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Domain specific attentional impairments in children with chromosome 22q11.2 deletion syndrome

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Abstract

One of the defining cognitive characteristics of the chromosome 22q deletion syndrome (DS22q11.2) is visuospatial processing impairments. The purpose of this study was to investigate and extend the specific attentional profile of children with this disorder using both an object-based attention task and an inhibition of return task. A group of children with the disorder was compared in these tasks with a group of age-matched typically developing children. The children with DS22q11.2 demonstrated impaired spatially based orienting which is consistent with previous findings in this group. Strikingly, the children with DS22q11.2 also demonstrated an improved ability to use object-based cues, relative to the typically developing group. Finally, the children with DS22q11.2 demonstrated an intact inhibition of return system, however, it appears to be delayed developmentally.

Keywords

22q11.2; Inhibition of return; Spatial attention; Object attention

Chromosome 22q11.2 deletion syndrome (DS22q11.2) results from a 1.5 to 3 Mb microdeletion on the long (q) arm of chromosome 22 (Driscoll, Budarf, & Emanuel, 1992). This disorder encompasses a number of other previously described disorders, such as, DiGeorge syndrome (DiGeorge, 1965), Conotruncal Anomaly Face (Burn et al., 1993) and Velocardiofacial syndrome (Shprintzen et al., 1978), and is one of the most common genetic causes of mental retardation and psychopathology. The currently accepted prevalence rate of DS22q11.2 is at least 1 in 4000 live births (Burn & Goodship, 1996).

The physical manifestations of DS22q11.2 are variable between individuals and include cleft palate, velopharyngeal insufficiency, congenital heart defects, hypocalcemia, and facial dysmorphisms (Emanuel, McDonald-McGinn, Saitta, & Zackai, 2001; Shprintzen, 2005). Recently, a series of studies using magnetic resonance imaging (MRI) have reported widespread brain dysmorphology in children and adults with DS22q11.2. The most consistent finding is an anterior to posterior pattern of greater tissue volume reductions, particularly in white matter (Eliez, Schmitt, White, & Reiss, 2000; Kates et al., 2001; Simon et al., 2005c). In addition to these global changes in brain morphology, a number of specific brain regions

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appear to be affected including the thalamus (Bish, Nguyen, Ding, Ferrante, & Simon, 2004), the cerebellum (Eliez et al., 2001; Bish et al., 2006), the basal ganglia (Eliez, Barnea-Goraly, Schmitt, Liu, & Reiss, 2002), and the corpus callosum (Shashi et al., 2004; Simon, Bearden, McDon ald-McGinn, & Zackai, 2005a).

The neurocognitive profile for individuals with DS22q11.2 is defined generally by an overall delay in cognitive development, including psychomotor and language delays and an IQ in the range of 70–85 (Gerdes et al., 1999; Swillen, Vogels, Devriendt, & Fryns, 2000). Impairments in specific cognitive domains have recently been reported. Bearden et al. (2001) established that one of the primary functional impairments in DS22q11.2 is in the domain of visual–spatial processing. The pattern of impairments is likely to include the temporal domain (Debbane, Glaser, Gex-Fabry, & Eliez, 2005), as well as the numerical processing domain (Simon et al., 2005a). Additionally, recent reports have established executive attention and inhibitory control as problematic in this population (Sobin et al., 2004; Bish, Ferrante, McDonald-McGinn, Zackai, & Simon, 2005). While knowledge of these impairments is very important, there is a need to further specify the precise nature of the impairments in this group in order to provide a foundation for cognitive remediation efforts.

It seems, therefore, that a deeper investigation into the spatiotemporal domain is likely to generate important data elucidating the nature and extent of processing impairments, as well as possible compensatory strengths in children with DS22q11.2. These could then be used as a basis for intervention and remediation. In this paper we extend our previous analyses into two closely related spatiotemporal aspects of visual attention, that we have previously claimed to be a key foundational cognitive competence for children with DS22q11.2 (Simon et al., 2005a). Specifically we demon-strated that children with DS22q11.2 are impaired in the ability to effectively disengage attention from an invalidly cued location and re-engage attentional processing in a new target location (Simon et al., 2005b). This impairment in visuospatial processing seems to extend into the ability to move between and enumerate greater than four objects (Simon et al., 2005b). Similar in nature to space-based attention, object-based attention involves the ability to use cues within an object to enhance the processing of target information elsewhere within the confines of the same object. While similar in function to space-based attention, object-based attention is thought to be an independent process (Farah, Wallace, & Vecera, 1993; Duncan, 1984), and is likely to depend on a different neurological mechanism (Egly, Driver, &Rafal, 1994a). Since previous investigations of DS22q11.2 have focused primarily on spatial processing, what remains unclear is whether or not the impairments in space-based attention extend into the domain of object-based attention. This is because spatial processing tasks involve target objects, some characteristics of which may influence performance. Without tasks specifically to disambiguate the effects of each, the ability to process different types of information carried by target stimuli cannot be assessed.

Despite the known temporal judgment difficulties recently reported by Debbane et al. (2005), very little is known about the nature of temporal processing in children with DS22q11.2. Inhibition of return (IOR) is a phenome-non that depends on the temporal dynamics of visuospatial attentional processing. Therefore, it is likely to be revealing when used as a vehicle to explore the temporal dynamics of visuospatial attention in DS22q11.2. IOR is a counterintuitive pattern of performance in which attention to recently processed items is inhibited in order to give preference to novel ones. It has been demonstrated that when human observers are provided with a visual cue to the location of a subsequently appearing target, processing of that target is typically enhanced or facilitated (Posner, Rafal, Choate, & Vaughan, 1985). However, several studies have found that facilitation of target processing occurs in typical adults provided that the length of time between the cue and target is short (100–350 ms). When the length of time between the cue and target increases (>500 ms) processing of the subsequent target location becomes inhibited (Posner et al., 1985; Maylor, 1985; Klein,

2000). In other words, the processing of the target location is now delayed rather than speeded up simply as a result of lengthening the SOA. The adaptive function of IOR has been assumed to be the facilitation of efficient visual search in a crowded environment. For example, when visually scanning a crowded scene, inhibiting processing in previously attended locations, if the target does not appear quickly, becomes advantageous (Klein & MacInnes, 1999). Thus, IOR can be seen as optimizing limited visuospatial attentional resources. Thus, changes in the temporal dynamics of IOR in children with DS22q11.2, may be related to impairments shown in other visuospatial tasks.

The purpose of the experiments reported in this paper was to examine whether children with DS22q11.2 have impairments in object-based attention to the same extent as the impairments shown in space-based attention. Additionally, we were interested in exploring whether temporal judgements shown to be impaired in this group (Debbane et al., 2005) extend to impairments of the temporal dynamics of visuospatial attention, as in IOR.

1. Method

1.1. Participants

A total of 30 children aged 7–14 participated in the study, which consisted of the two experiments described below. Of these 30, 15 were children with DS22q11.2, with diagnosis of the disorder confirmed by molecular Fluorescence In Situ Hybridization (FISH) between the ages of 6 and 14. The mean age of the DS22q11.2 was 9 years, 1 month (*SD* = 2.37) and the group consisted of seven females and eight males. Eleven of these children were recruited through their participation in the Velocardiofacial Syndrome Education Foundation Annual Conference (Atlanta, 2004). The other four children with DS22q11.2 were recruited through their ongoing involvement in the “22q and You” clinic at the Children’s Hospital of Philadelphia. The remaining 15 children were typically developing children that were age matched to the DS22q11.2 group between the ages of 7 and 14. The control group had a mean age of 9 years, 7 months (*SD* = 2.03) and consisted of eight females and seven males. Control children were recruited from the general population. A *t*-test to compare the group ages revealed a non-significant result, $t(28) = -.671$, $p = .508$. Both parental consent and child assent was collected prior to all experimentation. All participants were treated in accordance to the ethical guidelines established by the American Psychological Association as upheld by Institutional Review Board of the Children’s Hospital of Philadelphia.

To demonstrate that the current sample of children with DS22q11.2 is typical of the DS22q11.2 population at large, we surveyed parents of the children in both samples and asked whether the children currently required special education for reading and/or mathematics, whether the child had any co-morbid psychiatric diagnosis, and whether the child was currently on medication. Based on the survey, we are confident the children with DS22q11.2 are typical for that group in terms of level of function. Nine of 15 were currently either home schooled with special tutors or in special education classes at public schools. Of those, eight were currently receiving mathematics help and six were receiving reading/language arts tutoring. Within the typically developing sample, three of 15 were undergoing special education. Of those two were receiving reading tutoring and one was receiving mathematics help. Additionally, of the 15 children with DS22q11.2, four had been diagnosed with Attention Deficit Hyperactivity Disorder and one had been diagnosed with Autism Spectrum disorder. All four of the children with ADHD were currently on medication at the time of assessment. Of the 15 typically developing children, one had been diagnosed by a family physician as having Attention Deficit Disorder but had not yet had the diagnosis confirmed and was not currently on medication.

As part of large battery of computer-based cognitive tasks, all participants completed both the spatial/object-based attention task and the inhibition of return task. The order of the tasks was

counterbalanced within the larger battery ensuring that all participants had an equal chance of experiencing each task first.

2. Experiment 1. Space-based versus object-based attention

2.1. Procedure

The spatial/object-based attention task was adapted from Egly, Rafal, Driver, and Starrveveld (1994b). In this task, participants were presented with four rectangles oriented either horizontally or vertically (in separate trial blocks). Two rectangles are presented on either side of a fixation cross, which subtended 1° of visual angle. Each rectangle subtended approximately 4.5° of visual angle with each end presented 2.25° from the fixation cross (see Fig. 1a). Each trial began with 500 ms of fixation where participants are requested to focus on the fixation cross. Following this, one of the ends of one of the four rectangles was darkened, thus acting to reflexively cue attentional resources to that location (see Fig. 1b). The cue appeared for 100 ms after which the standard fixation screen remained for a delay of 200 ms. Following the delay, the target appeared until the participant responded, or until 2000 ms expired, whichever came first. The target was a solid square that filled the end of one of the rectangles (see Fig. 1c). The participant was required to press a button as quickly as possible after the onset of the target square.

Within each block (one with horizontally oriented rectangles, and one with vertically oriented rectangles), four types of trials occurred and were randomly distributed throughout the block with the pseudo-randomized condition of maintaining proportions of the various conditions of trials. The most common condition, i.e. Valid, occurred when the target appeared in the same location as the cue. Valid trials comprised 70% of all trials. In the Invalid-Within (I-W) condition (10% of all trials), the target appeared in a different location than the cue. In such cases, it was presented on the opposite end of the same rectangle, hence within the same object. In the Invalid-Between (I-B) condition (10% of all trials), the target appeared in both a different spatial location from that of the cue and inside a different rectangle. It is important to note that in both invalid conditions, the target location was the same distance away from the cue and hence the distance required by the shift of attention was equal in all cases. The only difference between the two invalidly-cued conditions was that the attentional shift was dependent on whether or not attention had to change location within a single object or between two different objects. It is the comparison between these two conditions, relative to the valid condition, that is used to evaluate the differentiation of space-based and object-based attention. The I-B condition provides a measure of space-based attention, while the I-W condition should reveal the benefit of object-based attention. The final 10% of trials were catch trials in which no target was presented and participants were instructed to withhold their response. The purpose of the catch trials was to ensure that participants maintained vigilance throughout the task.

2.2. Results

Prior to data analysis, data were examined for response errors as well as outliers in response time. First, response times were removed from condition means if the individual response time was 2.5 standard deviations above the condition mean for that participant or if response times were less than 100 ms. Additionally, percentage of false positive responses (i.e. errors) were counted and a comparison between groups revealed that there were no significant differences ($p = .202$) between typically developing children (mean = 1.33%, $SD = 1.18$) and children with DS22q11.2 (mean = 1.93%, $SD = 1.33$).

An omnibus 2 × 3 × 2 ANOVA, with group as a between subjects variable, and condition (valid, invalid-within, invalid-between), and orientation (horizontal, vertical) as within subjects variables revealed a significant main effect of group: $F(1, 27) = 5.689$, $p = .024$,

indicating slower performance for children with DS22q11.2 on all conditions (see Fig. 2). Specifically, children with DS22q11.2 had a grand mean 110.78 ms slower than typically developing children across the entire task. A significant main effect of condition $F(2, 54) = 68.740$, $p < .001$, revealed differences between conditions for both groups combined. Specifically, the valid condition was the fastest (600.61 ms), followed by the invalid-within condition (624.77), and the invalid-between condition (661.91) for all participants regardless of group. Simple post-hoc contrasts revealed significant differences between the valid condition and both invalid-within: $F(1, 27) = 41.505$, $p < .001$, and invalid-between: $F(1,27) = 103.705$, $p < .001$, for the combined groups. Given the lack of effects of orientation $F(1, 27) = .041$, $p = .840$, we collapsed across the vertical and horizontal blocks for the following analyses. A 3 × 2 ANCOVA with the three levels of condition as a within-subjects variable, two levels of group as a between subjects variable, and age as a covariate resulted in a significant main effect of condition, $F(2, 52) = 3.345$, $p = .043$, a significant main effect of group, $F(1, 26) = 5.885$, $p = .023$, a non-significant result for the age covariate, $F(1,26) = 3.084$, $p = .091$, and a significant interaction between group and condition, $F(2, 52) = 5.458$, $p = .007$. Simple post hoc contrasts for the interaction revealed a non-significant group difference for the object-based condition (invalid-within) relative to the valid condition ($p = .216$), and a significant difference between groups for the space-based condition (invalid-between) relative to the valid condition ($p = .039$).

This significant interaction indicates that there were differential amounts of response time cost in each group for the invalid conditions (object-based and space-based) relative to the valid condition. To evaluate this further, we subtracted the response times for the valid conditions from the two invalid conditions, giving an index of the cost of each invalid condition, with a larger difference indicating a greater cost. We then used these measures in a 2 × 2 ANCOVA in which group was a between-subjects factor and condition was a within subjects measure, while age was the covariate. The results indicated a group by condition interaction $F(1, 26) = 8.04$, $p = .009$, in which children with DS22q11.2 demonstrated a larger cost for invalid-between trials (space-based) compared to controls but not a significantly different cost for invalid-within trials (object-based) compared to controls (see Fig. 3). In other words, children with DS22q11.2 performed significantly better when making object-based responses compared to when making space-based responses.

2.3. Conclusions

The results of this study both replicate and significantly extend our knowledge regarding the attentional impairments shown by children with DS22q11.2. First, the difficulties in spatially mediated attentional shifts, demonstrated here as an increased cost of the I-B condition relative to the valid condition, have been shown to be a hallmark cognitive impairment in this group (Simon et al., 2005b). Surprisingly, these same children clearly showed significant facilitation in performance when using of object-based attention. Compared to age-matched typically developing children, children with DS22q11.2 show less of a cost when required to switch attention to a new location within the object to which they were already attending than when they had to switch attention by the same distance to a location in an unattended object. So, rather than being equally impaired in using attentional processes to parse space in terms of specific locations and the objects that occupy those locations, children with DS22q11.2 appear to have a relative strength in using object boundaries to structure visual space and to use that structure for navigation and the information extraction. The fact that the same group of children is relatively poor on spatially mediated attention and relatively strong on object-mediated attention lends support to the notion that although similar, these two attentional domains are supported by different brain networks (Farah et al., 1993). This may provide some behavioral evidence of a hemispheric asymmetry in children with DS22q11.2, in that previous evidence exists for a right posterior parietal bias for spatial-based shifts and left posterior parietal bias

for object-based shifts (Egly et al., 1994a). Alternatively, this finding may provide evidence to the impaired functionality of the posterior portion of the corpus callosum shown to be a atypical in this group (Shashi et al., 2004; Simon et al., 2005c). Previous research has suggested that an intact corpus callosum is necessary for spatially mediated shifts across the midline, while object-based shifts do not require the same callosal integrity (Egly et al., 1994b).

Thus, strategies aimed at remediating spatial attention weaknesses in this group should attempt to exploit this apparent adaptation and on the neural substrate on which it is based.

3. Experiment 2. Inhibition of return

3.1. Procedure

The Inhibition of return task was adapted from MacPherson, Klein, and Moore (2003). In this task three yellow boxes occupying approximately 6° × 6° of visual angle with lines .25° in thickness were presented on a black background with a distance of 3.5° between boxes. A yellow fixation cross subtending 1° of visual angle was presented in the center of the middle box (see Fig. 4). Participants completed two blocks (one single cue and one double cue) counterbalanced to avoid any order effects.

In the single cue condition (see Fig. 4), each trial began with a fixation period of 500 ms followed by a peripheral cue which lasted 50 ms. The peripheral cue was indicated by a thickening (from .25° to 1° of visual angle) of the lines of one of the two peripheral boxes. Following the cue, the fixation screen was again presented for a variable stimulus onset asynchrony (SOA) of either 100, 300, 500, or 700 ms. Finally, the target appeared in either of the peripheral boxes and was maintained until the participant responded or for 2000 ms, whichever came first. The target was a red “smiley” face with diameter equal to the size of the boxes. The participant was required to respond via button press, to determine which side the smiley face was presented on (left button = left side, right button = right side). The target could appear in either the validly cued box or in the invalidly cued box with equal probability across all SOAs.

In the double cue condition, each trial again began with a fixation period of 500 ms followed by a peripheral cue which lasted 50 ms, just as in the single cue condition. Following the cue, the fixation screen was presented for 25 ms, followed by a second central cue (indicated by a thickening of the fixation cross in the center box), which lasted 50 ms. The SOA period followed the central cue and could be either 25, 225, 425, or 625 ms. Following the SOA, the target appeared until the participant responded or for 2000 ms, whichever came first. It is important to note that the only difference in the single and double cue procedure is the presence of the second, central cue. All other timing and task conditions were identical.

3.2. Results

Anticipations (RT < 100 ms) and error trials encompassed fewer than 5% of trials for both groups and hence were excluded from all analyses. As in the object-based attention task, error rates were both low and similar between groups and hence all error trials were removed from further analyses. For each condition, cost/benefit scores were computed by subtracting the response times for valid trials from the response times for the invalid trials, hence a positive number indicates facilitation and a negative number indicates inhibition of return. Omnibus ANCOVAs were computed separately for the Single and Double cue procedure (see Fig. 5) using age as a covariate. In the single cue procedure, a 2 (group) × 4 (SOA) Repeated Measures ANCOVA revealed a significant main effect of group $F(1, 27) = 7.256$, $p = .012$, with children with DS22q11.2 showing greater effects of the cue type compared to controls. In other words, children with DS22q11.2 had a larger difference between the valid and invalid cue conditions relative to the age-matched typically developing children. There was also a main effect of SOA

across groups $F(3, 81) = 3.122$, $p = .030$, with the greatest cue effects at the extreme SOAs of 100 and 700 ms. Specifically this effect demonstrates facilitation at 100 ms SOAs and inhibition at 700 ms SOAs for all participants. The interaction between SOA and group was also significant, $F(3, 81) = 2.933$, $p = .038$. Post hoc contrasts ($p < .05$) for the interaction revealed that children with DS22q11.2 demonstrated significant facilitation at 100, 300, and 500 ms SOAs and significant inhibition at 700 ms, while the typically developing children demonstrated significant facilitation at 100 ms and significant inhibition at 700 ms and trended towards significant inhibition at 500 ms. The age covariate was non-significant, $F(1, 27) = .545$, $p = .467$.

For the double cued procedure, a second 2 (group) × 4 (SOA) repeated measures ANCOVA revealed a trend toward a significant main effect of group ($p = .054$) indicating a greater effect of cue type for children with DS22q11.2. The main effect for SOA was non-significant ($p = .133$), and the interaction between group and SOA was non-significant ($p = .515$). Visual inspection of the individual group data demonstrates trends towards facilitation at 100 and 300 ms and inhibition at 500 and 700 ms for the children with DS22q11.2 while the typically developing children demonstrate trends towards inhibition across all conditions (see Fig. 5).

3.3. Conclusions

The results of the inhibition of return task indicate a marked delay in the shift from facilitation to inhibition in children with DS22q11.1 relative to age-matched controls. In the single cued procedure, the typically developing children switched from facilitation to inhibition between 300 and 500 ms while that same switch did not occur for the children with DS22q11.2 until between 500 and 700 ms.

The purpose of the double cued procedure is to reflexively draw attention away from the initially cued location, theoretically allowing inhibition of return to that location to occur more readily. In this study, the double cued procedure was effective for the typically developing children, with either significant results or trends towards inhibition at each SOA. However, the double cue results for the children with DS22q11.2 look very similar to the single cued procedure with inhibition only at 700 ms. Despite the intention of the design, the double cued condition is much more complex in terms of demands on space-based attention, and their evident impairment with such processing may be the reason children with DS22q11.2 were unable to mobilize IOR until the longest SOA allowed them to navigate the spatial display effectively.

Interestingly, the pattern of performance for the typically developing children looks much like the typical performance of older children (aged 11–17) while the performance pattern for the children with DS22q11.2 looks more like the younger children (5–10) with the exception of the switch to inhibition at 700 ms in the single cued procedure and the lack of effectiveness in the double cued procedure (MacPherson et al., 2003).

These similarities may indicate that the children with DS22q11.2 have an intact visuospatial processing system that operates at a developmentally delayed level relative to age-matched control children. An alternative explanation, is that the visuospatial system of children with DS22q11.2 is not intact and that through abnormal development, other systems have been recruited to maintain the functioning of the cognitive processes involved with some impairment resulting. The data presented here suggest that the temporal dynamics of attentional search and target recognition and response are negatively impacted. Longitudinal studies and studies of adults with DS22q11.2 are required in order to fully distinguish between these alternatives.

Interestingly, these patterns of performance may again suggest impaired functionality of the corpus callosum. Previous research in split brain patients demonstrated that object-based

facilitation could transfer subcortically without the corpus callosum, while object-based inhibition required an intact corpus callosum (Tipper et al., 1997).

4. General discussion

This study attempted to further specify the visuospatial attentional impairments in children with DS22q11.2. Not only have we extended current knowledge of spatial orienting impairments in this group, but also we have demonstrated that these impairments are affecting multiple facets of the spatial orienting system (i.e. spatial selection, inhibition of return). In addition to these impairments, we have demonstrated here that children with DS22q11.2 have a preserved ability, relative to their spatial impairment, to use object-based cues when orienting attention. This preservation may indicate a compensatory mechanism in the face of impaired spatial orienting. In other words, children with DS22q11.2 may have developed a more efficient ability to use object-based attention as a result of their difficulties in using spatially mediated information. An alternative, albeit related, explanation that cannot be ruled out here, is that the children with DS22q11.2 have such significant difficulties processing spatial information that these difficulties give them more opportunity or need to use the object-based system. Whichever the case, since both the spatial and object conditions of this task require a spatial shift of attention, which has been shown both here and elsewhere (Simon et al., 2005a) to be impaired in children with DS22q11.2, the considerable advantage afforded them by the object-centered condition demonstrates a considerable relative strength in their visual information processing.

This profile is, in fact, not without precedent. Studies of individuals with Williams syndrome, who also exhibit severe visuospatial impairments, report a relative strength in the processing of object-based characteristics (e.g. Landau, Hoffman, & Kurz, 2006). In fact, it is possible that such a profile is far from specific to the chromosome 22q11.2. deletion and may be shared by individuals with one of many disorders (such as fragile X or Turner syndromes or spina bifida) that appear to produce some overlap in this aspect of cognitive processing. Some inferences can be made about this from our own data. Evidence of impairments in processing spatial but not object-based information reported here does appear to partially explain the findings we reported in our enumeration task (Simon et al., 2005a). Since all target objects were randomly arrayed identical green blocks they carried no distinguishing object-based information, either as individuals or as part of the larger configuration in the display. When spatial information was required to carry out enumeration (i.e. in the counting but not subitizing ranges) performance of children with DS22q11.2 suffered significantly. When no spatial information was required to carry out subitizing, performance was essentially identical to that of typically developing controls. We have directly replicated this effect in girls with Turner syndrome (Simon et al., submitted). Combined, our findings suggest that children with DS22q11.2 might be able to count large displays more accurately if they were presented in configural arrays where the gestalt creates a virtual object structure. The current findings also further characterize the nature of attentional impairments in children with DS22q11.2. This picture is now becoming increasingly clear, though much work remains to be done. We (e.g. Bish et al., 2005) and others (notably Sobin et al., 2004, Sobin, Kiley-Brabeck, & Karayiorgou, 2005) have begun to decompose the different kinds of attentional dysfunctions experienced by children with DS22q11.2 and to make inferences about the different neural basis of each one and its possible contribution to other outcomes including the risk for psychosis later in life.

It is our contention that our data also demonstrate that the impairments experienced by children with DS22q11.2 can not be fully explained by a global slowing of cognitive processing that is exacerbated by task complexity. Certainly, the overall group effects demonstrating slowed response times may be directly impacted by a general cognitive slowing. However, since the critical measurements here are comparisons within group (i.e. response time cost/benefit

relative to one's own performance) it is unlikely that general cognitive slowing would impact these patterns. In Experiment 1 we showed that, despite significant costs in performance in the spatially cued condition for children with DS22q11.2, the cost in their performance in the object-based condition was slightly less than was the cost for typical children. A general slowing account would predict that any change in difficulty should always create a larger performance decrement than the one seen in typical children. Additionally, in Experiment 2 we demonstrated that children with DS22q11.2 have an intact IOR system, even though performance patterns demonstrated that the IOR takes considerably longer (i.e. 700 ms SOA condition) to activate compared to typically developing children. Additionally, we previously showed (Simon et al., 2005c) that such children can respond with the same level of speed and accuracy in the part of an enumeration task (i.e. subitizing) where search using spatial attention is not required. This would not be possible if children with DS22q11.2 were slower to respond to all similar tasks. Finally, Simon et al. (submitted) show that children with DS22q11.2, of the same ages as those described here, produce simple manual motor reaction times that are not different from those of typically developed controls, despite differences on the Processing Speed (PS) index of the Weschler Intelligence Scale for Children (III and IV). The simple reaction time task is identical to the two experiments presented here except that no high level cognitive processing is required. In contrast, the PS index is calculated from tasks that require a considerable amount of visuospatial and visoumotor processing and so puts children with DS22q11.2 at a considerable disadvantage.

Despite the interesting findings, we must be cautious not to conclude that these impairments are static and permanent. Both longitudinal studies and studies of adults with DS22q11.2 will help to determine whether the pattern of performance demonstrated here lasts, or whether a slowed trajectory of cognitive development will help to overcome the impairments. Additionally, due to limitations in the testing environment, it was not possible to acquire IQ or other covariate measures, other than age for the present experiments and these factors may account for some of the variance in the data. Thus, we infer that the results we report here provide an increment of our understanding of the specific pattern of impairments and advantages experienced by most children with DS22q11.2 in the area of attentional processing. Of course, further study of these phenomena involving a wider array of data will be needed in order to develop definitive accounts of those competencies, their neurobiological basis and the possibilities for intervention that might exist.

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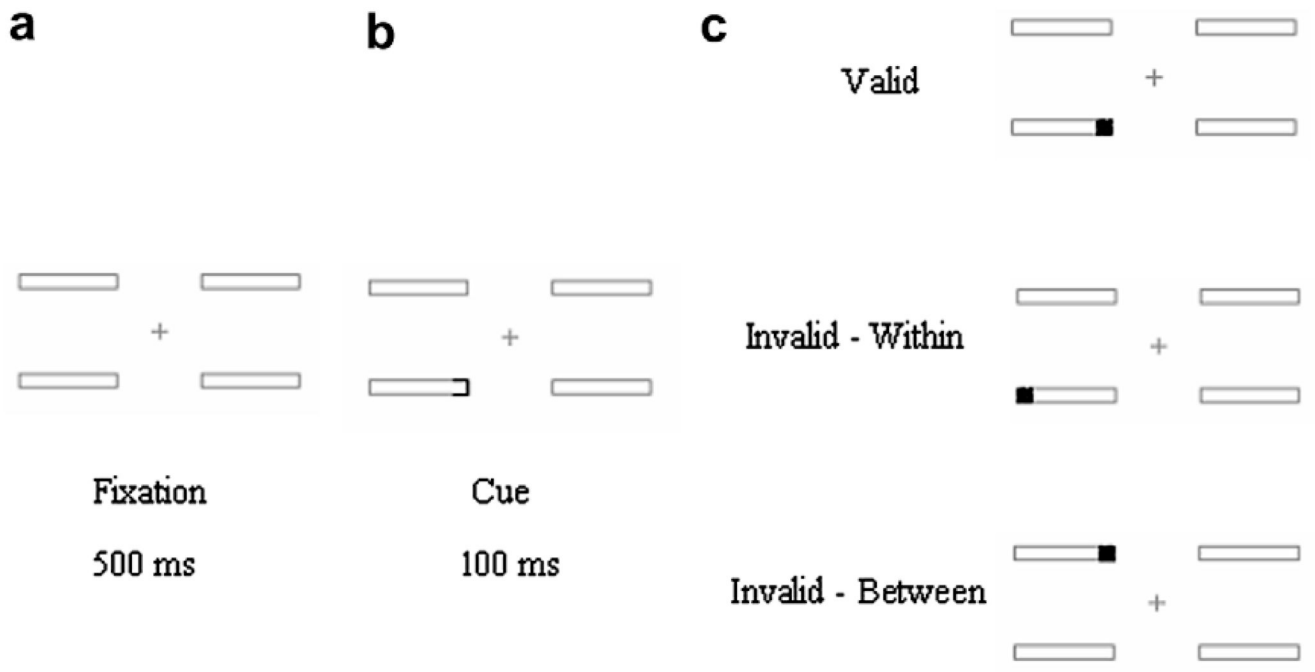

Fig. 1.
Graphical depiction of the object vs. spatial cueing task. Example of horizontal orientation. Vertical orientation is not demonstrated.

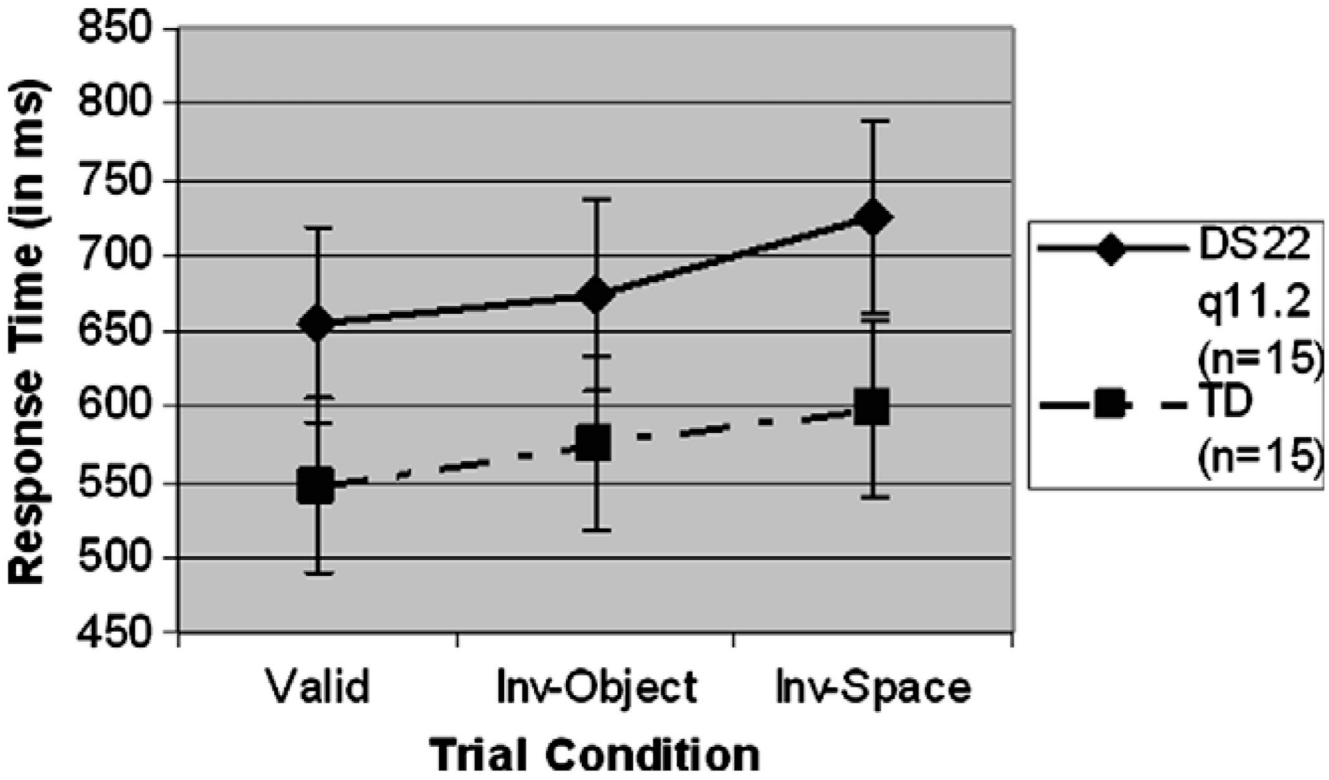

Fig. 2.
Overall response time data for the three conditions, valid, invalid-within object, and invalid-between object.

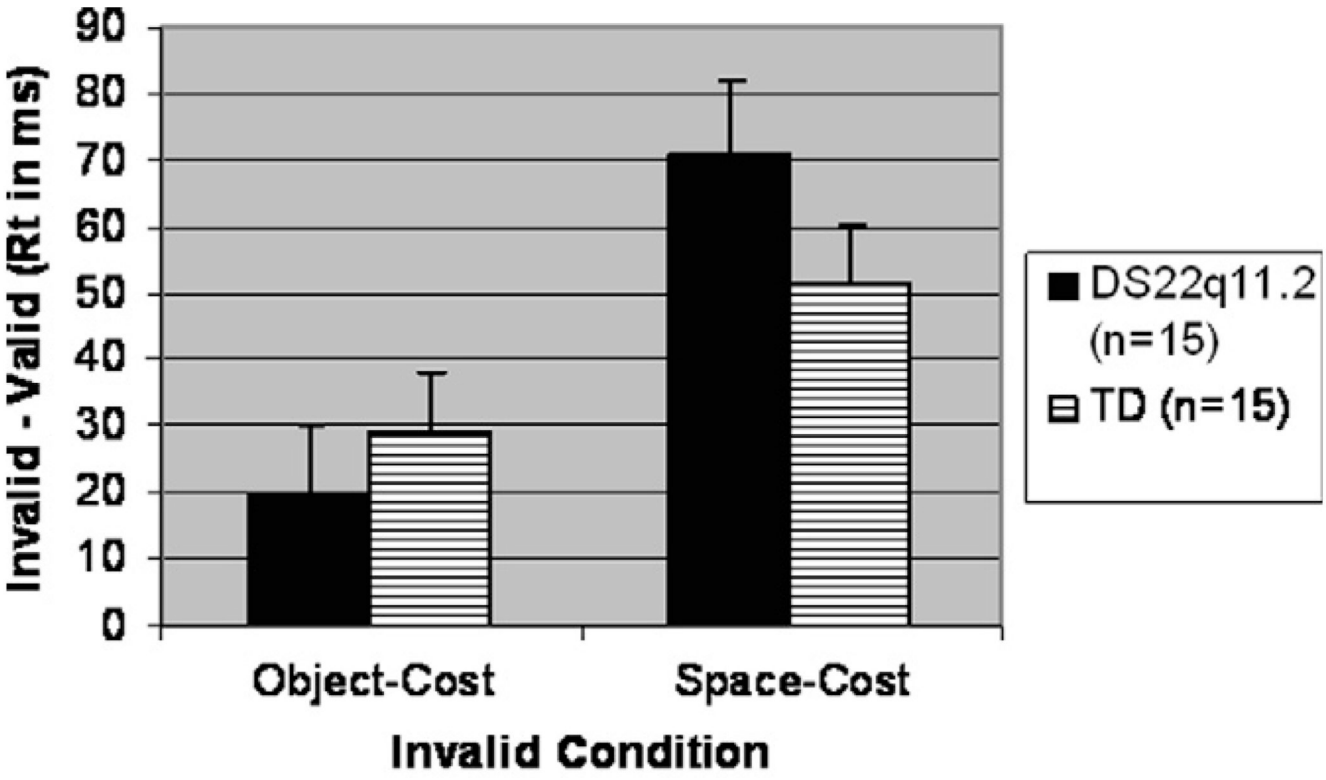

Fig. 3.
Cost/benefit comparison relative to validly cued trials.

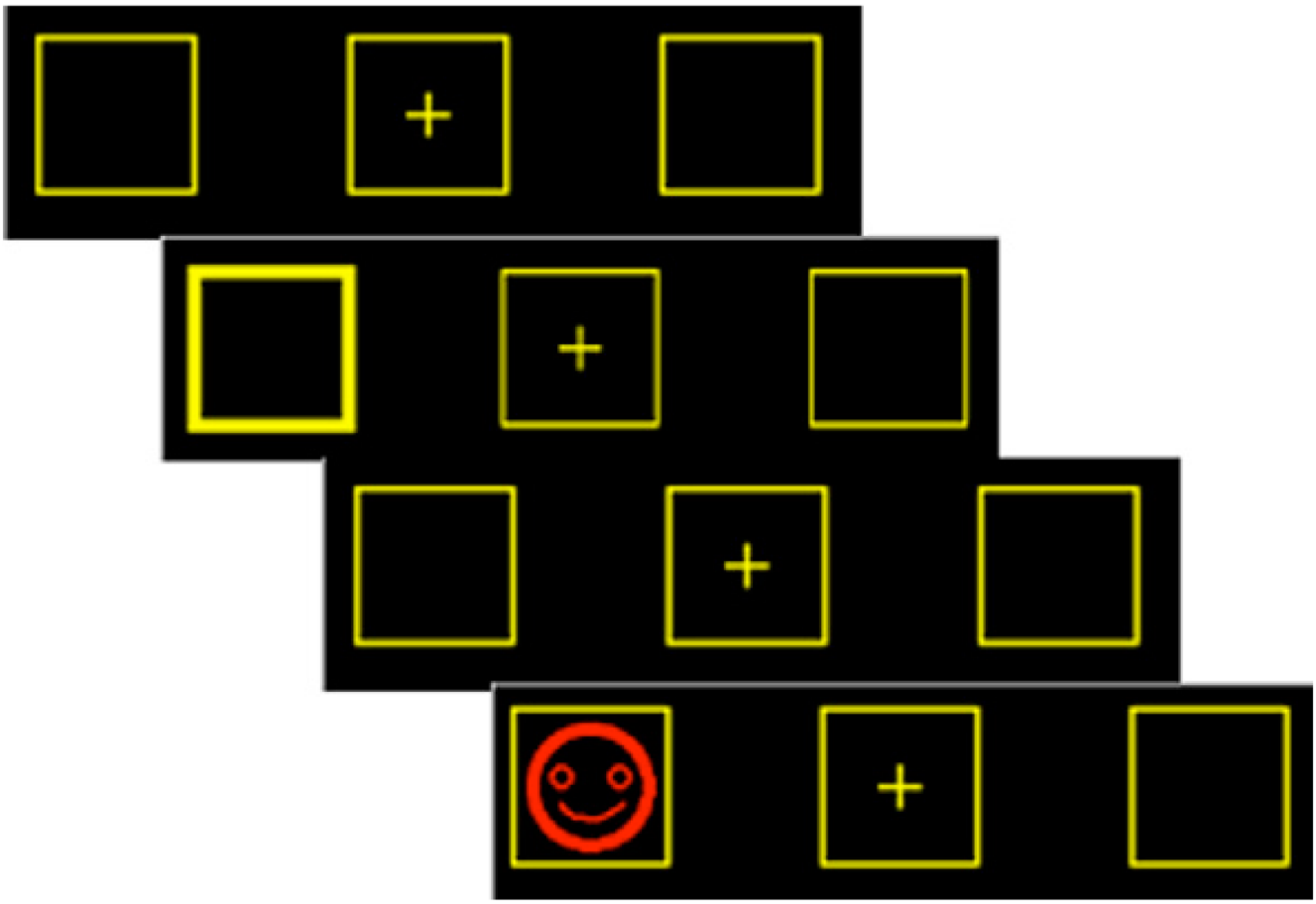

Fig. 4.
Graphical depiction of inhibition of return task.

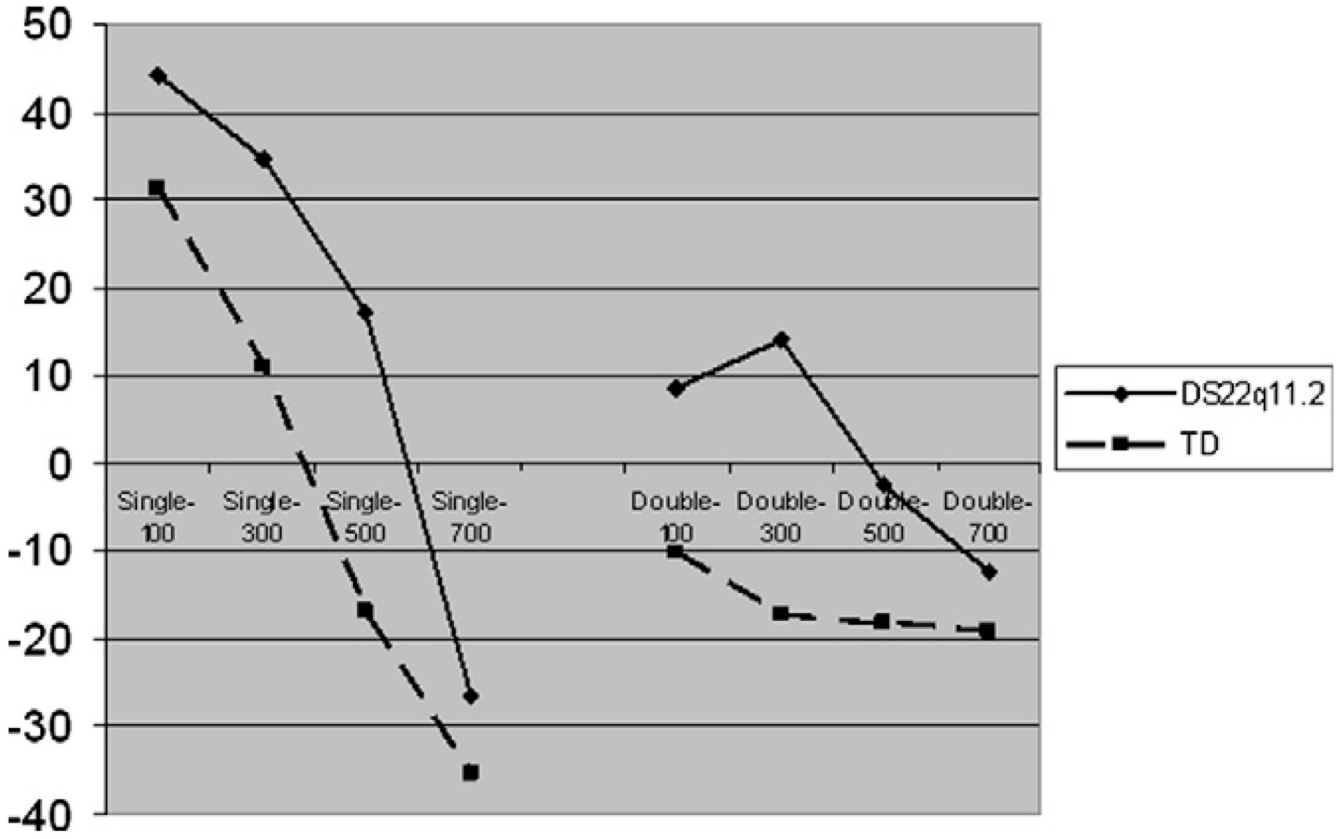

Fig. 5.
Inhibition of return–response time differences between invalid trials and valid trials. Positive numbers indicate facilitation, while negative numbers indicate inhibition.