Running Head: Switching Attention in Asperger's Disorder

Individuals with Asperger's Disorder Exhibit Difficulty in Switching Attention from a Local Level to a Global Level

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Abstract

The purpose of the present study was to determine whether individuals with Asperger's disorder exhibit difficulty in switching attention from a local level to a global level. Eleven participants with Asperger's disorder and 11 age- and gender-matched healthy controls performed a level-repetition switching task using Navon-type hierarchical stimuli. In both groups, level-repetition was beneficial at both levels. Furthermore, individuals with Asperger's disorder exhibited difficulty in switching attention from a local level to a global level compared to control individuals. These findings suggested that there is a problem with the inhibitory mechanism that influences the output of enhanced local visual processing in Asperger's disorder.

Keywords: Asperger's disorder, level-repetition, switching, global, local

Autism spectrum disorder (ASD) encompasses several different disorders that are characterized by significant social deficits, repetitive behaviors, and restricted interests (American Psychiatric Association 2000). ASD includes prototypic autistic disorder, Asperger’s disorder, and pervasive developmental disorder-not otherwise specified (Akshoomoff 2005; DiCicco-Bloom et al. 2006). As demonstrated in the embedded figures task and the block design task, individuals with ASD exhibit strong local processing compared to typically developing (TD) individuals (Shah and Frith 1983, 1993; Jolliffe and Baron-Cohen 1997).

The superior local processing by individuals with ASD in visual tasks has been explained by two hypotheses. The “weak coherence” hypothesis stresses a detail-focused processing style (Happé and Frith 2006). The latest refinements of the weak coherence hypothesis emphasize the notion of reduced global integration of information (Happé and Booth 2008). The “enhanced perceptual functioning” hypothesis proposed that, in ASD, low-level perceptual processing was both superior and the default setting of perception (Mottron et al. 2006). The enhanced perceptual functioning hypothesis emphasizes that individuals with ASD do not have deficits in the processing of global aspects of information, but rather are characterized by enhanced low-level perceptual processing and are more locally oriented than non-ASD individuals.

The local processing in ASD has been investigated through the use of global/local tasks with Navon-type hierarchical stimuli (e.g., a large letter composed of small letters, Navon 1977). However, the results of previous studies using hierarchical stimuli have not always been consistent with regard to their findings on local processing (e.g., Wang et al. 2007). Plaisted et al. (1999) found that individuals with ASD showed a local advantage effect (more errors were made at the global level than at the local level) for an incongruent stimulus (Fig. 1. No. 3; the global and local levels are incongruent) in a divided-attention task. In the divided-attention task, the participant is required to identify a target stimulus (A) presented as either a large stimulus or small stimuli (Fig. 1). Thus, participants must attend to both the local level and the global level in each trial. Furthermore, participants must switch their attention between a global level and a local level with incongruent stimuli (Fig. 1. Nos. 3 and 5). Individuals with ASD may show enhanced local processing in the absence of priming and/or a deficit in switching attention to the global level, since participants were not told what level of attention they should focus on in anticipation of a stimulus.

Fig. 1 about here

Navon-type hierarchical stimuli seem to be effective for capturing local processing when used in open-ended tasks such as the divided-attention task (Happé and Frith 2006). This task is associated with an executive function. Rinehart et al. (2001) reported that individuals with ASD showed a slower response to a global target that appeared after a local target, compared to TD individuals. Thus, individuals with ASD exhibited difficulty in switching attention from a local level to a global level. In this experimental task, the participant must inhibit the global or local target, as appropriate, when they switch their attention to another level. It may be difficult for individuals with ASD to both switch their attention and inhibit the local target.

Incongruent Navon-type hierarchical stimuli incorporate a high level of interference between a global level and a local level. Rinehart et al. (2000) indicated that reaction times (RTs) in response to global-level stimuli are more strongly affected by incongruent stimuli at the local level in ASD. This study suggested that a local target disturbs the switching of attention from a local level to a global level; i.e., individuals with ASD showed local interference with a global target. When there is competition between the responses to a global target and a local target in incongruent stimuli, it may be difficult for individuals with ASD to inhibit the output of local visual processing in the absence of priming by instruction (Plaisted et al. 1999). In particular, executive dysfunction such as in switching and inhibition is associated with a problem in the cognitive flexibility. This cognitive ability has been examined with the use of the Wisconsin card sorting task, in which participants are required to inhibit a previous sorting rule and discover a new one (e.g., Geurts et al. 2009).

Previous studies using the divided-attention task with Navon-type hierarchical stimuli did not necessarily show local processing in individuals with ASD (Mottron et al. 2003; Ozonoff et al. 1994). There are at least three possible explanations for the inconsistent results in previous studies. First, the visual-perceptual processing between a global level and a local level may be sensitive to variations such as the quality of the information present at the global and local levels (goodness of form), or the number and relative sizes of the local elements (see Kimchi 1992, for a review). Second, difficulty in switching attention from a local level to a global level in ASD may be due to an inability to broaden the spread of visual attention towards a target in the periphery (Mann and Walker 2003). This dysfunction may be related to the executive dysfunction. Finally, difficulty in switching to a global target may be the result of a cognitive style characterized by detail-focused processing, such as in “weak coherence” (Happé and Frith 2006), or the superiority of enhanced low-level perceptual processing, such as in the "enhanced perceptual functioning" account (Mottron et al. 2006). The local processing may be related to a selective local inhibitory deficit. Most previous studies did not sufficiently examine these influences. Thus, previous studies have not clarified why individuals with ASD only exhibit difficulty in switching attention from a local level to a global level.

The purpose of the present study was to determine whether individuals with Asperger's disorder exhibit difficulty in switching attention. To achieve this goal, we used a level-repetition procedure that requires participants to enhance local or global visual-perceptual processing. Furthermore, the goodness of form of a global configuration and a local element were carefully considered. As a novel experimental procedure, we used a level-repetition paradigm that involved switching trials and repetition trials. Hierarchical stimuli used in this paradigm were repeatedly presented at the same level, more than twice in a row, to provide additional focus on a global level or local level. In the level-repetition paradigm, RTs were reduced if the previous trial was at the same hierarchical level, but were increased if the previous trial was at a different level (e.g., Lamb and Yund 1996; Robertson 1996). The most noteworthy point is that the cost of switching is an effective means for capturing the effect of switching attention from a given perceptual level weighted by the level-repetition procedure.

We predicted that individuals with Asperger's disorder would exhibit the benefit of level-repetition at a local level. Due to the difficulty of inhibiting local-level stimuli in individuals with Asperger's disorder, the cost for switching attention from a local to global level is expected to be greater than that for global-to-local switching. If individuals with Asperger's disorder who show mild 'autistic' manifestations exhibit difficulty in switching attention from a local level to a global level, the results in the present study may provide important insights regarding local visual processing in ASD. To our knowledge, this is the first study to investigate the effect of level-repetition on switching using incongruent hierarchical stimuli in individuals with Asperger's disorder.

Methods

Participants

We examined 11 participants with Asperger's disorder (mean age = 31.1, *SD* = 6.13; 8 female, 3 male; mean full-scale IQ = 105, *SD* = 10.7, range 90-122) and 11 age- and gender-matched healthy controls (mean age = 28.3, *SD* = 5.35; 8 female, 3 male), who did not significantly differ in age (t (20) = 1.13, *n.s.*) and had no intellectual disability. All participants were right-handed and had normal or corrected-to-normal vision.

Participants with Asperger's disorder were recruited through the local Mental Health and Welfare Center. All of the participants had participated in a group psychotherapeutic intervention carried out at this center. Since many of the participants in the group intervention program were female, there were more female participants than males in this study.

All diagnoses of Asperger's disorder were established according to the DSM-IV-TR criteria for Asperger's disorder (American Psychiatric Association 2000) based on a series of clinical assessments that included an interview, information from each participant and childhood clinical records (developmental history, child psychiatric and psychological observations, and tests and neurologic investigations). The process used for the differential diagnosis of Asperger's disorder is described below. Clinical psychologists collected information from parents on developmental milestones (including joint attention, social interaction, pretend play and repetitive behaviors, with onset prior to age 3 years) and episodes (e.g., how the individual with Asperger's disorder behaved at kindergarten and school). The differential diagnosis of Asperger's disorder considered verbal communication and verbal development. Information about detailed observations of interactions with people (particularly non-family members) as well as repetitive behaviors, obsessive/compulsive traits, and stereotyped behaviors, was also provided by other professionals (teachers, social workers, etc.). For the assessment of IQ and neuropsychological characteristics, all participants with Asperger's disorder completed a Japanese version of the Wechsler Adult Intelligence Scales-third edition (WAIS-III). An expert psychiatrist interviewed each participant in the Asperger's disorder group at least three times (each on a separate day) before the final diagnosis was made. None of the participants in the Asperger's disorder group had other developmental or psychiatric disorders. Three of the 11 participants with Asperger's disorder were taking medications, but were free of these medications at the time of testing.

Control participants were recruited from among undergraduate and graduate university students. The IQ scores were not available for some participants in the control group who had previously learned about IQ assessments. They were required to be in good physical health, and were free of regular medication usage. An additional exclusion criterion for the healthy control group was a history of psychiatric disease in themselves or a family history of axis I disorder in their first-degree relatives.

Written informed consent was obtained for each participant before the test, according to the Declaration of Helsinki. The study protocol was approved in advance by the ethics committee.

Apparatus and stimuli

This experiment was conducted in a soundproof chamber, to reduce distractions, using E-Prime software and a Serial Response-Box (Psychology Software Tools, Inc). In each trial, a hierarchical stimulus was presented on a 17-inch computer monitor. The viewing distance for each participant was approximately 57 cm. The hierarchical stimulus was a large digit (global) composed of smaller digits (local). Global 2s and 3s were always composed of local 4s and 5s, whereas global 4s and 5s were always composed of local 2s and 3s. Thus, these were all incongruent stimuli composed of target (2 and 3) and distractor digits (4 and 5). Global stimuli subtended a visual angle of 3.7 in height and 2.5 degrees in width, and local stimuli subtended 0.4 × 0.3 degrees. All stimuli were displayed at the center of the monitor, and were drawn in white on a gray background (see Fig. 2).

Fig. 2 about here

Procedure

The experimental task was a divided-attention task that used a level-repetition procedure (Fig. 2). In the present study, the divided-attention task and stimuli were based on the study by Rinehart et al. (2001), and the level-repetition procedure was based on the study by Wilkinson et al. (2001). A fixation cross appeared for 1000 ms, and the hierarchical stimulus was displayed for 100 ms. Participants were instructed to press the left button when a ‘2’ appeared, and to press the right button when a ‘3’ appeared, regardless of the level (global or local), as quickly and accurately as possible using the forefingers. There were six patterns of repeated-level trials: target repetition occurred either at the global level or local level, and the number of repetitions at the same target level was two, four, or five. Switching trials were defined as those that occurred between global and local repeated-level trials (see Fig. 2). Thus, in a switching trial, the target level switched from either global-to-local or local-to-global, and this was part of the next repeated-level trial. Participants completed two practice blocks (total 24 repeated-level trials). Further practice was provided on request. After the practice blocks, participants performed eight experimental blocks (total 192 repeated-level trials). Between blocks, they were allowed to rest for some time. A complete session took between 30 and 45 min.

Wilkinson et al. (2001) indicated that the RT taken to identify a target in a changed-level trial following four repeated-level trials was longer than that after two repeated-level trials. However, a changed-level trial following six repeated-level trials did not produce any additional increases beyond the RT with four. To shorten the total experimental time, we used two, four and five repeated-level trials. Although the target identity changed randomly, the hierarchical level at which the target appeared was strictly controlled. The sequence of trials was presented serially on the screen in a pseudorandom order with an equal probability for each target level (local, global), target digit (2, 3), distractor digit (4, 5), and trial condition (number of repetitions, switching).

Statistical Analyses

Error rates and RTs for the response to the preceding stimulus were analyzed in repeated-level trials and switching trials, respectively. These data were subjected to a mixed-design ANOVA. For repeated-level trials, the factors were group (Asperger's disorder group, control group) as the between-subject factor, and target level (global, local) and number of repetitions (two, three, four, five) as within-subject factors. For switching trials, the factors were group (Asperger's disorder group, control group) as a between-subject factor, and switching direction (global to local, local to global) and number of repetitions (two, four, five) as within-subject factors.

To more directly examine the switching-attention operations, we calculated the "switching cost" by subtracting RTs in repeated-level trials from those in switching trials. For example, the switching cost in the global-to-local direction after a four repeated-level trial for a global target was calculated as (RTs for a local target in switching trials) minus (RTs for the fifth global target in five repeated-level trials). We calculated the cost for switching direction after two and four repetitions. Switching costs were statistically analyzed using three-way repeated measures ANOVA: group (Asperger's disorder group, control group) × switching direction (global to local, local to global) × switching cost in repetitions (two, four). In post-hoc tests, multiple comparisons were performed using the Bonferroni test.

Results

Error rate

Table 1 shows the mean error rates for repeated-level trials and switching trials.

With regard to error rates in repeated-level trials, only the number of repetitions had a significant main effect (*F* (3, 60) = 6.96, *p* < .001), and in switching trials only the switching direction had a significant main effect (*F* (1, 20) = 8.98, *p* < .01). There were no other statistically significant effects. There was also no significant difference in the mean of all error rates between the Asperger's disorder group (6.33%, *SD* = 8.4) and the control group (2.57%, *SD* = 1.73) in an independent samples t-test (*t* (20) = 1.45, *p* = .16).

Table 1 about here

Reaction time

With regard to RTs in repeated-level trials, only the number of repetitions had a significant main effect (*F* (3, 60) = 17.69, *p* < .001). The main effects of group and target level were not significant (*F* (1, 20) = 3.74, *p* = .068; *F* (1, 20) = .48, *p* = .50, respectively) (Fig. 3).

With regard to switching trials, the only significant interaction was between the group and switching direction (*F* (1, 20) = 7.76, *p* < .05). Post-hoc comparisons revealed that global-to-local switching generated longer latencies than local-to-global switching in the control group, and especially after two and five repetition-level trials (*F* (1, 20) = 5.62, *p* < .05; *F* (1, 20) =11.19, *p* < .01, respectively). This effect was insignificant for the Asperger's disorder group. None of the main effects or other interactions were significant (Fig. 4).

Fig. 3 and Fig. 4 about here

Switching cost

A three-way ANOVA revealed that there was a significant main effect of switching cost in repetitions (F (1, 20) = 4.45, p < .05). Interestingly, there was a significant interaction between the switching direction and group (F (1, 20) = 6.63, p < .05). Post-hoc comparisons revealed that the switching cost from the local level to the global level in both two and four repeated-level trials was higher for the Asperger's disorder group than for the control group (F (1, 20) = 7.73, p < .05, F (1, 20) = 4.81, p < .05, respectively). In the control group, the switching cost from the global level to the local level was greater than that for switching in the opposite direction in two repeated-level trials (F (1, 20) = 6.59, p < .05), while this difference was not significant in the Asperger's disorder group (two repeated-level trials: F (1, 20) = 3.29, p = .085) (Fig. 5).

Fig. 5 about here

Discussion

We predicted that individuals with Asperger's disorder would exhibit a benefit of level-repetition at a local level and a high cost when switching attention from a local to a global level. Our data yielded two main findings. First, although there were no statistically significant differences in the mean of all error rates between the Asperger's disorder group and the control group, both groups exhibited a benefit of level-repetition at both levels. Second, the Asperger's disorder group exhibited greater costs, in terms of RT, when switching from a local target to a global target compared to the control group. Consequently, individuals with Asperger's disorder exhibited enhanced visual processing at both perceptual levels and difficulty in switching attention from a local level to a global level compared to control individuals. These results replicated the results of a previous study (Rinehart et al. 2001) and constitute evidence of impaired local switching in ASD.

Difficulty in switching attention from a local level to a global level

Based on the error rates observed in this study, both target levels and level-repetition trials and switching trials were accurately detected in both groups. This result is inconsistent with that of Plaisted et al. (1999), who found more errors in the incongruent/global condition. Based on the mean RTs for repeated-level trials, both groups exhibited a benefit of level-repetition at both levels. These results regarding error rates and RTs suggested that visual-perceptual processing in individuals with Asperger's disorder was intact, which is consistent with the "enhanced perceptual functioning" hypothesis (Mottron et al. 2006). In addition, they did not necessarily show executive dysfunction when switching attention, but had difficulty in switching attention in the local-to-global direction. This finding is consistent with a selective deficit in broadening of the spread of visual attention in individuals with ASD (Mann and Walker 2003). These findings also suggested that local processing and global processing involve independent mechanisms (Happé and Booth 2008).

In the control group, RTs in switching from a global target to a local target were significantly longer than those in switching in the opposite direction but there were no significant differences in switching directions in the Asperger's disorder group. In addition, the control group showed greater switching costs upon going from a global level to a local level than when switching in the opposite direction. These results suggest that control individuals showed greater interference from the global level to the local level (global interference) and stronger global processing than individuals with Asperger’s disorder. The findings in individuals with Asperger’s disorder are also reflected in relatively enhanced local processing or attenuated global processing compared to control individuals.

Importantly, the results regarding the switching cost show that the Asperger’s disorder group showed difficulty in switching attention from a local level to a global level compared to the control group. Thus, individuals with Asperger’s disorder showed greater interference in switching from the local level to the global level (local interference). This finding suggested that it was difficult for individuals with Asperger’s disorder to inhibit local visual-perceptual processing that was enhanced by the repetition procedure in the context of competition between the global level and the local level.

Assumed mechanisms of level-repetition and inhibition

In the present study, the switching cost in a four repeated-level trial was greater than that in a two repeated-level trial in both groups. Furthermore, in the control group, the switching cost from the global level to the local level was greater than that for switching in the opposite direction in two repeated-level trials. When the control group continuously attended to global targets, this may have increased the activity of global visual processing that is involved in the processing of global information. In contrast, when the Asperger’s disorder group continuously attended to local targets, this may have increased the activity of local visual processing that is involved in the processing of local elements. Thus, the greater switching cost for each level suggests that control individuals were unable to inhibit target stimuli at the global level, while individuals with Asperger's disorder were unable to inhibit target stimuli at the local level.

The level-repetition effect results from the automatic activation of level-specific neural mechanisms (Lamb et al. 1998). This effect promotes the response to the same level and interferes with the response to a different level. The promotion of the reaction was enhanced by the repetition of an attentional level (Robertson 1996). In the present study, the control group showed low switching costs when they switched attention from a local target to a global target after a two repeated-level trial for a local target. This finding suggests that global processing in control individuals disappeared with attentional weighting in local level-repetitions. The properties of visual processing observed with Navon-type hierarchical stimuli can be explained by the relative levels of local and global visual processing (Plaisted et al. 1999). Local-level priming helped to enhance the saliency of local elements in individuals with Asperger's disorder. As a result, they were unable to filter out information at the local level, which supports the notion of Plaisted et al. (1999) that there is a problem in an inhibitory mechanism that influences the output of local visual processing. The problem with this inhibitory mechanism in individuals with Asperger's disorder may either produce a local bias or weaken a global bias. The notion of a selective local inhibitory deficit caused by enhanced local processing is consistent with the "enhanced perceptual functioning" hypothesis (Mottron et al. 2006), rather than the "weak coherence" hypothesis (Happé and Frith 2006).

Limitations and future research directions

Several methodological limitations should be noted. In the present study, while the participants were matched for both age and gender; both the control and Asperger's groups had more females than males. This bias may affect our ability to generalize our findings. In addition, while the control group had no deficits in mental ability, IQ scores were not available. It is possible that some cognitive abilities may have influenced the switching patterns in the participants. The present study did not examine the development of global processing or local processing in each participant. A recent study on the developmental trajectory of global-local processing showed that individuals with ASD do not transition to a global processing bias, which appears to begin in adolescence in TD individuals (Scherf et al. 2008). Future longitudinal studies on the development of local processing in children with Asperger's disorder and TD children should help to establish the connections between local processing and deficits in the perception of social information. These studies may reveal that the social deficits in ASD underlie a failure to integrate local details into a global entity (Jarrold et al. 2000).

Importantly, the present study cannot directly indicate that the difficulty in switching attention from the local level to the global level is enhanced by repetitions at the local level, due to the absence of no-repetition trials. Thus, although our findings are related to a processing deficit in individuals with Asperger's disorder, we cannot conclude whether the current findings reflect an enhanced local processing bias. Further research using both a cognitive task and observed behavior in individuals with ASD should investigate whether we can establish a relationship with everyday behavior (Geurts et al. 2009). The examination of atypical behaviors (such as repetitive behaviors and restricted interests) or some other unexplored possibilities may be useful for understanding the association between the difficulty in switching attention from a local level to a global level and social deficits, which could in turn provide insight into the development of clinical interventions in individuals with ASD.

Conclusions

In conclusion, individuals with Asperger's disorder and control individuals exhibited the benefit of level-repetition at both global and local levels. Furthermore, individuals with Asperger's disorder showed significantly greater costs (in terms of longer RTs) on switching from a local target to a global target. Consequently, individuals with Asperger's disorder exhibit difficulty in switching attention from a local level to a global level compared to control individuals. These results in individuals with Asperger's disorder who show mild 'autistic' manifestations may provide insight into local visual processing in ASD. This difficulty in switching attention suggested that there is a problem with the inhibitory mechanism that influences the output of enhanced local visual processing. A better understanding of the characteristics of local processing may contribute to clinical interventions in individuals with ASD. It is quite likely that our level-repetition switching task with incongruent hierarchical stimuli facilitated visual processing in each group, and more sensitively revealed a difficulty in switching attention.

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Figure captions

Fig. 1. Stimuli used in the divided-attention task (Plaisted et al. 1999).

Fig. 2. Sequence of the experimental trials. The first repeated-level trial shows a switch after a four repeated-level trial, and the second shows a switch after a two repeated-level trial. Abbreviations: G, global-level target; L, local-level target.

[a] Four repeated-level trial (repetition of four global targets)

[b] Global-to-local switching (switching from the global level to the local level after a four repeated-level trial)

[c] Two repeated-level trial (repetition of two local targets)

[d] Local-to-global switching (switching from the local level to the global level after a two repeated-level trial)

Fig. 3. Mean reaction times for repeated-level trials. Bars indicate the standard error of the mean. Abbreviations: AD, Asperger's disorder.

Fig. 4. Mean reaction times for switching trials. G-L indicates global-to-local switching after repeated-level trials, and L-G indicates local-to-global switching. Two, four and five indicate the number of repetitions in repeated-level trials. Bars indicate the standard error of the mean. Abbreviations: AD, Asperger's disorder. ** $p < .01$, * $p < .05$

Fig. 5. Switching cost for switching trials. G-L indicates global-to-local switching after repeated-level trials, and L-G indicates local-to-global switching. Two and four

indicate the number of repetitions in repeated-level trials. Bars indicate the standard error of the mean. Abbreviations: AD, Asperger's disorder; L, Local target; G, Global target. * $p < .05$

[a] Switching cost of G-L was calculated as (RTs for a local target after repeated-level trials with a global target (two or four)) - (RTs for a global target after three or five repetitions with a global target).

[b] Switching cost of L-G was calculated as (RTs for a global target after repeated-level trials with a local target (two or four)) - (RTs for a local target after three or five repetitions with a local target.

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We would like to thank all of the participants for making this research possible. We would also like to thank Dr. Tsukishima and Dr. Nakano for their help. We are grateful to Ms. Numata, Ms. Watanabe, Ms. Uematsu and Dr. Matsui for their helpful and insightful comments on this article. This study was supported by the Japan Society for the Promotion of Science (no. 23730870).

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Table 1 Mean error rates (percentage) in repeated-level trials and switching trials

	Repeated-level trials								Switching trials					
	Global target				Local target				Two		four		five	
	two	three	four	five	two	three	four	five	G-L	L-G	G-L	L-G	G-L	L-G
AD (*SD*)	5.49 (7.13)	3.88 (5.39)	3.69 (4.64)	1.80 (2.42)	5.49 (7.17)	2.75 (2.96)	2.94 (3.45)	1.42 (2.05)	9.66 (14.22)	8.81 (14.17)	9.09 (11.04)	6.82 (15.74)	12.5 (20.82)	9.94 (15.49)
Control (*SD*)	1.89 (1.79)	0.66 (0.96)	1.33 (1.48)	0.76 (1.33)	1.42 (1.94)	1.33 (1.33)	1.70 (1.82)	0.66 (1.26)	5.94 (6.66)	2.19 (3.31)	6.56 (4.28)	4.38 (3.95)	6.25 (4.65)	4.69 (4.23)

Two, three, four and five indicate the number of preceding repetitions at the target level. G-L, direction of switching after repeated-level trials (global-to-local), L-G, target-switching from local to global levels. Abbreviations: AD, Asperger's disorder, *SD*, standard deviation

Fig. 1.

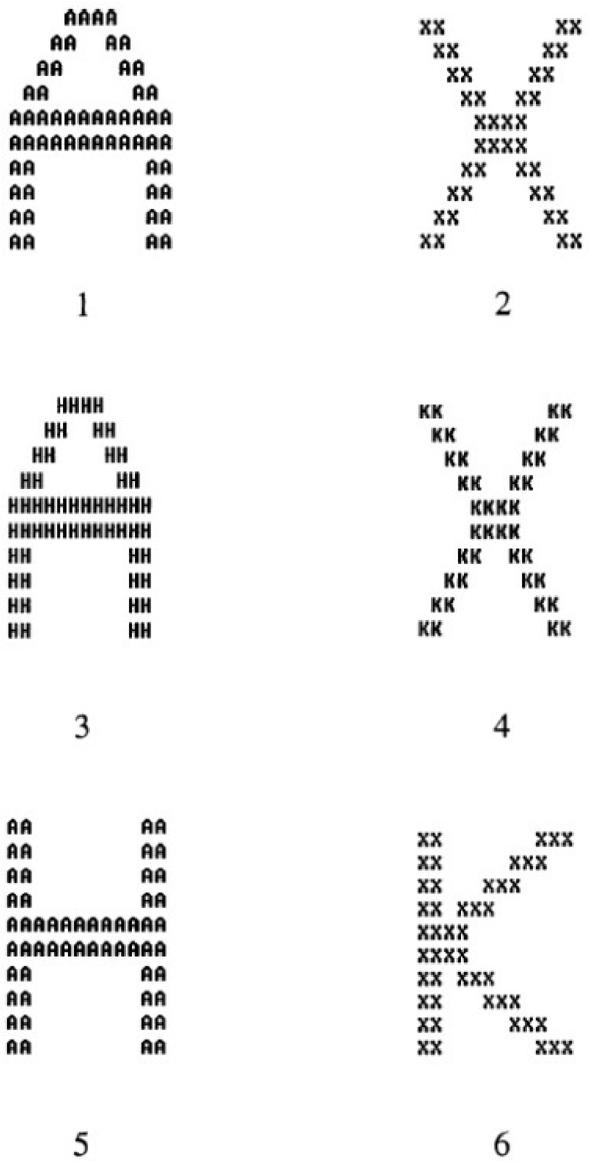


Fig. 2.

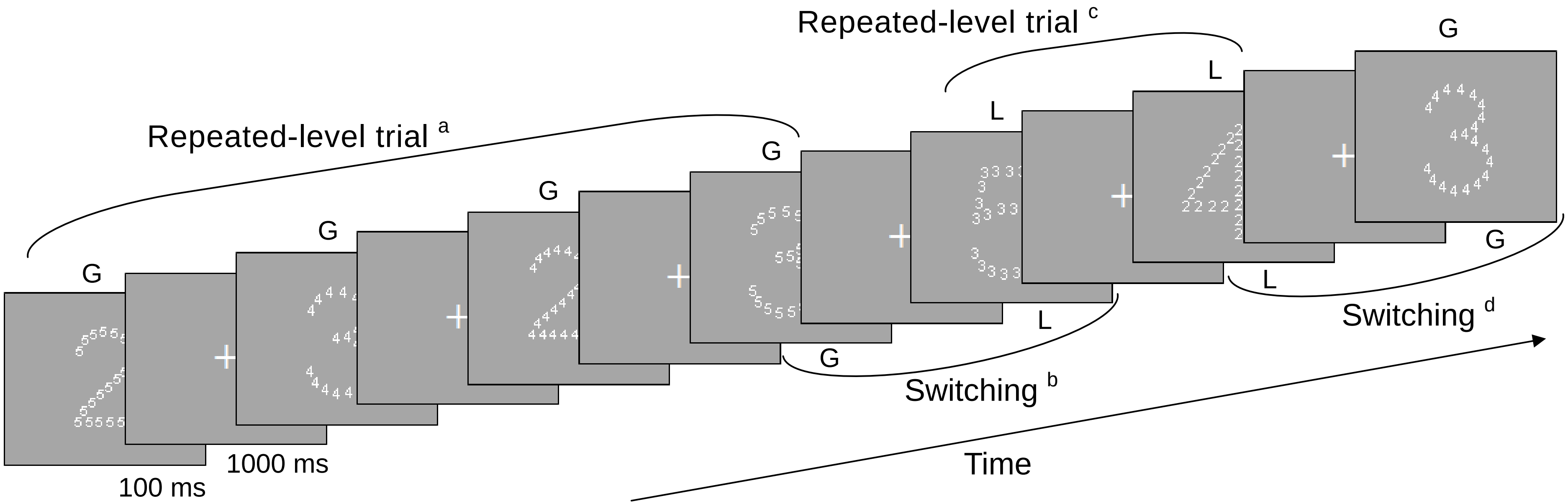

Repeated-level trial a
Repeated-level trial c
G
G
G
G
G
L
L
G
G
L
L
G
100 ms
1000 ms
Switching b
Switching d
Time

Fig. 3.

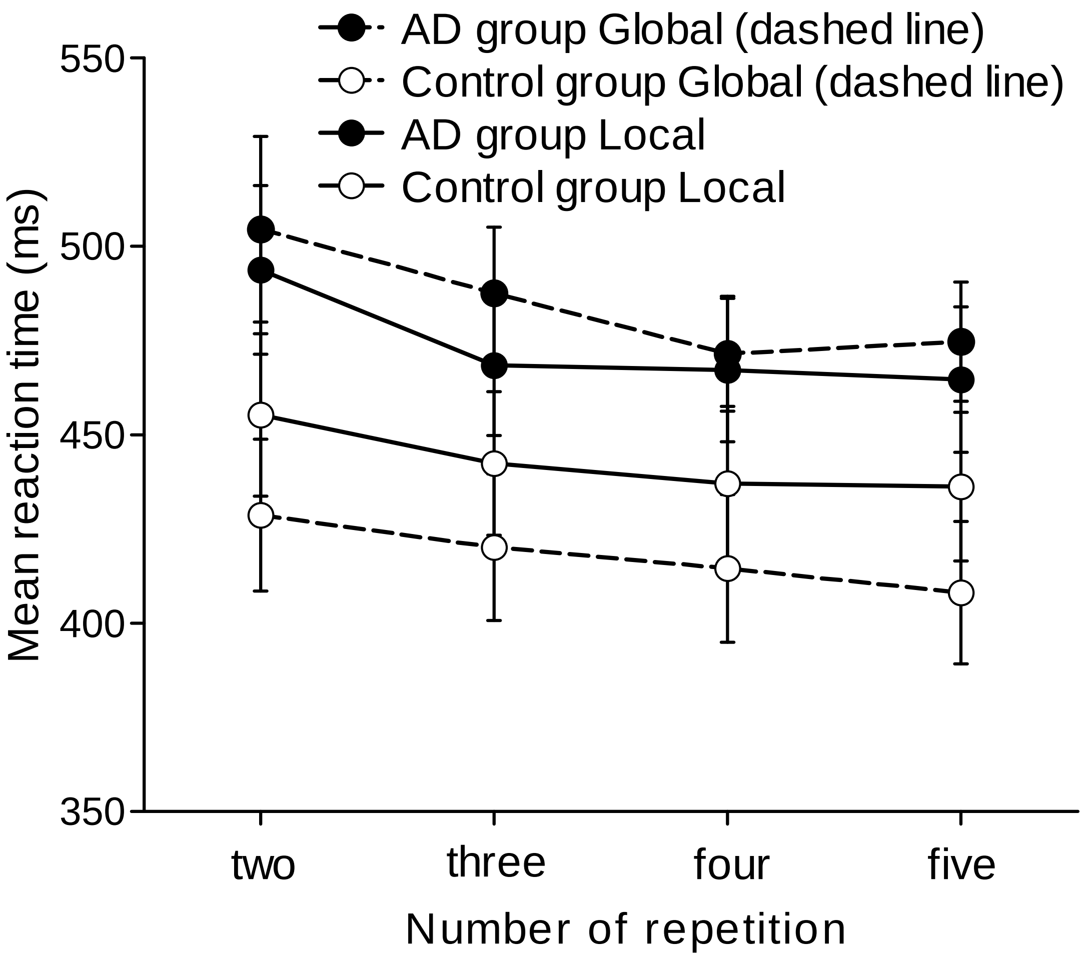

AD group Global (dashed line)
Control group Global (dashed line)
AD group Local
Control group Local
550
500
450
400
350
Mean reaction time (ms)
two
three
four
five
Number of repetition

Fig. 4.

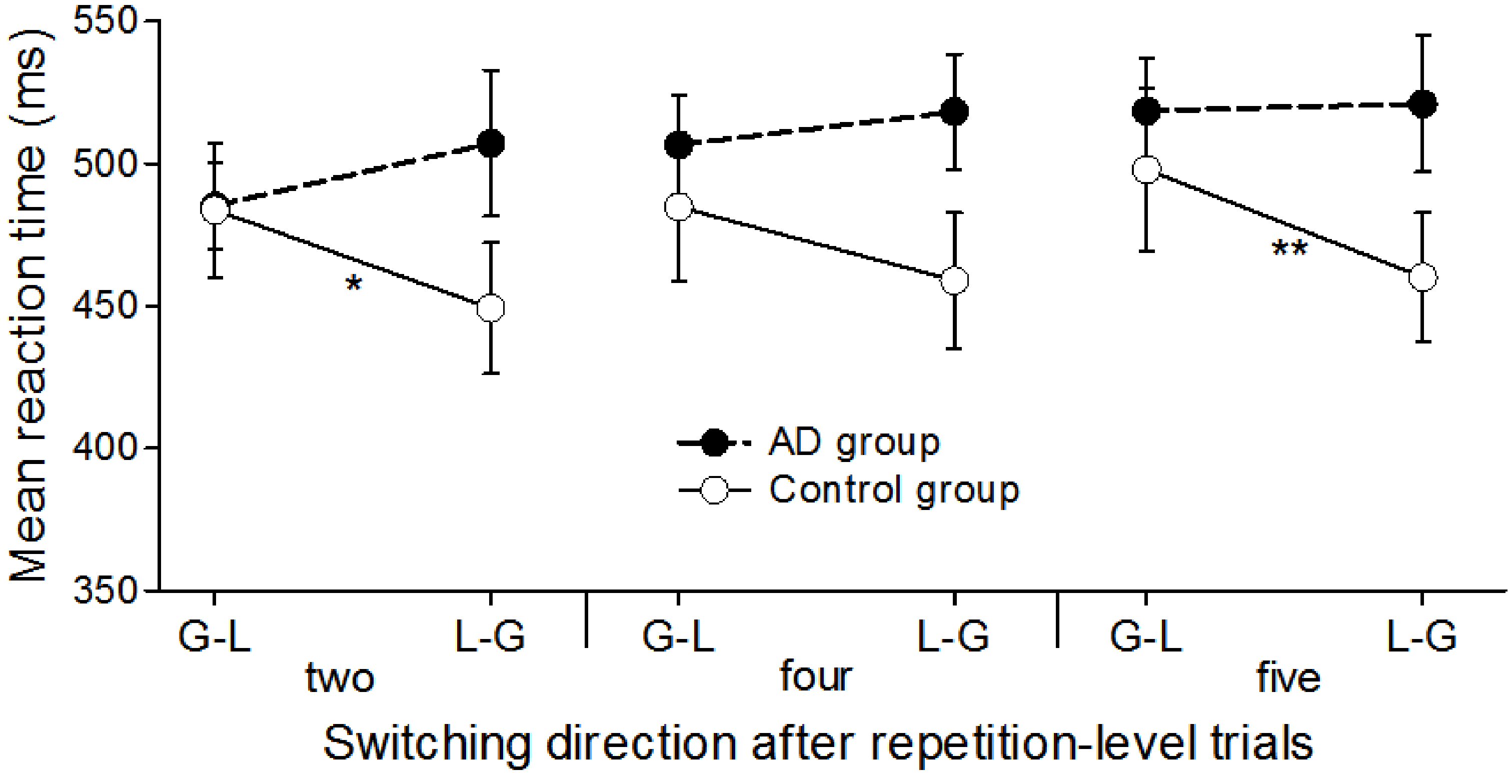
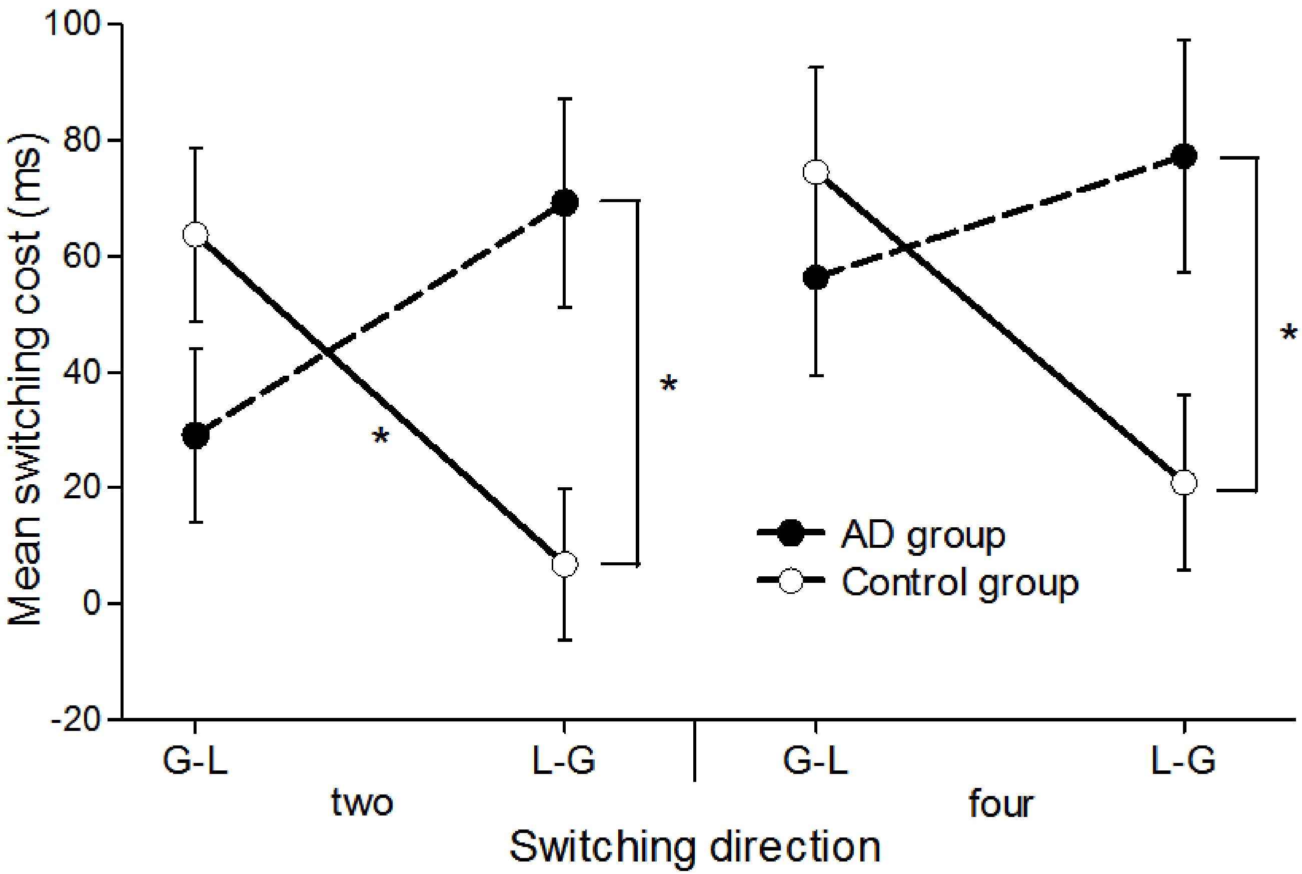

550
500
450
400
350
Mean reaction time (ms)
*
**
AD group
Control group
G-L
L-G
two
G-L
L-G
four
G-L
L-G
five
Switching direction after repetition-level trials

Fig. 5.


100
80
60
40
20
0
-20
Mean switching cost (ms)
*
*
*
AD group
Control group
G-L
L-G
G-L
L-G
two
four
Switching direction