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Childhood rituals and executive functions

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Abstract

Repetitive and ritualistic behaviours (RRBs) are a feature of both typical and atypical development. While the cognitive correlates of these behaviours have been investigated in some neurodevelopmental conditions these links remain largely unexplored in typical development. The current study examined the relationship between RRBs and executive functions in a sample of typically developing children aged between 37-107 months. Results showed that cognitive flexibility, and not response inhibition or generativity, was most strongly associated with the frequency of RRBs in this sample. In younger children (<67.5 months) cognitive flexibility was significantly associated with "Repetitive Behaviours" but in older children (>67.5 months) cognitive flexibility was associated with both "Just Right" and "Repetitive Behaviour", suggesting that the association between EF and RRBs may become stronger with age in typically developing children.

Repetitive and ritualistic behaviours (RRBs) are present in a number of neurodevelopmental conditions but are also a feature of typical development (Evans, et al., 1997; Evans & Gray, 2000; Greaves, Prince, Evans & Charman, 2006; Leekam et al., 2007; Lewis & Bodfish, 1998). These behaviours typically manifest at around 30-36 months (Gesell, Ames, & Ilg, 1974; Ilg, Ames & Baker, 1982) when children who were previously flexible can exhibit marked distress at changes in routine and insist upon tasks being performed until they are "just so". While by age 5 years children appear more comfortable adapting to change and rituals are less pronounced, these behaviours have been noted to extend, albeit in more sophisticated forms, well into adolescence (e.g. Leonard, Goldberger, Rapoport, Cheslow & Swedo, 1990)

In an effort to empirically map the prevalence and developmental trajectory of RRBs in typical development Evans and colleagues (Evans et al., 1997) developed the Childhood Routines Inventory (CRI); a parent report instrument that measures the frequency and intensity of childhood RRBs. This instrument was completed by parents of a large sample of typically developing children (8-72 months) and results indicated a peak in ritualised behaviour between 2 and 4 years of age followed by a decline in these behaviours from the age of 5 years. Furthermore, RRBs in this sample were found to cluster into two distinct factors, which the authors labelled "Just Right" and "Repetitive Behaviours". "Just Right" behaviours refer to ordering and arranging behaviours and the tendency for children to perform a given behaviour until some subjective sensory-perceptual criterion has been reached. In contrast, the "Repetitive Behaviour" factor included items relating to the repetition of actions, routines and play.

Despite being a widely acknowledged aspect of typical development the aetiology of RRBs remains largely unexplored in typically developing populations. What is responsible for the peak in ritualised behaviour in preschoolers and why do these behaviours decline after 5 years of age? Several explanations have been offered for early preschool rituals, such as, separation anxiety, fearfulness (e.g. the dark, strangers, harm) (Evans & Gray, 2000; Peleg-Popko & Dar, 2003; Zohar & Felz, 2001), family patterns and cohesion (Peleg-Popko & Dar, 2003) or magical thinking and reality testing (e.g. Bolton, Dearsley, Madronal-Luque & Baron-Cohen, 2002). However, it has been suggested that the subsequent decline in RRBs may be associated with the emergence of executive functions (Evans & Gray, 2000; Evans, Lewis & Iobst, 2004).

Executive functions (EF) are a group of cognitive processes necessary for flexible, goal-oriented responses in novel or demanding situations and consist of a number of components, such as, cognitive flexibility, inhibition, planning, working memory and generativity (Shallice, 1990; Shallice & Burgess 1991; Stuss & Benson, 1986). As a result of her work with autism spectrum disorders (ASD) Turner (1997) proposed that RRBs could be linked to EF in one of two ways 1) impairments in the inhibitory control of behaviour (response inhibition and cognitive flexibility), and 2) the reduced capacity to generate novel responses (generativity). Response inhibition refers to the conscious suppression of a prepotent behavioural response (see Nigg, 2000 for a working taxonomy of inhibition). Cognitive flexibility is a closely related executive component and refers to the capacity to shift attention between different stimuli or switch between strategies or response sets. Both inhibition and cognitive flexibility are said to undergo a 'developmental spurt' between the ages of 3-5 years and between 5-7 years (e.g. Anderson, Anderson, Northam & Taylor, 2000; Carlson, 2005; Espy, 1997; Jacques & Zelazo, 2001; Smidts, Jacobs & Anderson, 2004). There is also evidence that cognitive flexibility may undergo further refinement after 7 years (Huizinga & van der Molen, 2007; Paniak et al., 1996). Most preschoolers fail tasks such as the Day-Night Stroop test (Gerstadt, Hong & Diamond, 1994), a measure of inhibition, and the Dimensional Card Sort Test (Zelazo, Frye & Rapus, 1996), a measure of flexibility, but pass these tasks by age 4 or 5 years (see Zelazo, Muller, Frye & Marcovitch, 2003 for review) demonstrating maturation of these aspects of executive function during this time period.

Generativity is a term given to the capacity to spontaneously generate novel ideas or behaviours and is often measured using tasks of fluency that require the individual to produce "multiple responses to a single cue, stimulus or prompt" (Turner, 1999a pg 190). A reduced or impaired capacity to generate novel behavioural responses has been offered as a possible explanation for lack of imaginative play and the high rate of RRBs, particularly insistence on sameness, seen in autism (Turner, 1997; 1999a). While studies attempting to find links between RRBs and EF in the neurodevelopmental literature have yielded mixed results (e.g. Bishop & Norbury, 2005a, b; Evans, Lewis & Iobst, 2004; Joseph & Tager-Flusberg, 2004; Lopez, Lincoln, Ozonoff & Lai, 2005; Ozonoff et al., 2004; South, Ozonoff & McMahon, 2007; Turner, 1997), this remains a highly influential hypothesis (Evans, et al., 2004; Hill, 2004; Turner, 1997; Turner, 1999b).

So how might the executive system be linked with RRBs in both typical and atypical development? As outlined above, executive functions are defined as those processes essential for adaptation to novel, unfamiliar circumstances suggesting that they are relatively inactive when executing well-learned behaviours and familiar routines (Shallice, 1990; Walsh & Darby, 1999). Immaturity of the executive system in preschoolers and executive dysfunction in neurodevelopmental conditions might result in RRBs as children adhere to over-learned routines and behaviours. For example, an inability to think flexibly by switching attention and shifting between strategies, difficulties generating new behavioural patterns and ways of exploring objects or lack of inhibitory control could all result in rigid and repetitive patterns of behaviour, such as a strict adherence to routine or acting out the same behaviour over-and-over.

In their review article assessing the role of the orbitofrontal cortex in compulsive-like behaviour, Evans et al. (2004) outline the findings of a study exploring the role of inhibition and cognitive flexibility in normative childhood rituals. Typically developing children aged between 6 and 11 years completed a series of computer-generated tasks designed to tap cognitive constructs of motor suppression/response inhibition and set-shifting (cognitive flexibility) and parents rated their level of ritualistic behaviour using the Childhood Routines Inventory (CRI). Regression analysis indicated that while none of the tasks significantly predicted mean CRI total score or mean “Just Right” behaviours, “Repetitive Behaviours” were predicted by performance on both a task of set-shifting and a task measuring response inhibition. A recent study from the same group (Pietrefesa & Evans, 2007) followed up this work in a sample of 42 children aged between 4 and 8 years. Results indicated that the affective and neuropsychological correlates of RRBs may differ with age showing that while poorer set-shifting and response inhibition were significant predictors of RRBs in younger children (<72 months), “Just Right” behaviours in older children (>72months) were predicted by a combination of *greater* inhibitory control and the presence of fears and social anxiety. This result appears to stand in contrast to the findings of Evans and colleagues (2004) who found a *positive* association between RRBs and difficulties with inhibitory control in typically developing children of a similar age. While it is plausible that the antecedents of ritualistic behaviour in older children may include an additional social-cognitive component, it is difficult to explain how deficits in response suppression may be associated with RRBs in preschoolers and in individuals with OCD (see Evans et al., 2004) for example, but correlate with fewer RRBs in school-aged typically developing children. If this were the case it may have important implications for understanding cognition behaviour links in clinical populations.

In summary, RRBs are common during the course of typical development, Behaviours seen in preschool children are similar to those displayed by individuals with neurodevelopmental conditions and yet we know relatively little about the normative course of these behaviours or the cognitive mechanisms that may underpin them. To date, studies examining the cognitive correlates of RRBs in typically developing populations have produced mixed results and raised important questions about the different ways in which RRBs may be mediated in younger versus older school-aged children.

The present study aimed to test how each component of Turner's framework (outlined above), namely response inhibition, cognitive flexibility and generativity, is associated with RRBs in typically developing children. Further it investigates whether any patterns of association are similar or different in younger vs. older children.

Method

Participants

Families with children attending mainstream primary school and who had no statement of Special Educational Needs were invited to take part in the study. Recruitment packs were sent out through 3 schools and preschools and families interested in participating returned consent forms to the research group. Personal details of families approached by the schools were unknown to the research group, which received information only from families who consented to take part in the study. Of those families invited to take part, 84 opted-in to the study (35.5% response rate). Of these, 78 children were available for assessment in school. Children participating in the study were recruited from middle income families in a rural community and were predominantly of white Caucasian ethnicity (n=76). Participants were divided into two groups for analysis by median split (67.5 months). Children in the younger group (<67.5 months) (n=39; 25 male) were aged between 37 and 67 months (mean 54.5; SD 9.5) and children in the older group (>67.5 months) (n=39; 20 male) ranged in age between 68 and 107 months (mean 85.3; SD12.1).

Procedure

All children taking part in the study were seen individually at school by the same member of the research team. Preschool children were seen over two shorter sessions to minimise attentional confounds but older children were assessed in a single session lasting approximately

30-40 minutes. All children were given incentives to complete the cognitive battery (stickers, certificates). Questionnaire packs were mailed to parents in the week following the cognitive assessments. These were completed and returned to the research group by post. Reminder letters and replacement questionnaires were sent to parents if packs were not returned within one month. Of the 78 questionnaire packs mailed to parents, 70 were completed and returned to the group (90% return).

Executive Function Measures

Card sorting test (e.g. Hughes, Dunn & White, 1998). A card sorting task was employed as a measure of cognitive flexibility. Materials for this task included three 'character cards' and three decks of cards that differed along dimensions of colour (red and blue, yellow and green, black and pink), shape (squares and hearts, stars and moons, smiley faces and lightning) and size (half of the cards in each deck were large and half were small). Each deck contained 64 coloured cards measuring 6cm x 9cm.

At the start of the task children were shown one of the character cards, which included a photograph of a 'character' and told: *"We're going to play a game. This is Sally."* The character card is placed in front of the child. "Sally has a pack of cards. Here are some of Sally's cards." One deck of cards was selected and shuffled. Children were then shown four cards randomly selected from the top of the deck. "*Now I am going to show you some more cards. Some of the cards you will see are Sally's favourite cards, and some of the cards Sally doesn't like at all. Your job is to work out which cards are Sally's favourite cards*." The examiner showed cards one at a time and asked the child '*Is this one of Sally's favourite cards, or is it not one of her favourites?*' Children were given feedback about their decisions and asked to put the character's favourite cards in a pile face-down next to the character's picture; cards that were not the character's favourite cards are placed face-down in another pile. The criterion for success in this task was six consecutively correct decisions; if this criterion has not been reached in 20 trials, the sort is discontinued and the next sort begins. Each time a target card was sorted incorrectly this was recorded as an error; at the end of each sort the errors were summed to give total error score for each of the three sorts.

Different characters and card decks were used for each sort (colour, shape and size) to minimise inhibitory demands across trials and the order of the sorting rules was randomised across participants. Set-shifting demands are greatest on the third sort and so the number of errors made on this sort were used as a measure of cognitive flexibility.

Luria hand game (Hughes, 1996). This is a task of response inhibition in which children must withhold a prepotent motor response. In the imitation phase, which is not scored, children were asked to imitate the hand position of the examiner (either a point or a fist). For example, the examiner made the target hand shape and said, *"Show me how you make a fist with your hand/point your finger"*. After the child successfully imitated six hand positions (three points, three fists) the examiner introduced the conflict phase *"Well done! Now it gets a bit harder. This time, when I show you a fist* (examiner makes a fist) *I want you to point your finger. Can you show me how you point your finger? And when I point my finger* (examiner points finger) *I want you to make a fist! Can you show me how you make a fist?"* The new rule was practiced *"What do you do if I make a fist/point my finger?"* until the child successfully completed four consecutive trials after which the child completed fifteen test trials. A trial was scored as successful if the child performed the correct hand shape on the first attempt; failure to make the correct hand shape on the first attempt, for example if the child imitated the examiner, was marked as an error. The total number of errors in the conflict phase of this task was used as the main dependent variable. Trials on which the child made an error but then subsequently self-corrected were noted and these scores, along with correct responses on the first attempt, were combined to the produce the "self-correct total" which represented the total number of trials (max 15) on which the child ultimately produced the correct hand shape.

Category fluency (e.g. Lezak, 1995; Turner, 1999a). This is a task measuring semantic verbal fluency. Participants were given one minute to generate as many *different* words as possible belonging to two predetermined categories (animals and foods) without repeating themselves. Each child was given two total scores 1) a total output score consisting of the sum total number of words generated across both categories including repetitions and incorrect responses; and 2) a total valid score which was the total number of responses across the two categories minus repetitions of the same word and invalid responses that did not belong to the target category. The total valid score was the main dependent variable and was used as a measure of generativity.

The Childhood Routines Inventory (CRI; Evans et al., 1997)

The CRI is a 19-item parent report questionnaire designed to measure the frequency and intensity of RRBs present in typical childhood. Items are rated on a 1 (not at all/never) to 5 (very much/always) scale for frequency and intensity and both a CRI Total score (total number of behaviours present) and a CRI Frequency/Intensity score (the mean frequency rating for all 19 items on a 1-5 scale) can be derived. In this analysis individual item scores were used to create a 'Just Right' score and a 'Repetitive Behaviour' score based upon the factor analysis outlined in Evans et al (1997). Factor scores were derived by summing individual item scores and dividing by the total number in each factor. This resulted in an average score indicating the frequency/intensity of ritualistic behaviour on a 1-5 scale. The 'Just Right' factor consists 5 items relating to ordering and arranging and behaviours with a perfectionist quality (e.g. "Arranges objects or performs certain behaviours until they seem 'just right'" or "Insists of having certain belongings around the house 'in their place'"). The 'Repetitive Behaviour' factor score comprises 4 items relating to repetitive behaviours (e.g. “Repeats certain actions over and over”) and insistence on sameness (e.g. “Prefers the same household schedule and routine everyday”).

Results

Childhood Routines Inventory

Means and standard deviations for the CRI summary scores are shown in Table 1. Group differences (Younger vs. Older) were examined using an independent samples t-test that revealed no significant group differences on any of the CRI indices. The groups showed comparable CRI total (t(86=1.42, p>0.1), CRI frequency/intensity (t(68)=0.68, p>0.1), Just Right (t(68)=0.65, p>0.1) and Repetitive Behaviour scores (t(68)=1.14, p>0.1). There was no significant effect of gender (p>.10).

<TABLE 1 HERE>

Executive Function Measures

<TABLE 2 HERE>

Data from the Card sorting test were analysed using a two-way mixed ANOVA with Group (Younger vs. Older) entered as the between subjects factor and Sort (1, 2 or 3) as the within subjects factor (see Table 2). Levene’s Test indicated unequal variance across groups for Sort 1 (F(2,76)=4.65, p<.05) and Sort 3 (F(1, 76)=10.31, p<0.01) therefore the analysis was conducted on square root transformed data for sorts 1, 2 and 3. This analysis revealed a significant main effect of Group (F(1,76)=16.49, p<.01), with younger children making significantly more errors overall than older children, and a significant Group x Sort interaction (F(2,152)=4.01, p<0.05). The main effect of Sort fell just short of significance (F(2,152)=2.75, p=0.07). This result was equivalent to analysis conducted on the untransformed scores. Post hoc exploration of the interaction using independent samples t-tests showed that younger children made significantly more errors than older children only in Sort 3 ($t(76)=4.55$, $p<0.01$). There were no significant group differences for Sort 1 ($t(76)=1.15$, $p>0.1$) or Sort 2 ($t(76)=1.65$, $p>0.1$).

Data from the Luria hand game and the Category fluency test were analysed using an independent samples t-test with Group (Younger vs. Older) entered as the independent variable. Significant group differences were found for the number of errors on the Luria hand game ($t(76)=3.53$, $p<0.01$), with younger children making a significantly greater number of errors on this task than older children. No significant group difference was found, however, for the total number of errors after self-correction ($t(76)=1.00$, $p>0.1$), indicating that while younger children made significantly more errors than older children on their first attempt, this was not a product of poor understanding of task requirements as they scored similarly to older children after self-correction. When examining the results of the Category fluency task, significant group differences were found for both Total output ($t(76)=-6.22$, $p<0.01$) and Total valid scores ($t(76)=-6.83$, $p<0.01$). Older children produced both a greater number of responses overall and a greater number of valid responses compared with children in the younger group.

<TABLE 3a & b HERE>

Associations between EF measures

When examining the intercorrelations between the different EF task variables by age group there were few significant associations. Errors in the conflict phase of the Luria hand game were significantly correlated with the total number of valid responses on the Category fluency task in both age groups (younger: $r=-0.38$, $p<0.05$; older: $r=-0.32$, $p<0.05$). Variables from the Card Sorting Task were not significantly correlated with the other EF tasks in younger children, but errors on Card Sort 2 were associated with fewer valid responses on the Category fluency task in older children ($r=-0.36$, $p<0.05$).

Linking behaviour to executive functions

Correlations between the EF tasks and the CRI variables are reported by age group in tables 3a and 3b. In the older children, the number of errors in Card Sort 3 significantly correlated with all CRI variables; however, in the younger children this variable was associated with "Repetitive Behaviours" alone. The number of errors in the conflict phase of the Luria hand game was also significantly correlated with "Reptitive Behaviours" in the older group only. In contrast, the number of errors in Card Sorts 1 and 2 and the total number of valid responses in the Category fluency task did not significantly correlate with any of the CRI variables in either age group. Overall, results indicate that EF and repetitive behaviours were more strongly associated in the older children.

Discussion

The present study examined the association between normative childhood RRB s and three aspects of the executive system (cognitive flexibility, response inhibition and generativity). Results showed that (1) performance on the executive measures across age groups was consistent with developmental gains in EF across this age range; (2) there was no significant difference between the age groups on overall number or frequency of RRBs; and (3) cognitive flexibility, but not response inhibition or generativity, was significantly associated with RRBs in both age groups but was more strongly associated with behaviour in the older children.

Poorer performance on the Card Sorting task, as indexed by a greater number of errors on sort 3, was associated with parent reports of more frequent RRBs in both younger (preschool) and older (school-aged) children. More specifically, a greater number of errors on sort 3 predicted a higher frequency of "Repetitive Behaviour" in younger children and both "Just Right" and "Repetitive Behaviour" in older children. This result can be contrasted with that of Evans and colleagues (2004) which found that a combination of set-shifting and inhibitory control contributed to a regression model predicting "Repetitive Behaviours" but none of the EF tasks predicted variance in "Just Right" behaviours. Inflexible thinking could conceivably underpin both groups of behaviours, for example, difficulty disengaging from a particular strategy or mode of thinking could result in both the repetition of familiar over-learned patterns of behaviour, and rigid and perfectionistic adherence to rituals, such as, lining up. Our results support that the processes associated with RRBs in typically developing children may be those required for flexible thought rather than those involved in the inhibition of motor responses. For example, a child may repeatedly act out the same thing in pretend play not because they are unable to inhibit the *motor* sequence but because they are unable to switch to another cognitive set.

Successfully shifting between sorts in sorting tasks requires (1) inhibition of previous rules that were reinforced in preceding sorts i.e. *cognitive inhibition* or *attentional inertia* (Kirkham, Cruess & Diamond, 2003; Diamond, Carlson & Beck, 2005); (2) *representational flexibility* i.e. the ability to represent a single stimulus in a number of different ways (e.g. Perner, Stummer, Sprung & Doherty, 2002; see also Zelazo, et al., 2003); and, (3) the ability to hold the present rule within *working memory*. The card sorting task in the present study was based on a paradigm used by Hughes, Dunn and White (1998) to measure EF in "hard-to-manage" preschoolers. It was designed to control for perseveration on a given exemplar by using different card packs and characters for each sort (which also provide an implicit cue to switch sorting rule). The sorting paradigm used in the present study still requires children to shift between sorting rules but eliminates the likelihood of poor performance due to difficulty inhibiting a perseverative response elicited by an exemplar that is present across all sorts. Relating this to the components above, the present task would still require the inhibition of previous rules and require the present rule to be held within working memory, but may place fewer demands on representational flexibility as new exemplars were used for each of the three sorts.

The present study found that generativity was unrelated to RRBs, which might suggest that the association between cognitive flexibility and RRBs is driven by the cognitive inhibitory component rather than the generative aspect of thinking of a new sorting rule. However, the category fluency task used as a proxy for generativity in the current study does not tap representational flexibility i.e. it does not involve representing a stimulus in a number of different ways, but measures the ease with which information can be accessed from semantic networks. A generativity task such as an ideational fluency task (see Turner, 1999a) for example, in which a number of different uses for a single object must be generated may be more analogous to the representational flexibility necessary for switching between rules in the Card Sorting task and could be a fruitful avenue for future work.

Results from the present study suggest that there may be a convergent relationship between RRBs and EF over development, with EF (particularly cognitive flexibility) and RRBs becoming more closely associated with age. This is particularly interesting when considering the possible direction of association between RRBs and EF. Within the neurodevelopmental literature there has been considerable debate about the primacy of executive deficits in ASD and their capacity to give rise to RRBs in clinical populations. The most recent studies conducted with preschool aged children with ASD suggest that EF is not impaired at this early stage of development (Dawson et al., 2002; Yerys et al., 2007) and may be a secondary feature of the disorder. Possible explanations may be that EF and RRBs are indirectly related through another as yet unidentified factor, or that the association runs in the opposite direction to that which was originally proposed. For example, early onset of rigid and repetitive patterns of behaviour may impact upon the emergence of specific EFs by limiting exposure to critical experiences early in life. In typical development it could be hypothesised that sub-clinical levels of RRBs might influence the acquisition of EF, for example, highly rigid and routinised behaviour, perhaps due to high anxiety or lower developmental level, might reduce exposure to relevant environmental stimuli necessary for the development of EF. In typically developing children this may merely manifest as lower efficiency on EF tasks rather than lack of ability. That RRBs and EF are more closely associated in older children despite there being no significant age group differences in RRBs could be interpreted in support of this hypothesis.

However, the results of the present study are seemingly at odds with that of Pietrefesa and Evans (2007) who found that none of the sorting tasks predicted variance in any of the CRI variables in their sample. In addition they found an inverse relationship between EF and RRBs in older children (72-96 months) who were of comparable age to older children in the present study (67.5-107 months). In particular they found that errors of commission on the Connors' Continuous Performance Test (CPT; Conners, 2000), a computerised go/no-go task, predicted higher CRI Total scores in younger children (<72months) but lower CRI Total and "Just Right" scores in older children (>72 months). i.e. greater inhibitory control was associated with more frequent RRBs, particularly perfectionist behaviours, in older children. On consideration, this result has high face-validity in that it is children who have greater inhibitory control (or are more careful not to make errors) that demonstrate a greater repertoire of restricted behaviours where behaviours must be performed until they are "just so". Perhaps, inhibitory control could contribute to RRBs in one of two ways: 1) poorer inhibitory control (for example in preschool children) is associated with a greater number of repetitive behaviours, and 2) greater inhibitory control (in older school-aged children) is associated with a higher frequency of restricted behaviours.

Differences in results between the present study and that of Pietrefesa and Evans (2007) could be explained by task attributes used in each of the studies. For example, as mentioned previously, the Card Sorting task used in the present study differs to traditional sorting paradigms as it reduces perceptual cues in subsequent sorts. It may be the cognitive shifting between sorting rules that is most closely associated with RRBs in typically developing children rather than the inhibition of more automatic perseverative patterns of responding elicited by perceptual features of a stimulus. Additionally, the inhibition tasks used in the studies differ; the task used in the present study requires the inhibition of a prepotent gross motor movement, however, the CPT is a go/no-go task that involves the inhibition of subtle motor movements (clicking a mouse button) and requires children to make a speed-accuracy trade-off; the effects of which can be closely measured due to the computerised nature of the task.

Results from the present study dovetail with research carried out in the neurodevelopmental literature. Lopez and colleagues (2005) conducted a similar study examining links between executive functions and RRBs in a group of adults with ASD. Comparable to present findings, their results indicated that cognitive flexibility (a composite measure comprised of performance on the California Trail Making Test and the Wisconsin Card Sorting Task) was highly correlated with a composite measure of RRBs. Results also showed significant associations between RRBs and response inhibition and working memory, but not generativity (comprised of category and design fluency tasks), planning or IQ. A recent study by South, Ozonoff and McMahon (2007) provides further support for an association between RRBs and cognitive flexibility in ASD. Although the instruments used to measure RRBs in these studies were diagnostic instruments that included behaviours such as motor stereotypies that are not well represented in the CRI; it is of interest that cognitive flexibility has been identified as a correlate of RRBs in both studies using typical and atypical populations.

Limitations of the present study

One limitation of the present study is the lack of information about IQ which is a known correlate of RRBs in clinical populations and may also play a role in the presentation of normative RRBs (see Evans & Gray, 2000). It is possible, therefore, that variation in developmental level may have introduced bias into group assignments. For example, grouping children based on chronological age using a median split may produce groups of uneven ability which may also impact upon the level of repetitive behaviours reported in a group overall. While this is unlikely as all children were recruited through mainstream schools and did not have a statement of special educational needs, this is a possibility that cannot be ruled out in the present study. A second limitation is the lack of significant group differences in CRI scores in the present study. While differences are in the expected direction, with older children showing fewer such behaviours compared to younger children, they did not reach significance as was the case for Pietrefesa and Evans (2007). This is the first time the CRI has been administered with a UK sample and comparing across Evans et al. (1997), Pietresfa & Evans (2007) and the present study the scores are within the ranges of other samples, although in a relatively small sample there will inevitably be sample-specific effects that may influence parents' rating of behaviour. Finally, while it could be argued that set-shifting demands are greatest in the third card sort as children must now inhibit two previously reinforced rules and select a new rule from only one remaining possibility, fatigue cannot be ruled out as a factor contributing to performance on this task, especially in the youngest children. However, children were highly engaged with the task and motivated by the rewards (stickers, pencil cases etc); the changing of characters and card packs after each sort served to refresh interest in the game and all three sorts were completed in under 10 minutes. Furthermore, similar stronger associations between sort 3 and RRBs were found in the older children (>67.5 months) and the performance of these children on sort 3 was not significantly poorer than their performance on the previous sorts suggesting that an identical association in older children at least was not representative of fatigue.

Conclusions

Establishing correlates of RRBs in typically developing children is essential if we are to place maladaptive RRBs, such as those seen in neurodevelopmental conditions, in a developmental context (see Leekam et al., 2007; for an excellent example of this approach). The results of the current study indicate that cognitive flexibility is associated with both “Just Right” behaviours that involve perfectionistic ordering and arranging behaviours, and “Repetitive Behaviour” that includes the repetition of actions, routine and play. There is also evidence that the association between EF and RRBs becomes greater with age. The absence of a significant association between RRBs and response inhibition (or generativity) suggests that the number and frequency of these behaviours in typically developing school-age children may be associated with difficulties switching between strategies or cognitive sets rather than difficulties inhibiting behavioural responses or generating new ones. However, more research is needed using a range of paradigms, for example, inhibition tasks that systematically vary level of motor involvement and representational similarity and generativity tasks measuring representational flexibility, to further clarify these associations.

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Table 1

Results from parent report ratings on the Childhood Routines Inventory (CRI)

	Younger (n = 34)	Older (n = 36)	Total (n = 70)
CRI variables			
- CRI Total (0-19)	11.09 (5.0)	9.39 (5.0)	10.21 (5.0)
- CRI Frequency (1-5)	1.98 (0.6)	1.87 (0.7)	1.92 (0.6)
- “Just Right” (1-5)	1.96 (0.7)	1.84 (0.9)	1.90 (0.8)
- “Repetitive Behaviour” (1-5)	2.02 (0.8)	1.81 (0.8)	1.91 (0.8)

Table 2

Results of the cognitive tasks across the two age groups showing significant group differences

	Younger (n = 39)	Older (n = 39)	Total (n = 78)
Card sorting test			
-Errors trial 1	3.8 (3.6)[a]	3.0 (2.8)[a]	3.4 (3.3)
-Errors trial 2	4.5 (3.4)[a]	3.3 (3.1)[a]	3.9 (3.3)
-Errors trial 3	6.4 (3.9)[a]	2.8 (3.0)[b]	4.6 (3.9)
-Total errors	14.6 (6.1)[a]	9.0 (5.5)[a]	11.8 (6.4)
Luria hand game			
-Errors	4.9 (2.9)[a]	2.5 (2.8)[b]	3.7 (3.1)
-Self-corrected	1.6 (3.5)[a]	0.8 (3.4)[a]	1.2 (3.4)
Category fluency			
-Total output	16.2 (5.0)[a]	24.8 (7.0)[b]	20.5 (7.5)
-Total valid	14.5 (4.7)[a]	23.1 (6.3)[b]	18.8 (7.0)

Note. Letters that are different (e.g. a b c) denote significant group differences on the tasks. Data presented are raw (untransformed) mean (SD).

Table 3a

Pearson correlation coefficients between CRI scores and the cognitive tasks in younger children

RRB measures	CS1 Errors	CS2 Errors	CS3 Errors	Luria Errors	Category Valid
CRI Total	-.04	-.24	.19	-.01	.10
CRI Frequency/Intensity	-.02	-.23	.25	.05	.12

CRI 'Just Right'	-.12	-.02	.10	-.03	.20
CRI 'Repetitive Behaviour'	-.20	-.11	.37*	.00	.17

Note. CS1 = Card Sort 1; CS2 = Card Sort 2; CS3 = Card Sort 3. * p < .05. ** p < .01

Table 3b

Pearson correlation coefficients between CRI scores and the cognitive tasks in older children

RRB measures	CS1 Errors	CS2 Errors	CS3 Errors	Luria Errors	Category Valid
CRI Total	.14	.12	.48**	.32	-.06
CRI Frequency/Intensity	-.02	.11	.67**	.23	-.06
CRI 'Just Right'	-.11	.10	.67**	.25	-.11
CRI 'Repetitive Behaviour'	.01	.01	.61**	.38*	-.12

Note. CS1 = Card Sort 1; CS2 = Card Sort 2; CS3 = Card Sort 3. * p < .05. ** p < .01