Spatial Coding for Items of Varying Semantic Value in Adults With or Without Down Syndrome

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Abstract

Spatial coding of adults with or without Down syndrome was assessed for arrays of more or less concrete objects. Individuals with Down syndrome, with undifferentiated developmental disabilities (UDDD), and from the general population (CONT) viewed sets of objects laid out for study on a board marked with a grid pattern. Following 15s of study, the objects were removed and participants were asked to replace the items as close to their original positions as they could. Four item types were used: everyday objects, coloured blocks, printed words, and nonsense shapes. Overall, persons in the Down syndrome and UDDD groups performed with greater average error than participants in the CONT group. As well, smaller errors were found for the real-world items than for the other item types. A group by object type interaction indicated that, unlike control participants, the people in the groups with developmental disabilities were more accurate in replacing real-world objects than they were for the other categories. In addition, individuals with Down syndrome showed a relative advantage for nonsense shapes when compared with individuals with UDDD. Contrary to research involving verbal coding, the persons with Down syndrome in this study group were not disadvantaged in recalling the spatial position of objects relative to other persons of a similar chronological and mental age.

A variety of researchers have identified spatial processing as an area in which persons with Down syndrome are often less proficient than members of the general population (Dulaney, Raz, & Devine, 1996; Hartley, 1985; Mangan, 1992; Uecker, Mangan, Obzrut & Nadel, 1993). Spatial coding deficiencies also have been identified in mice selectively bred as a potential animal model of Down syndrome (Demas, Nelson, Krueger & Yarowsky, 1996). Uecker et al. cited neurobiological, neuropsychological and behavioural evidence for difficulties in spatial processing for people with Down syndrome, and suggested that many of these difficulties may be due to abnormal hippocampal development in this population (see Pennington, Moon, Edgin, Stedron & Nadel, 2003 for a recent review).

Dulaney et al. (1996) tested a hypothesis arising from Hasher and Zacks' (1979) proposed dissociation between effortful and automatic coding processes. The hypothesis was that so-called automatic processes would be spared for people with developmental disabilities, whereas those activities requiring so-called effortful processes would be associated with deficient abilities. They characterized spatial memory as being at the automatic end of the spectrum and thus less likely to be a source of difficulty for people with developmental disabilities. Earlier attempts to assess this hypothesis had suffered from confounding effects of age and intellectual ability. Dulaney et al. attempted to control for group differences along those dimensions. Studied items were photographs of everyday objects and memory for them was tested in a recognition paradigm. Having identified an item as old (i.e., as having been previously studied) participants then indicated at which of four possible spatial locations it had initially appeared. The results indicated that for recognition performance, participants with Down syndrome and with undifferentiated mental disabilities performed less accurately than control participants from the general population. Similarly, in location memory, control participants outperformed both groups with developmental disabilities.

In another study concerned with the same issues, Zucco, Tessari and Soresi (1995) presented people with Down syndrome and mental age matched children with separate lists of four different types presented in varying positions on square cards; concrete words, pictures of everyday items, nonsense pictures, and abstract words. In the initial exposure, items were presented one at a time within a list, and the participants were to make a pleasantness rating for each item. Each item appeared in one of four positions. Subsequently the items were presented in the centre of a card and the task was to indicate in what position it had initially appeared. Zucco et al. found main effects for both group and item type in percentage of correct location responses, but no interaction between those factors. Overall the results suggested that more concrete items supported better spatial information storage than the more abstract items (words and nonsense items). Both the Dulaney et al. and the Zucco et al. studies suggest that the supposed sparing of such processes for individuals with intellectual difficulties is unlikely.

McDade and Adler (1980) provided data indicating that visually presented sequences of words and pictures were recalled at the same level by individuals with Down syndrome and individuals matched to them for mental age, while both groups had dramatically lower recall than a group of participants matched for chronological age. Interestingly, unlike the other two groups, correct recognition in the people with Down syndrome was no better than recall, suggesting that individuals with Down syndrome have relatively poor storage ability for visually-presented information. This notion is consistent with findings by Bunn, Welsh, Watson, Simon, & Elliott (2002) who reported that adults with Down syndrome had more difficulty than persons of a similar mental age reporting the names pictures presented in a sequence either 0 or 5 seconds earlier. Because they performed as well as the other group when they were required to silently read and then repeat the names of the same objects (i.e., 0 or 5 s later), it is possible that at least some of their difficulty was associated with using the visual information contained in the picture to access lexical information.

Here, we report a study on spatial coding in which we manipulated semantic quality of physical stimuli as well as whether or not participants were able to attach a name to the items presented. We tested individuals from the three different groups on their ability to accurately recall the correct spatial locations of a small array of studied objects. On different trials, five objects from a common category (everyday objects, printed words, coloured blocks, and nonsense shapes) were placed in different positions on a table top. Participants were to study the array for a brief period and then, following a short interval, replace the objects as close to their studied positions as possible.

Consistent with earlier work from our laboratory (e.g., Bunn, et al., 2002), we anticipated that individuals with Down syndrome would have greater difficulty accessing lexical information associated with items than either chronologically age-matched controls (CONT) from the general population, or individuals with undifferentiated developmental disabilities (UDDD). Although naming was not part of the task, our expectation was that replacing an object with a concrete verbal label would be easier that reproducing the spatial position of an abstract object (Smith & Milner, 1981, 1989). Our hypothesis was that this advantage would be absent in persons with Down syndrome, but not persons from the other two groups. However, for objects that did not correspond to a lexical item in memory (i.e., nonsense shapes), we reasoned that memory for the location of those shapes might be relatively good in people with Down syndrome because linguistic processing would be irrelevant for these objects.

Method

Participants

Participants were 41 adult volunteers, consisting of 14 people with Down syndrome (8 men and 6 women: average age 30.2 years, *SD*=4.2 years), 13 with undifferentiated developmental disabilities (6 men and 7 women: average age 28.4 years, *SD*=4.6 years), and 14 adult controls (5 men and 9 women: average age 24.0 years, *SD*=2.8 years). All participants (and, in the case of the people with developmental disabilities, their parents/guardians) signed an informed consent form prior to taking part in this experiment. The research received ethical approval from the Research Ethics Board at McMaster University prior to being conducted. The two groups with developmental disabilities were recruited from two local Centres, one a local learning centre and the other an educational training centre. Both Centres were in populous Canadian communities, and representatives from both Centres were in both groups. The control sample was recruited from the population of students at a large Canadian University. In order to gauge verbal ability of the two groups of people with developmental disabilities, Peabody Picture Vocabulary scores were used to estimate receptive language ability (*M* for people with Down syndrome=7.8 years, *SD*=1.33 years, *M* for people with UDDD =9.3 years, *SD*=1.4 years)[1]. Peabody scores were not collected for the control sample as they were expected to have scores reflective of their chronological ages.

Materials & Apparatus

Four types of stimulus items (2 sets of 5 objects per type) were presented to participants. The four item-types were; everyday objects (comb, pen, soap, etc.), printed words ("lamp", "pot", "duck" etc.), coloured blocks (red, blue, green, etc.), and nonsense shapes (irregularly shaped pieces of foam rubber covered in black tape). On a given trial the five items were placed on a grid (56 x 56 cm) marked off in 2cm squares. Pre-prepared overlay templates with cut-outs for the respective shapes of the relevant objects were used to place the items at the beginning of each trial. Each template was presented twice, with a different orientation each time, so that with the two sets of items of a given type, a total of four trials of each type were presented to each participant. While the objects were being placed, participants were asked to look away or to close their eyes so as to standardize exposure duration to the to-be-remembered array. A video camera was used to record the starting positions of the objects on each trial and again once after they had been replaced by the participant at the end of the recall period. Still images of each array were extracted using Snappy, a video-still capture program that enabled a desktop computer to be interfaced with the video camera. The visible grid lines enabled accurate estimation of the distance between the recalled and the studied location for each item in the array.

Procedure

Prior to data collection, participants were given experimental instructions about the task they were to perform. They were also asked to identify each of the everyday objects, read aloud the printed words, and state the colours of the blocks in order to confirm that they had no trouble identifying and discriminating between those stimuli[2]. In order to ensure that the participants understood the nature of their task, sample trials were given. The experimenter placed two objects on the grid, and then, after a brief period, removed them. The participant was then to replace the items in the same positions that they had been seen. The experiment proceeded only when the experimenter was satisfied that the participant understood the task.

On each experimental trial, five objects of the same category were laid on the grid using the templates for placement. The participant studied the array of objects for 15s and then the objects were removed from grid. In what amounted to a test of immediate recall, the participant was then asked to replace the items as accurately as possible and no time limits were imposed on this process. The full set of five items was available to the participants and no distractor items were included, so that the test was not of what had appeared on the grid, but rather where the respective items had been seen. When the participant had finished placing the objects, the position of the objects was captured with the camera.

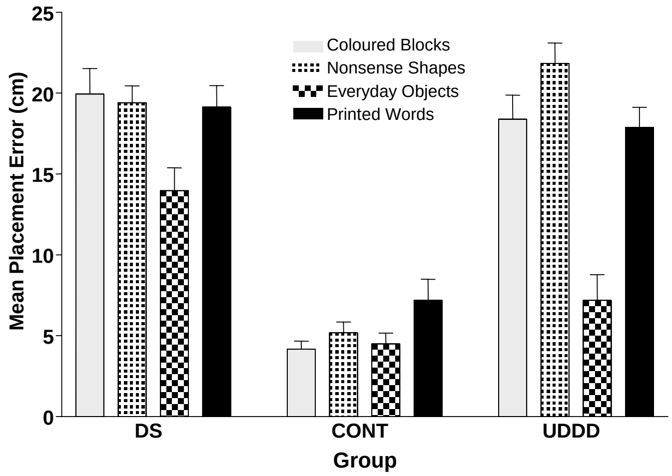
Data Reduction

For each completed trial, a still image was acquired from videotape using "Snappy" video capture software. From each such image, the linear distance of the centre of each object from its correct position was determined using the grid pattern as a reference.

Results

Placement error data (see Figure 1) were analyzed in a 3 (Group: Down syndrome, UDDD, CONT) x 4 (Object type: colored blocks, nonsense shapes, real-world objects, printed words) x 4 (trial) univariate analysis of variance, with object type and trial as within-participants factors. Post hoc comparisons involved Tukey HSD tests with alpha set to .05.

Figure 1. Mean placement error as a function of group and item type.



(DS = Down syndrome, CONT = Control; UDDD = undifferentiated developmental disabilities)
Note: Error bars represent one standard error of the mean. Asterisks indicate conditions where, within each group of participants placement errors differed significantly from the other conditions (p< .05).

There was a main effect of group on the size of placement errors, $F(2,38)=50.27$, $MSE=228.32$, $p<.001$. Post-hoc analysis revealed that the CONT group had smaller average placement error ($M=5.39$ cm) than the Down syndrome and UDDD groups, which did not differ from one another ($M=18.12$ cm and $M=17.58$ cm). There was also a main effect of item type, $F(3,114)=22.67$, $MSE=40.33$, $p<.001$. This effect was such that placement error was smaller for real objects ($M=10.22$ cm) than for coloured blocks ($M=14.35$ cm), nonsense shapes ($M=15.48$ cm), and printed words ($M=14.74$ cm). Placement errors did not differ between coloured blocks, nonsense shapes and printed words.

The only other significant effect was an interaction between group and item type, $F(6,114)=5.69$, $MSE=40.33$, $p<.001$. Post hoc analysis indicated that for the people with Down syndrome, real objects were more accurately replaced than the other three item types. In contrast, for the CONT group, all item types were equally well replaced. Interestingly, the UDDD group was similar to the Down syndrome group in that real-world objects were more accurately replaced than both the coloured blocks and the printed words. In addition, people in the UDD group, unlike those in the DS group, showed significantly more errors for nonsense shapes than for the other three item types.

Discussion

As anticipated, CONT participants made fewer errors than did the participants in the two groups with developmental disabilities. However the people in those two groups differed somewhat in how they coped with the different item-types. The people with Down syndrome replaced the everyday objects better than the other three types (which did not differ), but even the everyday objects were not as well replaced as by the CONT group. The UDDD group also replaced the everyday objects most accurately (though again less so than the CONT group). In line with our predictions, though, placement errors for the other three item types were larger for both printed words and coloured blocks, and were larger still for nonsense shapes.

The Down syndrome group performance was partially in line with our predictions. In comparison with the UDDD group, the nonsense shapes were not more poorly remembered relative to the other categories. Thus, although nonsense shapes were not better placed by people with Down syndrome, the fact that they were not less well placed than coloured blocks and printed words, indicates that they have a relative advantage over other groups for items that do not readily afford a verbal label. Results for the CONT group need not be seen as evidence contrary to that notion: Their performance was superior in all item categories, and thus may represent a floor effect for positioning error, so that items that are not readily named had little scope to be less well replaced than other items.

The present results are consistent with those of Dulaney et al. (1996) and Zucco et al. (1995) in that they suggest that overall spatial abilities are not spared in people with Down syndrome and UDDD. These results thus further refute the hypothesis that spatial processing, being on the more automatic end of the processing spectrum, should be preserved in individuals with developmental disabilities. Also, the fact that the everyday objects, the coloured blocks, and the printed words were not more uniform in supporting spatial recall accuracy suggests that individuals in these populations will perform better in relating concrete objects to spatial information, than symbols in the form of coloured markers or printed verbal labels. Ability to identify and name an item or its characteristic, (e.g., colour; a prerequisite for participation), therefore should not be taken as an indicator of distinctiveness, at least with regard to spatial information about the item. Though not explicitly tested in this study, these findings may be relevant to depicting important spatial information, such as maps or layout schematics for people in these populations. For example, it seems likely that a map on which locations were marked with pictorial representations would likely be better remembered than one with verbal labels, even for those who have a demonstrated ability to read and understand those labels.

Not tested within this paradigm was the ability of the participants to recall which particular items they had studied on a given trial. Had they been asked to pick the studied items from a set of same-category distractors before replacing them, we may have seen a group by item-type interaction even more strongly in line with that hypothesized. Future work will focus on establishing verbal/non-verbal processing distinctions in Down syndrome.

Endnotes

[1] Peabody scores for these two groups differed significantly. However, separate analysis of their data, in which performances were compared both with and without Peabody scores as a covariate, indicated that receptive language ability accounted for less than 1% of the between-participant variability in spatial memory performance. Hence this difference was not of critical concern in interpreting the performance data. A similar analysis, involving all 3 groups of participants, indicated that group differences in memory / coding performance could not be attributed to chronological age.

[2] Ideally, the nonsense shapes ought to have been pre-exposed also so that any priming effects would be attenuated, but because the location and not the specific items per se were to be recalled this omission is less serious than it would otherwise have been. Further, the fact that in the control condition the printed words were, numerically at least, the worst recalled with respect to location, suggests that pre-exposure to the items did not determine location recall levels.

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