1, 36) = 5.4$, $p = .03$. This indicated that children in the control group were more strongly affected by task interference than children with ASD.

DISCUSSION

We compared task-switching performance in children with ASD and typically developing children using a novel task-switching paradigm. The novelty of this study was that the demand on memory for arbitrary rules was manipulated. Children in both groups showed the typical effects observed in other task-switching studies, such as task-switch costs and costs associated with incongruent stimuli. Further, they performed more slowly and less accurately in the high-memory than in the low-memory condition. In both groups, a number of children performed at chance level in the high-memory condition. There were a number of striking differences between the two groups. In the high-memory condition, children in the ASD group made generally more errors than the children in the comparison group, and they had a bigger problem with task switching. In the low-memory condition we could not establish any difference in the total number of errors, the speed, or the capacity to switch. Yet there was one surprising difference in this condition: Children with ASD were less affected by incongruent stimuli than typically developing children.

These findings give us important clues about executive functions in basic cognitive tasks in children with ASD. First of all, children with ASD have impaired cognitive flexibility, but only in combination with a strong demand on memory for arbitrary rules. This finding is entirely novel in the study of task-switching performance in children, but fits well with existing models of autism, which propose that people with autism have increased difficulty with increasing processing demands (Minshew, Goldstein, & Siegel, 1997; Williams et al., 2006b). Various studies have reported good performance of even younger children than those studied here (Crone, Bunge, van der Molen, & Ridderinkhof, 2006; Poljac et al., 2010). And various studies have demonstrated that children with ASD have no detectable problem with switching between tasks (Poljac et al., 2010; Whitehouse et al., 2006). Those studies used relatively simple tasks to switch between, and stand in stark contrast to the typical task-switching paradigms used with adults (Monsell, 2003) and in cognitive neuroscience (Stoet & Snyder, 2009), which are more similar to our high-memory condition. Our finding of the difficulties children

with ASD have in the high-memory task-switching condition is consistent with previous studies showing difficulty with the use of arbitrary rules in other executive function tasks in children with ASD (Bíró & Russell, 2001; Hughes & Russell, 1993). Altogether, these results complement existing studies of task-switching performance in children with and without ASD.

Apart from findings related to task-switching abilities, a surprising finding in regard to dealing with incongruent stimuli was found. In the high-memory condition, children with autism struggled with incongruent stimuli, but in the low-memory condition, they were less affected by incongruent stimuli than typically developing children. This suggests that the children with ASD had either perfect inhibition of irrelevant features in the low-memory condition, or that they did not break down stimuli in their constituent features (colour vs. shape) and associate these features with a task. A study conducted by Plaisted, O'Riordan, and Baron-Cohen (1998) may provide an explanation for this surprising result. In their study, children with ASD excelled in a visual search task that required them to search for a target among distractors. The target could be identified either by a single feature (i.e., colour) or by two features (colour and shape). Results showed that children with ASD perform similarly in the two conditions while the comparison sample was significantly slower when the target was a combination of two features. Moreover, children with ASD were not as affected by the number of distractors in the display. This pattern of results can be explained by enhanced ability to focus on the cues relevant to a task and ignore irrelevant information. This enhanced ability is also seen in the current study showing that the ASD sample were not as affected by the cues relevant to the alternative task. Possibly, therefore, children in the ASD group used a different strategy. Rather than thinking of the trials as being of two task types (colour and shape), these children might simply have matched whatever features were available in the cues. This strategy works, but only in the low-memory condition (in the high-memory condition, participants had to remember the meaning of the cue). It is the simplest and most straightforward strategy. Of course, they still needed to switch between attending to colour on some trials and to shape on other trials, but that was irrelevant for strategy. It seems that children in the control group built up a more complex representation of the paradigm, which helped them with the difficult high-memory condition, but hampered them in the low-memory condition, because the alternative meaning of stimuli affected their responses negatively.

We found that both groups of children made many errors in the high-memory condition, and in both groups of children some children failed to perform better than chance level. Failure to perform better than chance could entirely be explained by poor performance in trials requiring a

task-switch, and it was the group of children with ASD who had the greater difficulty with switching.

Another aspect touched upon in this study is chance performance. We found that a number of children performed at chance level in some conditions. This is not entirely surprising in itself, but it has consequences for dealing with these participants, and it creates difficulties in data analysis. For example, we decided to abstain from interpreting RT data in the high-memory condition, simply because a number of participants performed no better than chance level. Our impression is that chance performance is rarely addressed in task-switching studies with special populations, and it is possible that, in some studies, this has wrongly assumed better performance than reported. We would like to use the context of our research to appeal to other researches to focus more on error rates of individual participants in data analyses.

With regard to chance performance, we would also like to mention that, not entirely unsurprisingly, the two children with the lowest IQ performed at chance level in the most difficult condition of the high-memory task. One could argue that IQ is the best explanation for poor performance in this task, rather than ASD itself. Or one could argue that we should only have included children above a certain IQ level. Yet, we have good reasons to include the full range of IQs. First, we wanted a representative sample of children with ASD and it turned out that our sample included some children with low IQs. That is a real aspect of ASD, we believe, and we think that not including those children could limit our understanding of cognitive functioning of ASD as a disorder. More importantly in our decision not to select based on IQ was that half of the children that performed at chance level had an over-average IQ. Second, children with low IQs could perform the low-memory task quite well, which proves that it is not the switching per se, but the combination of switching and memory demand that is most challenging.

In summary, impairments in executive control in children with ASD are more complex than hitherto thought. It is not generally the case that children with ASD have no problem with task switching, even though a number of studies, including the current study, show that these children do well as long as the task is relatively simple—once the tasks require memory and use of arbitrary rules, their task-switching abilities deteriorate. In general, task-switching performance cannot generally be taken as a general purpose measure of mental flexibility; whether someone can easily switch between tasks or not depends to a large degree on how well they can memorize and apply rules.

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