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Developing set-shifting improvement tasks (SSIT) for children with high-functioning autism

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Abstract

Background Children with autism spectrum disorder (ASD) experience set-shifting deficit as a part of *executive function*, which can lead to cognitive and behavioural flexibility deficits and/or restricted behaviours. Despite the increasing body of research on this cognitive deficit, set-shifting training has not been exclusively studied in ASD.
Aims In this study, a training condition [set-shifting improvement tasks (SSIT)] was developed to improve set-shifting ability; afterwards, the possible effects of these tasks were investigated.
Methods and Procedures With the aim of improving set-shifting ability in children with autism, a training program (SSIT), involving a computer game (Tatka, a puzzle game produced by our research team) with some home-based tasks (for generalisation purposes), was developed. Then, in a quasi-experimental design, the effects of SSIT tasks were studied on children (n = 13, 5–7 years old) with high-functioning autism. Outcome measures (pre-training, post-training and a 6-week follow-up) were assessed using Modified Wisconsin Card Sorting Test, Bender-Gestalt Test and Behavioural Flexibility Rating Scale.
Results and Outcomes A significant change was observed in both cognitive (Bender Gestalt, $\eta_p^2 = 0.84$; WCST; $_p^2 = 0.87$) and behavioural flexibilities ($\eta_p^2 = 0.79$) and also in repetitive behaviours ($\eta_p^2 = 0.45$). Furthermore, the result remained stable to some extent for about 1 month after the training condition.
Conclusions and Implications Developing the SSIT is just an initial step in the major target of creating cognitive rehabilitation tools to be used by clinicians and parents for children diagnosed with ASD and should be understood as a supplement, rather than an alternative, to the main treatments such as *applied behaviour analysis*. Future research with larger samples are needed to confirm whether this intervention is effective for children with ASD.

Keywords behavioural flexibility, cognitive flexibility, high-functioning autism, repetitive behaviour, set shifting

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Introduction

Set shifting (also referred to as cognitive shifting or mental flexibility) is an executive function that allows attention to shift between several tasks, activities, thoughts or strategies when changes occur in a situation (Hill 2004; Geurts *et al.* 2009; Yerys *et al.* 2015). Dramatically developing during childhood, this ability of switching from a previously learned rule to a new rule (Cepeda *et al.* 2001; Bunge & Zelazo 2006 (has been shown to be affected by some neurodevelopmental disorders, especially in individuals with autism spectrum disorders (ASD; Prior & MacMillan 1973; Rinehart *et al.* 2001; Ozonoff *et al.* 2004; Green *et al.* 2007; South *et al.* 2007; Geurts *et al.* 2009; Yerys *et al.* 2009; Shahrokhi *et al.* 2012; Miller *et al.* 2015).

The numerous difficulties in neurodevelopmental disorders such as autism that can interfere with daily life may be partly caused by set-shifting deficit (Berger *et al.* 2003; De Vries *et al.* 2014; Miller *et al.* 2015). For instance, the difficulty in shifting and maintaining new responses can be used to predict the restricted and repetitive behaviour (Turner 1999; Lopez *et al.* 2005; Miller *et al.* 2015). Known to be more common among individuals with high-functioning autism (South *et al.* 2005; Green *et al.* 2007), this lack of behavioural flexibility can lead to some behavioural and cognitive problems such as perseveration, insistence on sameness, inflexible adherence to specific routines, resistance to changes in family routines and difficulties in shifting between different subjects and situations (Yerys *et al.* 2009; Maes *et al.* 2011; Ollington 2012; Rosenthal *et al.* 2013; Smithson *et al.* 2013; Leung & Zakzanis 2014; Miller *et al.* 2015).

Deficits in cognitive flexibility can affect level of intelligence or educational level, aggressive behaviour, self-control and the level of social activity (Memari *et al.* 2013; Visser *et al.* 2014; Farrelly & Mace 2015). On the other hand, inflexibility can be used to predict behavioural and emotional problems which aggravate maternal stress (Peters-Scheffer *et al.* 2013).

A growing body of evidence suggests that shifting can be trained (Minear & Shah 2008; Karbach & Kray 2009; Soveri *et al.* 2013). Persicke *et al.* (2013) successfully taught children with autism how to attend to stimuli with socially relevant features through the use of behavioural teaching procedures in home settings. Their training included rules, modelling, role playing and specific feedback across multiple exemplars. The study mainly focused on visual shifting attention that is a sub-mechanism of set-shifting ability. De Vries *et al.* (2014) also explored set shifting through a computerised training (Brain game Brian) and investigated the effects of the intervention on working memory (WM) and flexibility – as two components of executive function – in children with autism. Results of this research showed that the effect of WM training exceeded that of the flexibility training and the children who received the flexibility training improved just as much as children that received the placebo training. This may occur due to the various tasks in WM part versus few tasks in flexibility part. Hence, although the computerised flexibility training was effective to some extent for children with ASD, the experiment did not focus exclusively on set-shifting training, and cognitive flexibility as one component of shifting was trained. Moreover, there was a large gap in terms of cognitive flexibility between the research setting and daily life, a fact which undermined the generalisability of the intervention. The researchers concluded that a cognitive behavioural therapy may be more effective for enhancing cognitive flexibility (Kenworthy *et al.* 2014).

Aiming to enhance the flexibility via cognitive behavioural therapy approach, Kenworthy *et al.* (2014) used an executive function intervention, called unstuck and on target (UOT), in order to improve the insistence on sameness, flexibility, goal setting and planning in children with ASD. In this study, UOT and social skills intervention were compared. Findings showed significant improvement in mainstream flexibility-related classroom behaviours, including making transitions, conformity to rules and instructions and getting unstuck in school that was greater than the social skills intervention. In fact, UOT intervention manipulated various cognitive variables such as planning, flexibility and problem solving simultaneously; so it was not possible to evaluate and measure the pure changes in flexibility. This UOT training worked on social and behavioural consequences of cognitive flexibility regardless of whether these derive from set shifting as a cognitive function. It remains unknown if the learned ability or other possible outcomes of set-shifting impairment can be extended to everyday life activities.

Given the importance of cognitive flexibility in daily life, Farrelly and Mace (2015) developed an intervention in order to enhance the cognitive flexibility in a group of 20 adolescent boys with ASD aged 11–13. First two sessions were focused on social aspects of flexibility like flexible thinking and the related social situations. In the third session, Stroop Test and Wisconsin Card Sorting Test

(WCST) were used to capture the cognitive aspects of flexibility. The intervention program helped improve high levels of cognitive skills (e.g. flexible thinking and planning) in adolescents with ASD. So it was limited to a specific age group with a high cognitive level. On the other hand, due to lack of follow-up for the intervention sessions, the results cannot be generalised to other situations or relevant skills.

In all, while many of studies underpin set-shifting deficits and implications in children with autism, none of them have exclusively focused on interventions targeting set-shifting enhancement in ASD (De Vries *et al.* 2014). In addition, no study has addressed preschool children despite the fact that many studies have emphasised the importance of early interventions in ASD (Matson & Konst 2014). Using computer-based intervention can restrict intervention results to experimental setting, reducing the generalisability of the learned skills to daily life. On the other hand, in interventions, such as cognitive behavioural therapy, that do not target the core problem (shifting deficit), the learned skills will not apply to the larger problems. In this study, therefore, an intervention was developed in order to improve the set shifting, and the possible effects were investigated in a group of ASDs in a non-controlled pilot study as intervention was newly designed.

Method

Participation

A total of 110 children with autism were screened for the following inclusion criteria: (1) being diagnosed with high-functioning autism according to the Diagnostic and Statistical Manual of Mental Disorders-IV by a multidisciplinary team specialising in ASD; (2) aged 5–7 years old; (3) not suffering from seizure or comorbid disorders; and (4) no previous training in shifting attention, flexibility or other cognitive-based interventions. During the intervention, all children were treated by home-based applied behaviour analysis (ABA) but were restricted by learning ability which is related to set shifting or its dependent variables. A total of 24 children met the inclusion criteria. During the experiment, 11 children could not participate or continue the training. Therefore, the analysis was performed on a sample with 13 children (mean age = 6.2, IQ above 80, 11 boys and 2 girls) (Fig. 1).

Measurement

Cognitive flexibility

Wisconsin Card Sorting Test (WCST; Berg, 1948, Heaton, 1993) has been used to measure set shifting in children with autism (Robinson *et al.* 2009; Soveri *et al.* 2013; Visser *et al.* 2014) and is characterised by good internal consistency and validity (Shahgholian *et al.* 2011). In this study, the Modified Card Sorting Test (Nelson, 1976; Cianchetti *et al.* 2007) was employed. The tasks require the subjects to sort cards according to one of three categories: colour, shape or number. In Modified Card Sorting Test, the participant is informed about accuracy but is unaware of the scoring principle. Then, six consecutive correct responses are required to form a category. Perseveration error score is used as the outcome measure (Barnard *et al.* 2008; Shahgholian *et al.* 2011).

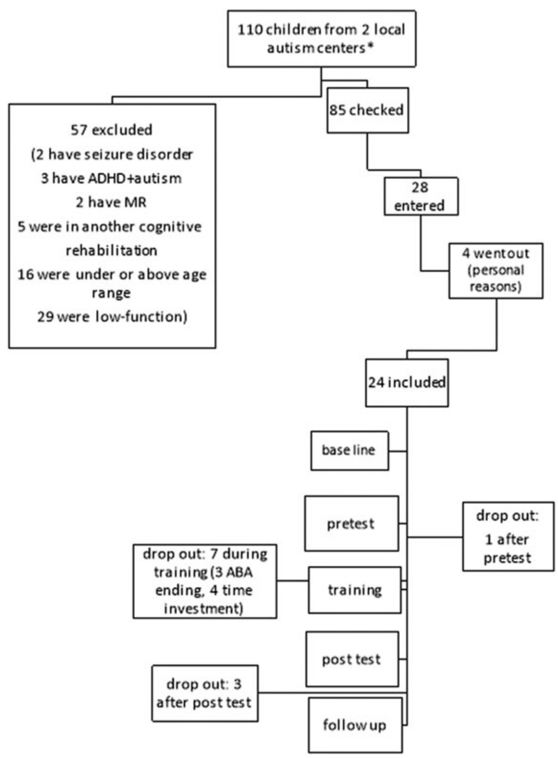

Figure 1. Flow chart of subjects inclusion across the study.

Bender Visual Motor Gestalt Test (Lauretta Bender, 1938) is a psychological test that assesses the visual–motor functioning, developmental disorders and neurological impairments in children aged 3 or older and adults with high consistency and validity (Poursharifi, Gharamaleki, Alizadeh, Rakhshan, 1996; Bahrami, Kiamanesh, Keshavarzian, 2013). This includes nine figures that should be copied onto a paper. Here, the perseveration errors, regarded as evaluation criteria, are measurable in three out of nine figures, following Koppitz's scoring system. Perseveration error occurs when features or stimuli of a preceding figure are inappropriately substituted in the new figure or when a figure is continuously redrawn beyond the limits called for by the stimulus.

Here, two distinct tests with different features were considered along the training task in order to control the possible practice effect(s). However, previous research suggest that the WCST is suitable for repeated administrations (Basso *et al.* 2001).

Behaviour flexibility

Behavioural Flexibility Rating Scale-Revised version (BFRS-R; Green *et al.* 2007) (16 items, 4-point Likert scale) has good intra-rater and inter-rater reliability of the total scale and an excellent internal consistency (Peters-Scheffer *et al.* 2008). The total score represents the outcome measure. Higher scores indicate more inflexible behaviours.

Autism symptoms

Gilliam Autism Rating Scale (GARS; Gilliam, 1995) (34 items, 4-point Likert scale) has good reliability and validity (Ahmadi *et al.* 2011). Total standard score and three main subscale raw scores were outcome measures. Lower scores indicate fewer symptoms.

Autism Treatment Evaluation Checklist (ATEC; Rimland & Edelson 2000) (four sections, 77 items) has satisfactory reliability and validity (Pouretemad & Khoshabi, 2005; Geier, Kern & Geier, 2013). The outcome measures were obtained by adding the four subscales scores. *Higher scores indicate fewer problems.*

Procedure

Program design

Set-shifting improvement tasks (SSIT). In this study, a computer game was developed in order to enhance set-shifting ability. Home-based tasks were given to mother and child so that the learned abilities can be extended to daily life because it is so important in teaching autistic children (Hetzroni & Tannous 2004; Whalen *et al.* 2006; Ramdoss *et al.* 2012). One of the main reasons in using computer is that not only it encourages children to learn but it also provides a consistent and predictable environment critical for individuals with ASD (Battocchi *et al.* 2009).

Computer game

In constructing this game, the available games for cognitive shifting were investigated. Then, possible features of appropriate game were extracted according to opinions of cognitive specialists. One of the best games that are close to features considered here is Disillusion, a puzzle game that aims to reinforce flexibility (www.lumosity.com). Using the template of disillusion, a new game was designed in line with present research goals. It was run for five children with high functioning autism in order to ensure its practicality. Then, some experts in computer games and programming were consulted. After that, a prototype was sent to a game developer company.

The basic version of the game was created a few months later due to the characteristics of children and related considerations such as age, cognitive level and their disorders. Then, the comments of one director of an autism centre, four experts in working with autistic children, five teachers and one expert of clinical neuropsychology were reviewed. Eventually, the basic version of the game was performed by five other children with high-functioning autism. Game bugs and problems were fixed and the final version of the game was prepared after four reviews (Fig. 2).

Home-based tasks

As mentioned in the previous studies, children with autism have difficulty shifting and dealing with some situations and changes in their daily activities (Green

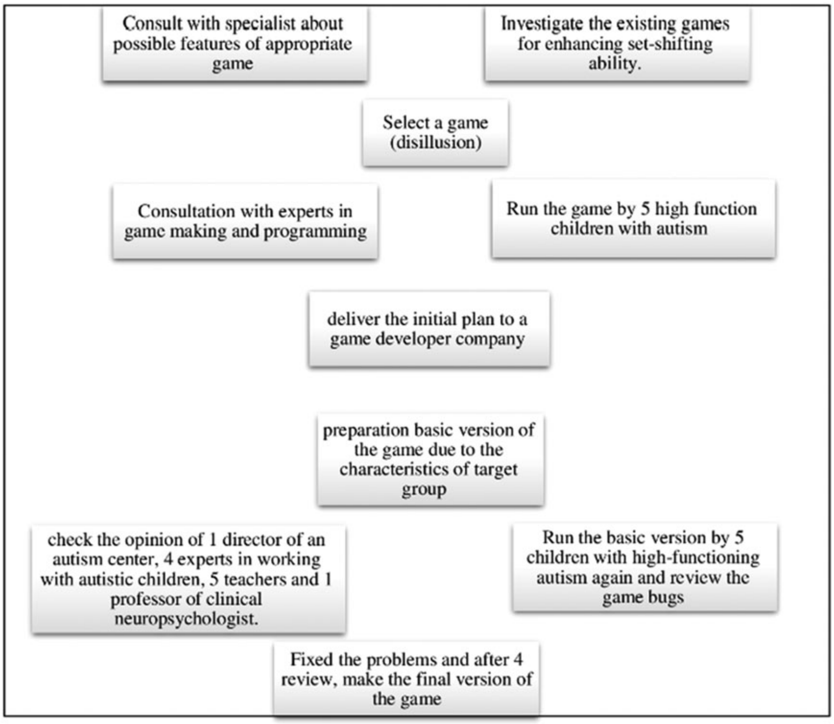

Figure 2. Computer game making procedure.

et al. 2007; Ollington 2012). For instance, rejection changes in family routines, difficulty playing with various toys, objects displacement, wearing new clothes and eating variety of foods are some of the situations which pose many problem for families. In order to resolve these issues, the main goal in this part is to convince the child to frequently shift between various daily activities and to adapt to new conditions. The activities have to be chosen based on child's interests, needs (based on chorological age) and favourite activities with which the child engages as a restricted behaviour. Hence, children, aided by mothers, try to rapidly shift between different activities during a day.

About the possible effects

Due to the small sample size in this study, a *one-group* quasi-experimental design with *pretest–posttest* was employed. For those variables, such as autism symptoms, which can be affected by background treatment (ABA), a second pretest (baseline) was added prior to the intervention in order to help provide evidence that can be used to refute the phenomenon of regression to the mean and confounding as alternative explanations for any observed association between the intervention and the posttest outcome.

After initially explaining the intervention process and the possible effects to parents, testimonials were assigned by parents. Because one of the main goals of this study was to investigate the effect of intervention on autism symptoms, the effect was evaluated 1 month before the intervention as a baseline. In order to obtain a pretest measure, all participants completed the assessment tasks individually under experimental conditions (i.e. in a quiet clinical room where the disturbing stimuli were minimised).

Before intervention begins, mothers and children received similar basic training instructions separately so that no ambiguity remained regarding the training. Both parts of training (computer and home-based tasks) began at home. Children received five 15-min home-based interventions and four 15-min computer game interventions per day. During the 2 months of training, parents were contacted weekly about their child's progress and checked by biweekly structured reports. During the weekly telephone calls or chats, questions, problems and barriers were discussed and the progress in the training, possible reward systems for the child and time of weekly training were also investigated. After the training, all reports were collected and game information was retrieved from the automatically saved log files. Second evaluation was conducted a month after the intervention and stability of the results was assessed (Fig. 3).

Ethical considerations

Before the intervention begins, the main research goals, the optional nature of presence in research and data confidentiality were explained to all parents. During the intervention, the results of each section were reported to parents and the overall results were described at the end of the training.

Intervention

The intervention program process is presented in detail in Table 1.

About the computer game

The computer game used in this study is basically a puzzle which is solved by adapting the mind to some changing rules. Puzzle pieces could be matched via two dimensions: colour and shape. For instance, when the sample piece is black, matching must follow colour, and when it is white, matching must follow shape. Colour and shape change regularly. There are three hardship levels (easy, medium and hard) in the

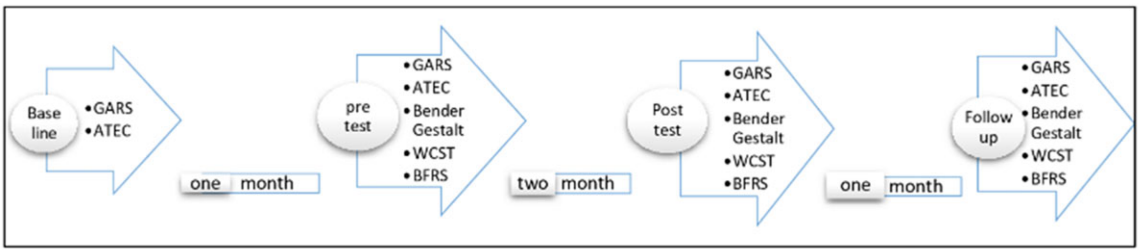

Figure 3. Evaluation procedure. ATEC, Autism Treatment Evaluation Checklist; BFRS, Behavioural Flexibility Rating Scale; GARS, Gilliam Autism Rating Scale; WCST, Wisconsin Card Sorting Test. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 1 Intervention (set-shifting improvement tasks) program

Base line		
Pretest		
Week	Home-based tasks	Computer game
One	Shift between *favourite activities* (FA)	Play *easy* levels
Two		
Checked structured reports		
Three	Shift between FA and *required activities* (RA)	Play *medium* levels
	Use *at least one required activity* during each 15 min	
Four	Shift between FA and RA	
	Use at least two required activity during each 15 min	
Five	Shift between FA + RA + *stereotypic activities* (SA)	Play medium and *hard* levels
Six	Use *at least one required activity* during each 15 min	
Seven	Shift between FA + RA + SA activities	Play medium and hard levels
Eight	*Use at least two stereotyped activity* during each 15 min	*At least one hard level during each 15 min*
Posttest		
Follow-up		

game. The degree of difficulty is defined by size of puzzles, the number of colours and shapes of puzzles and time limitation. In this study, children received stickers and a small weekly gift (already given to mothers) after each level is complete so that they become motivated (Fig. 4).

Home-based task

At first, mothers provided a list of favourite activities of their children. Then, two further lists of activities were added: one including those activities each child needs to do according to their chorological age and also a list of repetitive and restricted interests or behaviours. Then, the mother should try to quickly shift the child between activities (every 3 min in 15 min). Initially, children switched between favourite activities, and then they were required to shift between the activities which were more difficult to change; that is, between interesting or uninteresting activities (Table 1). Meanwhile, the mother should try to stand against child's resistance and encourage the child to correct changes by some gifts or other means to encourage the child and begin with favourite activities which are easy to shift between them and then gradually add other activities to the program, while using gifts as a motivation to advance the program.

Intervention fidelity

Mother's reports were checked on a biweekly basis. In each weekly telephone call or chat, mothers were required to hand over sample videos of the task's implementation, which were sent via social networks (Telegram or WhatsApp).

All questionnaires were conducted under the full supervision of the research team.

Results

Based on the descriptive data, significant mean differences were observed after the intervention in cognitive and behaviour flexibility and autism symptoms as well (Table 2). Thus, a repeated measures analysis of variance (ANOVA) was used to determine the effect of intervention on the main variables (cognitive and behaviour flexibility) over intervention time (Table 3).

Cognitive flexibility

A significant change in perseveration error was observed in Bender Gestalt ($F_{1.3,16.5} = 66.69$, $P < 0.01$, $\eta_p^2 = 0.84$) and WCST ($F_{1.4,16.9} = 83.68$, $P < 0.01$, $\eta_p^2 = 0.87$) as a result of the intervention. *Post hoc* analyses (after the Bonferroni correction) showed a significant difference between pre-training

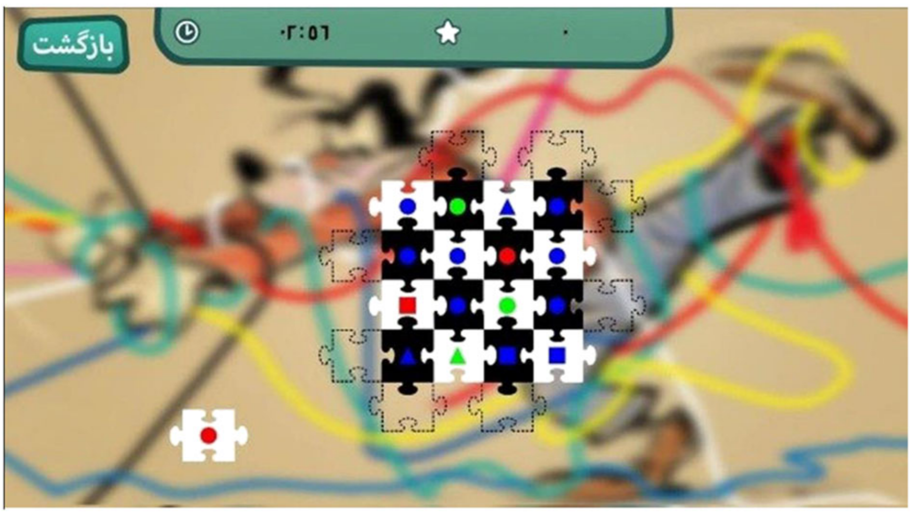

Figure 4. One of the main page of the computer game. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 2 Mean (M) and standard deviations (SD) of outcome measures in four evaluation stages

Measure	Baseline mean (SD)	Pretest mean (SD)	Posttest mean (SD)	Follow up mean (SD)
BFRS-R	-	23.61 (9.90)	15.84 (9.29)	14 (7.63)
Preservation error in Bender Gestalt	-	2.69 (0.63)	0.69 (9.29)	0.84 (0.8)
Preservation error in WCST	-	12.61 (2.84)	4.15 (9.29)	3.23 (2.27)
Total scores of GARS	78.53 (11.42)	75.92 (10.53)	66.92 (9.29)	67.38 (11.72)
Total scores of ATEC	112.15 (17.45)	118 (16.67)	130.61 (11.47)	134.61 (9.43)
RRB in GARS	7.3 (3.42)	7.15 (3.31)	4 (9.29)	4.23 (1.64)
Communication in GARS	15.84 (7.04)	13.08 (6.39)	8 (4.47)	7.23 (4.3)
Social interaction in GARS	17 (6.57)	13.85 (6.01)	8.69 (4.82)	7.46 (4.52)

ATEC, Autism Treatment Evaluation Checklist; BFRS-R, Behavioural Flexibility Rating Scale-Revised version; GARS, Gilliam Autism Rating Scale; WCST, Wisconsin Card Sorting Test; RRB, restricted and repetitive behaviour.

Table 3 Effect of intervention in WCST, Bender Gestalt, GARS (total and subscale), and ATEC over the time

Measure	*F*	*P*	*H*
BFRS-R	45.89	0.0001	0.79
Preservation error in Bender Gestalt	66.69	0.0001	0.84
Preservation error in WCST	83.68	0.0001	0.87
Total scores of GARS	11.69	0.001	0.49
Total scores of ATEC	18.98	0.0001	0.61
RRB in GARS	10.197 **2.66**	0.006 **0.179**	0.45 **0.85**
Communication in GARS	16.62	0.0001	0.58
Social interaction in GARS	20.82	0.0001	0.63

ATEC, Autism Treatment Evaluation Checklist; BFRS-R, Behavioural Flexibility Rating Scale-Revised version; GARS, Gilliam Autism Rating Scale; WCST, Wisconsin Card Sorting Test; RRB, restricted and repetitive behaviour

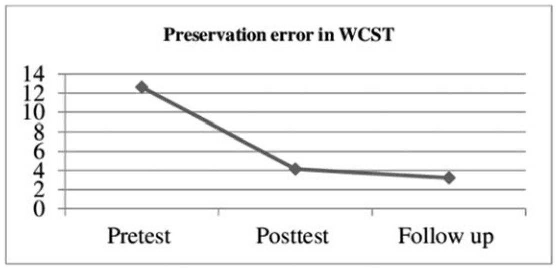

Figure 5. Perseveration error WCST in three training condition. WCST, Wisconsin Card Sorting Test.

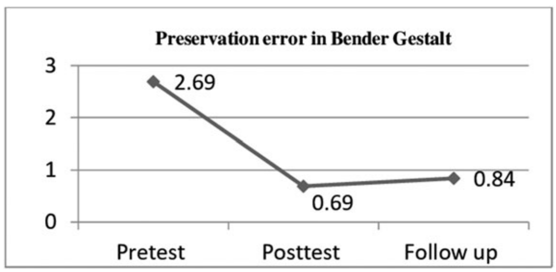

Figure 6. Perseveration error in Bender Gestalt in three training condition.

and post-training in both of these indicators (WCST: $MD_{1,2}$ = 8.46, $P > 0.0001$; Bender: $MD_{1,2}$ = 2, $P > 0.0001$). Perseveration error reduction in WCST continued after the training ($MD_{2,3}$ = 0.92, 0.08, NS) whereas it did not continue in Bender Gestalt ($MD_{2,3}$ = −0.15, 0.33, NS) (Figs 5 and 6).

Behaviour flexibility

Results showed a significant impact of training on BFRS-R with a large effect size ($F_{1.84,22.1}$ = 45.89, $P < 0.01$, $\eta_p^2 = 0.79$). A significant difference in BFRS-R was observed between pre-training and post-training ($MD_{1,2}$ = 7.76, P = 0.0001) whereas no significant difference was observed between post-training and follow-up in spite of score reduction after the training ($MD_{2,3}$ = 1.84, P = 0.08) (Fig. 7).

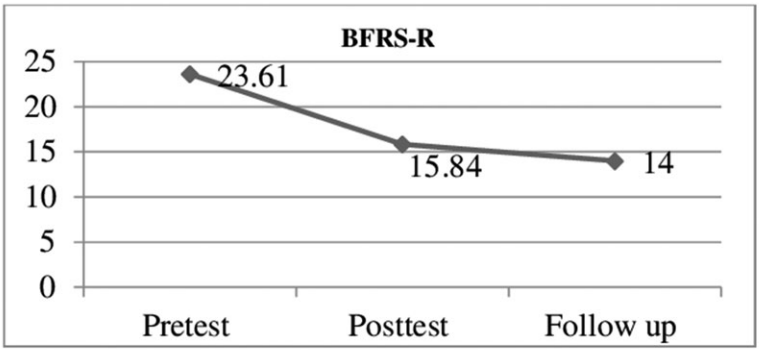

Figure 7. Total scores of BFSR-R in three training condition. BFRS-R, Behavioural Flexibility Rating Scale-Revised version.

Autism symptoms

Initially, a repeated measure ANOVAs was conducted to test whether the autism symptoms differed across the four intervention conditions. Because the background treatment (ABA) can affect autism symptoms, baseline data were useful in determining the possible effect of the intervention (the study is a non-controlled study). Second, an additional multivariate analysis of variance was applied in order to estimate three GARS subscales (Table 3).

A repeated measure ANOVA with a Greenhouse–Geisser correction determined that total scores of GARS ($F_{1.8,21.6} = 11.69$, $P < 0.001$, $\eta_p^3 = 0.49$) and ATEC ($F_{1.4,16.9} = 11.69$, $P < 0.001$, $\eta_p^3 = 0.61$) differed significantly between time points. *Post hoc* analysis revealed a significant increase in both GARS and ATEC between pre-training and post-training, a difference that continued into follow-up only in ATEC (ATEC: $MD_{3,4} = -4$, 0.084; GARS: $MD_{3,4} = -0.46$, 0.83). Moreover, a significant mean difference was observed between baseline pretest and pretest–posttest (GARS: $MD_{1,2} = 2.6$, 0.009 vs. $MD_{2,3} = 9$, 0.006; ATEC: $MD_{1,2} = -5.84$, 0.001 vs. $MD_{2,3} = -12.61$, 0.004) (Figs 8 and 9).

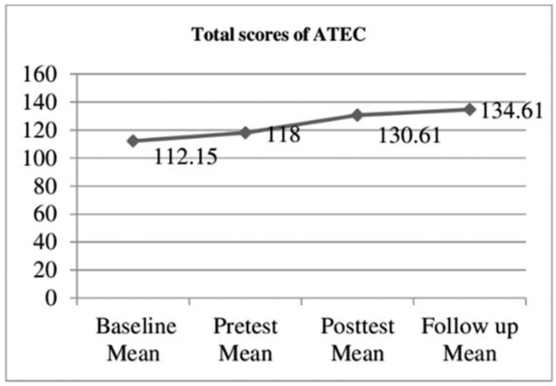

Figure 8. Total scores of ATEC in four training condition. ATEC, Autism Treatment Evaluation Checklist.

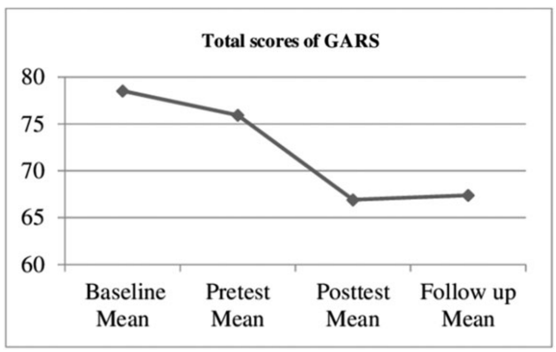

Figure 9. Total scores of GARS in four training condition. GARS, Gilliam Autism Rating Scale.

Second, a one-way multivariate analysis of variance was applied, and it demonstrated a multivariate main effect for three subscales of GARS ($F_{9,4} = 2.66$, $P < 0.17$; Wilk's $\Lambda = 0.14$, partial, $\eta_p^3 = 0.85$). Given the significance of the overall test, the univariate main effects were examined. Significant univariate main effects were observed with medium effect size in restricted and repetitive behaviours ($F_{df=2} = 10.19$, $P < 0.01$, $\eta_p^2 = 0.45$), communication ($F_{df=2} = 16.62$, $P < 0.01$, $\eta_p^2 = 0.58$) and social interaction ($F_{df=2} = 20.82$, $P < 0.01$, $\eta_p^2 = 0.63$), all of which were also improved significantly with medium effect size, respectively. *Post hoc* analysis revealed a significant difference in communication ($MD_{1,2}$ = 2.76, 0.03) and social interaction ($MD_{1,2}$ = 3.15, 0.001) in the baseline that was resulted from ABA, while no significant difference was found in repetitive behaviours ($MD_{1,2}$ = 0.15, 0.43). Significant decrease was observed in all subscales after the training ($P < 0.05$) (Fig. 10).

Discussion

Findings demonstrate that all children improved considerably in cognitive and behaviour flexibilities when they were given the SSIT. More specifically, the participants displayed fewer perseveration errors and more flexible behaviour after the training. As predicted, more improvement was observed in cognitive flexibility than in behavioural flexibility after the intervention. It seems that the intervention brought about more changes in the cognitive level as a basic level of intervention because the problems in shifting are considered as cognitive deficits. Given that a cognitive shift was introduced, changes in the behaviour are expected because cognition plays an important role in forming the behaviours (Wilson & Hayes 1997). Therefore, it is possible that changes in observed behaviours are not only due to the direct impact of intervention but also partly due to the cognitive changes.

Most interestingly, improved flexibility lasted for 1 month after the training in both behaviour and cognitive flexibilities. It seems that a cognitive and behavioural change occurred during the intervention and continued after the training. In order to have more generalizable results, both phases of the intervention were conducted with parents engaged in a natural environment, using home-based tasks. Permanent improvement presumably can be attributed to changes in lifestyles. In other words, controlling the inflexible behaviours turns into a routine part of everyday life. Nonetheless, further research conducted over a longer period of time and with more trials is needed to confirm this hypothesis.

This study supports the findings of previous research on enhancing cognitive flexibility in individuals with autism (De Vries *et al.* 2014; Farrelly & Mace 2015). Here, variety and number of tasks and generalising them to daily life activities are probably the main factors that led to changes in flexibility.

Despite the fact that ABA induced improvement in autism symptoms, some changes observed in restricted and repetitive behaviours can be related to the training. Indeed, autism symptoms decreased before the training as a result of ABA (the background treatment); however, this decline was more remarkable after the training. In line with previous studies that associated set-shifting deficit with autism symptoms (Yerys *et al.* 2009; Maes *et al.* 2011; Miller *et al.* 2015), a comprehensive training covering all behavioural and cognitive domains can be effective along with a background treatment, particularly in those sections that are most related to shifting deficits.

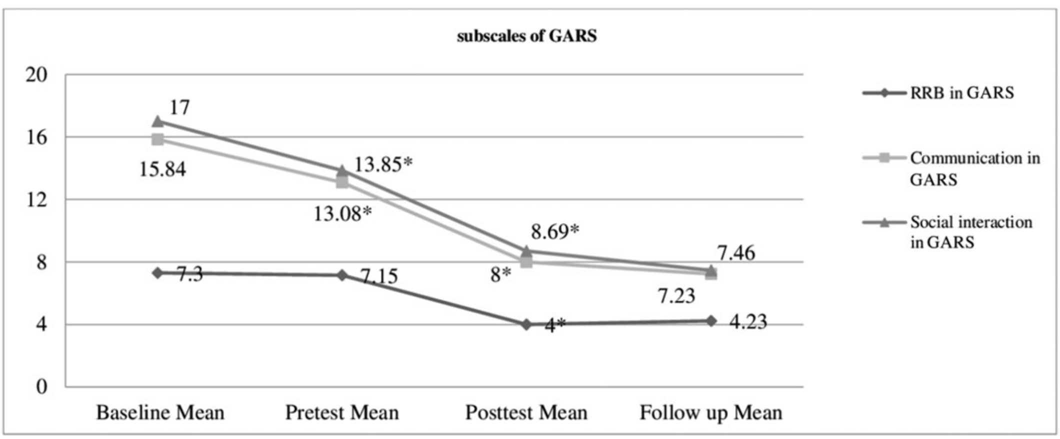

Figure 10. Scores of subscales of GARS in four training condition. GARS, Gilliam Autism Rating Scale; RRB, restricted and repetitive behaviour.

In other words, specific rehabilitations can be more effective on particular cognitive/behavioural deficit than general interventions such as ABA.

Importantly, the abilities learned in an efficient rehabilitation program should be extendable to child's daily life. Those programs that focus exclusively on enhancing the cognitive functions are likely to remain isolated and will not have a significant impact on the cognitive skills needed in everyday life.

In an effective program, such as ABA that is mainly focused on changing the behaviour in all domains, the role of the parents is mostly neglected and the major part of the intervention occurs between children and therapists. One reason is that parents often feel clueless in dealing with their child's behavioural problem which is usually due to the stress they feel and the help they need (Lecavalier *et al.* 2006). One of the principal goals in the program developed in the present study is to engage parents in the intervention by providing them with a clear program and supporting them during the implementation. In this way, they can better encounter the child's problem while being equipped with a solution to manage it.

Our findings indicate potential utility in systems theory. One might argue whether a change in a subsystem can lead to change in the entire system. In other words, SSIT led to improved cognitive and behavioural flexibility in the present study through enhancing the set-shifting ability while altering other symptoms of autism such as communication or social interaction which were not manipulated separately. Future research based on systems theory may answer this question.

This is the first study to explore the effect of set-shifting intervention on dealing with changes in mental process using cognitive rehabilitative computerized tasks embbeded in daily life. This is a pioneering study as it simultaneously uses technology and everyday activities in children with ASD in order to enhance set-shifting ability whereas previous research concern some aspect of behavioural demonstration or few tasks which could not have a significant effect on cognitive bases (De Vries *et al.* 2014; Farrelly & Mace 2015).

One of the most important limitations in this study is the lack of control group. Therefore, changes in main research variables can also be related to other variables not included in the intervention. This is especially true about the variables affected by the background treatment (ABA) such as repetitive behaviours. In such a non-controlled quasi-experimental study, the main problem is that it improves the internal validity at the cost of external validity. There is no way of judging whether the process of pre-testing actually influenced the results because there is no baseline measurement for the groups that remained untreated. Therefore, it is helpful to some extent to take baseline into account.

Including a control group was not possible in the present study due to the small available qualified participation with parents who tend to spend more time with their children and multiple individual difference in high-functioning autism.

Because there is no possibility of distinguishing the effects of SSIT intervention and ABA, there are some doubts about the actual effect of intervention. Furthermore, because it is the first time that such intervention has been developed exclusively for increasing the set-shifting ability in individuals with autism and evaluating its outcomes, it is reasonable to use small experimental group. However, to confirm the effectiveness of the intervention and in order to train children with autism with set shifting exclusively, a control group with larger participation would be obligatory. Moreover, this study included only individuals with high-functioning ASD, future studies should include individuals with a greater variety of IQs, ages and genders. In this regard, our findings also require replications with larger samples and different autism subtypes.

Despite the limitations, the findings of this study are encouraging for rehabilitating the shifting deficits among children with high-function autism, specifically in a context of daily life activities. In future research, it is necessary to evaluate other components of the training package in order to establish a comprehensive package that would include more tasks with more interesting computerised content.

Because our main intent in developing the SSIT package is to improve the set shifting as one of the main executive functions, other functions related to shifting ability such as WM (Miyake *et al.* 2000), inhibition (Friedman & Miyake 2004) and intelligence (Arffa 2007) were not evaluated and can be addressed in future research.

This study involved high-functioning children with autism. Thus, future research should address the low-functioning ASDs with severer symptoms. It will be an important next step to identify the effectiveness of interventions on low-functioning children who may benefit from this training.

Because the generalisability was the underlying reason for simultaneous consideration of two parts of intervention, future research should also consider separating two parts of the interventions (computer and home base) in order to investigate the corresponding effects. Because each part may vary in their contributions to improving the set-shifting ability, the effect of each individual part can show us how much of each section should be applied in order to achieve optimal results.

Overall, the current study indicates that the SSIT intervention can improve cognitive and behavioural flexibilities. Furthermore, repetitive and restricted behaviours were improved during the intervention, and the result remained stable for about 1 month. Finally, this intervention is just an initial step toward the larger target of providing a new tool for clinicians and parents to apply for individuals with ASD as supplement, rather than alternative, to the main treatments such as ABA.

Compliance with Ethical Standards

Ethical approval

All procedures performed in these studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The data presented in this manuscript have not been published elsewhere.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Conflict of Interest

The authors declare no conflict of interest.

References

Ahmadi J., Safari T., Hemmatyan M. & Khalili Z. (2011) Psychometric Evaluation of *Gilliam Autism Rating Scale* in Iran. *Journal of Cognitive and Behavioral Sciences* **1**, 87–104.

Arffa S. (2007) The relationship of intelligence to executive function and non-executive function measures in a sample of average, above average, and gifted youth. *Archives Clinical Neuropsychology* **22**, 969–78.

Barnard L., Muldoon K., Hasan R., O'Brien G. & Stewart M. (2008) Profiling executive dysfunction in adults with autism and comorbid learning disability. *Autism* **12**, 125–41.

Bahrami H., Kiamanesh A. & Keshavarzian M. (2013) The validity and reliability of the development chart of Bender-Gestalt Visual-motor test in children aged 6 to 8.8 years in Karaj. *Psychological Research* **21**, 1–5. [Persian]

Basso M. R., Lowery N., Ghormley C. & Bornstein R. A. (2001) Practice effects on the Wisconsin Card Sorting Test – 64 card version across 12 months. *The Clinical Neuropsychologist* **15**, 471–8.

Battocchi, A., Pianesi, F., Venuti, P., Ben-Sasson, A., & Gal, E. (2009). Collaborative puzzle game: fostering collaboration in children with autistic spectrum disorder (ASD) and with typical development, in Proc. International Conference on Interactive Tabletops and Surfaces, 197–204.

Bender L. (1938) A visual-motor Gestalt test and its clinical use. American Orthopsychiatric Association Monograph Series No. 3. American Orthopsychiatric Association, NY.

Berg E. A. (1948) A simple objective technique for measuring flexibility in thinking. *Journal of General Psychology* **39**, 15–22.

Berger H. J. C., Aerts F. H. T. M., van Spaendonck K. P. M., Cools A. R. & Teunissen J. P. (2003) Central coherence and cognitive shifting in relation to social improvement in high-functioning young adults with autism. *Journal of Clinical and Experimental Neuropsychology* **25**, 502–11.

Bunge S. & Zelazo P. D. (2006) A brain-based account of the development of rule use in childhood. *Current Directions in Psychological Science* **15**, 118–21.

Cepeda N. J., Kramer A. F. & Gonzalez de Sather J. C. (2001) Changes in executive control across the life span: examination of task-switching performance. *Developmental Psychology* **37**, 715–30.

Cianchetti C., Corona S., Foscoliano M., Contu D. & Sannio-Fancello G. (2007) Modified Wisconsin Card Sorting Test (MCST, MWCST): normative data in children 4–13 years old, according to classical and new types of scoring. *The Clinical Neuropsychologist* **21**, 456–78.

De Vries M., Prins P. J. M., Schmand B. A. & Geurts H. M. (2014) Working memory and cognitive flexibility-training for children with an autism spectrum disorder: a randomized controlled trial. *Journal of Child Psychology and Psychiatry* **56**, 566–76.

Farrelly K. & Mace S. (2015) An intervention to enhance cognitive flexibility in boys aged 11-13 with autism spectrum disorder. *Surrey Undergraduate Research Journal (SURJ)* **1**.

Friedman N. P. & Miyake A. (2004) The relations among inhibition and interference cognitive functions: a latent variable analysis. *Journal of Experimental Psychology: General* **133**, 101–35.

Geier D. A., Kern J. K. & Geier M. R. (2013) A comparison of the Autism Treatment Evaluation Checklist (ATEC) and the Childhood Autism Rating Scale (CARS) for the quantitative evaluation of autism. *Journal of Mental Health Research in Intellectual Disabilities* **6**, 255–67.

Geurts H. M., Corbett B. & Solomon M. (2009) The paradox of cognitive flexibility in autism. *Trends in Cognitive Sciences* **13**, 74–82.

Gilliam J.E. (1995) *Gilliam Autism Rating Scale*. Pro-ed, Austin, Texas.

Green V. A., Sigafoos J., O'Reilly M., Pituch K. A., Didden R., Lancioni G. E. *et al.* (2007) Behavioural flexibility in individuals with autism: theory, assessment, and intervention. In: *Autism Research Advances*, pp. 63–77. Nova Science Publishers, Inc., New York ISBN 978-1-60021-523-8.

Heaton R.K., Chelune G.L. Talley J.L., Kay G.G. & Curtis G. (1993) *Wisconsin CardSorting Test manual: Revised and expanded*. Psychological AssessmentResources, Odessa, FL.

Hill E. L. (2004) Executive dysfunction in autism. *Trends in Cognitive Sciences* **8**, 26–32.

Joseph R. M. (2006) Neuropsychological frameworks for understanding autism. *International Review of Psychiatry* **11**, 309–24.

Karbach J. & Kray J. (2009) How useful is executive control training? Age differences in near and far transfer of task-switching training. *Developmental Science* **12**, 978–90.

Kenworthy L., Anthony L. G., Naiman D. Q., Cannon L., Wills M. C., Luong-Tran C. *et al.* (2014) Randomized controlled effectiveness trial of executive function intervention for children on the autism spectrum. *Journal of Child Psychology and Psychiatry* **55**, 274–383.

Lecavalier l., Leone S. & Wiltz J. (2006) The impact of behaviour problems on caregiver stress in young people with autism spectrum disorder. *Journal of Intellectual Disability Research* **50**, 172–83.

Leung R. C. & Zakzanis K. K. (2014) Brief report: cognitive flexibility in autism spectrum disorders: a quantitative review. *Journal of Autism and Developmental Disorders* **44**, 2628–45.

Lopez B. R., Lincoln A. J., Ozonoff S. & Lai Z. (2005) Examining the relationship between executive functions and restricted, repetitive symptoms of autistic disorder. *Journal of Autism and Developmental Disorders* **35**, 445–60.

Maes J. H., Eling P. A., Wezenberg E., Vissers C. T. & Kan C. C. (2011) Attentional set shifting in autism spectrum disorder: differentiating between the role of perseveration, learned irrelevance, and novelty processing. *Journal of Clinical and Experimental Neuropsychology* **33**, 210–17.

Matson J. L. & Konst M. J. (2014) Early intervention for autism: who provides treatment and in what settings. *Research in Autism Spectrum Disorders* **8**, 1585–90.

Memari A. M., Ziaee V., Shayestehfar M., Ghanouni P., Mansournia M. A. & Moshayedi P. (2013) Cognitive flexibility impairments in children with autism spectrum disorders: links to age, gender and child outcomes. *Research in Developmental Disabilities* **34**, 3218–25.

Miller H. L., Ragozzino M. E., Cook E. H., Sweeney J. A. & Mosconi M. W. (2015) Cognitive set shifting deficits and their relationship to repetitive behaviors in autism spectrum disorder. *Journal of Autism and Developmental Disorders* **45**, 805–15.

Minear M. & Shah P. (2008) Training and transfer effects in task switching. *Memory and Cognition* **36**, 1470–1483.

Miyake A., Friedman N. P., Emerson M. J., Witzki A. H., Howerter A. & Wagner T. (2000) The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cognitive Psychology* **41**, 49–100.

Nelson H. E. (1976) A modified card sorting test sensitive to frontal lobe defects. *Cortex* **12**, 313–24.

Narzisi A., Muratori F., Calderoni S., Fabbro F. & Urgesi C. (2013) Neuropsychological profile in high-functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders* **43**, 1895–909.

Ollington, N.D. (2012). Assessing behavioural flexibility in children with autism spectrum disorder using play-based procedures. BA (Hons) University of Tasmania.

Ozonoff S., Cook I., Coon H., Dawson G., Joseph R. M., Klin A. *et al.* (2004) Performance on Cambridge neuropsychological test automated battery subtests sensitive to frontal lobe function in people with autistic disorder: evidence from the collaborative programs of excellence in autism network. *Journal of Autism and Developmental Disorders* **34**, 139–50.

Persicke A., Clair M. S., Tarbox T., Najdowski A., Ranick J., Yu Y. *et al*. (2013) Teaching children with autism to attend to socially relevant stimuli. *Research in Autism Spectrum Disorders* **7**, 1551–7.

Peters-Scheffer N., Didden R., Green V. A., Sigafoos J., Korzilius H., Pituch K. *et al*. (2008) The Behavior Flexibility Rating Scale-Revised (BFRS-R): factor analysis, internal consistency, inter-rater and intra-rater reliability, and convergent validity. *Research in Developmental Disabilities* **29**, 398–407.

Peters-Scheffer N., Didden R., Sigafoos J., Green V. A. & Korzilius H. (2013) Behavioral flexibility in children with autism spectrum disorder and intellectual disability. *Research in Autism Spectrum Disorders* **7**, 699–709.

Poursharifi H., Gharamaleki N., Alizadeh R., Rakhshan & F. (1996) Normalization of Bender gestalt in the Primary Schools of Tabriz. *Journal of Psychological Research* **7**, 30–7. [Persian]

Pouretemad H. & kKhushabiK. (2005) A Research Plan Report of Investigation the Effectiveness of Specific Structural Behavioral Therapy "Autism-Lovaas" on children with autism. The Iranian Research Center of Medical Science.

Prior M. R. & MacMillan M. B. (1973) Maintenance of sameness in children with Kanner's syndrome. *Journal of Autism and Childhood Schizophrenia* **3**, 154–67.

Ramdoss S., Machalicek W., Rispoli M., Mulloy A., Lang R. & O'Reilly M. (2012) Computer-based interventions to improve social and emotional skills in individuals with autism spectrum disorders: a systematic review. *Developmental Neurorehabilitation* **15**, 119–35.

Rimland, B., & Edelson, S.M. (2000). Statistical analysis of autism treatment evaluation check list. Sandiego: Autism Research Institute. www.Autism.com.

Rinehart N. J., Bradshaw J. L., Moss S. A., Brereton A. V. & Tonge B. J. (2001) A deficit in shifting attention present in high-functioning autism but not Asperger's disorder. *SAGE Publications and the National Autistic Society* **5**, 67–80.

Robinson S., Goddard L., Dritschel B., Wisley M. & Howlin P. (2009) Executive functions in children with autism spectrum disorders. *Brain and Cognition* **71**, 362–8.

Rosenthal M., Wallace G. L., Lawson R., Wills M. C., Dixon E., Yerys B. E. *et al*. (2013) Impairments in real-world executive function increase from childhood to adolescence in autism spectrum disorders. *Neuropsychology* **27**, 13–18.

Shahgholian M., Azad Fallah P., Fathi Ashtiani A. & Khodadadi M. (2011) Design software version of the Wisconsin Card Sorting Test: theoretical foundations, construction, psychometric properties. *Journal of Clinical Psychology Studies* **4**, 112–32.

Shahrokhi H., MahmoodAliloo M., Mehdizadeh Fanid L., Amiri S. & Yadegari N. (2012) Attentional capacities of children with autism spectrum disorder. *Neuropsychiatrie de l Enfance et de l Adolescence* **60**(5). https://doi.org/S208.10.1016/j.neurenf.2012.04.433.

Smithson P. E., Kenworthy L., Wills M. C., Jarrett M., Atmore K. & Yerys B. E. (2013) Real world executive control impairments in preschoolers with autism spectrum disorders. *Journal of Autism and Developmental Disorders* **43**, 1967–75.

South M., Ozonoff S. & McMahon W. M. (2005) Repetitive behavior profiles in Asperger syndrome and high-functioning autism. *Journal of Autism and Developmental Disorders* **35**, 145–58.

South M., Ozonoff S. & McMahon W. M. (2007) The relationship between executive functioning, central coherence, and repetitive behaviors in the high-functioning autism spectrum. *Autism* **11**, 437–51.

Soveri A., Waris O. & Laine M. (2013) Set shifting training with categorization tasks. *PLoS ONE* **8**(12):e81693. https://doi.org/10.1371/journal.pone.0081693.

Hetzroni O. E. & Tannous J. (2004) Effects of a computer-based intervention program on the communicative functions of children with autism. *Journal of Autism and Developmental Disorders* **34**, 95–113.

Turner M. (1999) Annotation: repetitive behaviour in autism: a review of psychological research. *Journal of Child Psychology and Psychiatry* **40**, 839–49.

Visser E. M., Berger H. J., Prins J. B., Van Schrojenstein Lantman-De Valk H. M. & Teunisse J. P. (2014) Shifting impairment and aggression in intellectual disability and autism spectrum disorder. *Research in Developmental Disabilities* **35**, 37–2147.

Whalen C., Liden L., Ingersoll B., Dallaire E. & Liden S. (2006) Behavioral improvements associated with computer-assisted instruction for children with developmental disabilities. *Journal of Speech and Language Pathology – Applied Behavior Analysis* **1**, 11–26.

Wilson K. G., Hayes S. C. & Gifford E. V. (1997) Cognition in behavior therapy: agreements and differences. *Journal of Behavior Therapy and Experimental Psychiatry* **28**, 53–63.

Yerys B. E., Wallace G. L., Harrison B., Celano M. J., Giedd J. N. & Kenworthy L. E. (2009) Reversal shifting deficits on the intradimensional/extradimensional shift test correlate with repetitive behaviors. *SAGE Publications and The National Autistic Society* **13**, 523–38.

Yerys B. E., Antezana L., Weinblatt R., Jankowski K. F., Strang J., Vaidya C. J. *et al*. (2015) Neural correlates of set-shifting in children with autism. *Autism Research* **8**, 386–97.

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