Subtypes of Developmental Coordination Disorder

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Although the heterogeneity of children with developmental coordination disorder (DCD) has been well documented, the search for subtypes within the DCD population with distinguishable profiles has been limited. The present study investigated whether a group of 80 children identified as having DCD could be classified into subtypes based on their performances on six perceptuo-motor tasks. Five clusters were identified and are discussed in terms of current understanding of DCD. This exploratory study supports the notion of heterogeneity within DCD samples, with five patterns of dysfunction emerging.

The wide-ranging difficulties of children who bear the label clumsy, dyspraxic, or DCD are well documented. Within the clinical/descriptive literature, problems with tasks such as standing on one leg and hopping are mentioned as frequently as problems with catching a ball, fastening buttons, drawing a triangle, and using a knife and fork (Arnheim & Sinclair, 1979; Gordon & McKinlay, 1980; Gubbay, 1975b; Henderson & Hall, 1982). However, separate studies have also focused on individual aspects of motor behavior and have provided data on the consequences of failure in these areas of performance. For example, in the gross motor area activities such as running, jumping, and hopping have been shown to present problems for the child with DCD, which results in lack of participation in sport (Larkin & Hoare, 1991) and lack of physical fitness (O’Beirne, Larkin, & Cable, this volume) as well as social isolation and loss of self-esteem.

In addition to studies that simply describe the range of functional tasks that children with DCD find difficult, recent research efforts have also attempted to identify processing deficits that might underlie poor performance. In particular much effort has gone into the investigation of links between problems of perception and impairment of movement. This has included kinesthesis (Bairstow & Laszlo, 1981; Laszlo & Bairstow, 1983, 1985a, 1985b; Laszlo, Bairstow, Bartrip, & Rolfe, 1988) and vision (Hulme, Biggerstaff, Moran, & McKinlay, 1982; Hulme, Smart, & Moran, 1982; Lord & Hulme, 1987a, 1988).

Throughout the literature just described, it has implicitly been acknowledged that the terms clumsiness, DCD, and developmental dyspraxia are used to describe children who vary considerably in the pattern of perceptuo-motor difficulty they manifest (Ayres, 1985; Dare & Gordon, 1970; Dawdy, 1981; Gubbay, 1975b), as well as in the extent

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to which they experience additional difficulties (De Ajuriaguerra & Stambak, 1969; Henderson & Hall, 1982). Explicitly, however, very few attempts have been made (a) to determine whether it is possible to identify coherent subgroups within the general population of children labeled DCD/clumsy and (b) to establish what the practical implications of such subdivision might be.

Various approaches have been taken to the identification of subtypes of children with developmental problems. One dimension on which the approaches vary is the level at which the homogeneity is sought. At one level, it may be that patterns of co-occurrence across different domains of behavior are investigated. For example, children with different primary problems may be thought to show different associated perceptual or social/emotional difficulties. At another level, it may be that the search for subtypes is confined to one domain of behavior, such as language or motor performance. Although both of these approaches can be found within the literature on children with DCD, the first is far the most common (Ayres, Mailloux, & Wendler, 1987; Dare & Gordon, 1970; De Ajuriaguerra & Stambak, 1969; Henderson, 1992; Henderson & Hall, 1982; Sugden & Sugden, 1991).

Another dimension on which the search for subtypes varies is the method used to determine homogeneity. These are often described as clinical/descriptive and statistical approaches. Broadly speaking, the defining feature of the clinical approach to subtyping is that it relies heavily on the theoretical position, experience, and intuition of the clinicians involved. Generally, a group of children’s scores on a range of preselected tests are standardized and plotted as profiles on the same scales. These profiles are then inspected for similarities and any emergent subgroups described. Although this approach can be very useful, as Fletcher and Satz (1985) and Hooper and Willis (1989) point out it has two disadvantages. It is difficult to use with large data sets and may be subject to a priori bias on the part of the investigator.

In contrast to the clinical approach, the statistical approach to subtyping relies exclusively on mathematically based procedures as a means of searching for subgroups among the population/sample being studied. By far the most common procedure used is cluster analysis. In this case, the initial selection of variables is just as likely to bias the outcome as it is with the clinical approach but there are more sophisticated procedures for excluding redundant measures and for ensuring that the subtypes that emerge are stable (Hooper & Willis, 1989; Lyon & Watson, 1981; Lyon, Stewart, & Freedman, 1982; Milligan & Cooper, 1987).

As noted, a number of studies have attempted to describe subgroups within the population of children labeled DCD. However, most of these have adopted an entirely clinical approach and have focused on a level of analysis that ignores differences within the perceptuo-motor domain. The purpose of the present study, therefore, was to investigate the possibility that the movement difficulties themselves might be divisible into subtypes. To achieve this, a statistical approach was adopted and the performance of a large group of children with moderate to severe movement difficulties was examined.

Method

Sample

The study included 80 children identified as having DCD. The sample was chosen from children referred to a movement education program conducted at the University of Western Australia. Referrals typically came from teachers, doctors, physiotherapists, psychologists, and parents.
After referral, confirmation as DCD subjects was based on performance of the McCarron Assessment of Neuromuscular Development (MAND; McCarron, 1982). The MAND was chosen because it measured a broad range of skills and included tasks DCD children were known to experience difficulty with. Both these characteristics are desirable for cluster analysis (Milligan & Cooper, 1987; Morris, Blashfield, & Satz, 1981).

The MAND battery consists of 10 items with the child’s performance over these tasks converted to a NeuroDevelopmental Index (NDI). The mean NDI for each age is 100 with a standard deviation of 15. Children were deemed to be DCD if their overall NDI was less than 90 and their performance was more than 1 standard deviation below the mean scaled score for their age on 4 of the 10 test items. Thus, selection of the DCD sample was based on multiple criteria: referral to a movement education program, NDI score on the MAND, and profile of performance across the MAND.

Within the sample there were 20 children each in four age groups: 6, 7, 8, and 9 years. The sample consisted of 63 boys and 17 girls. Other than the diagnosed coordination problems, no child had reported physical impairments or intellectual disabilities that prevented enrollment in a regular school classroom.

Selection of Variables

One of the most important issues in cluster analysis is the selection of variables (Milligan & Cooper, 1987). The variables must be chosen to maximize subtype differences and therefore need to be based on theoretically relevant dimensions (Hooper & Willis, 1989). For example, if the assumption is that children can be subdivided according to their visual or kinesthetic functioning, then appropriate measures of these variables must be included. When variables are selected it is also important to reject redundant variables as these obscure the analysis (Milligan & Cooper, 1987). Thus, if two tests are known to measure the same function, only one should be included (Petrauskas & Rourke, 1979). Justification should be given for the inclusion of each variable and how it might contribute to the discrimination of clusters. It is also necessary to balance the number of variables between domains to prevent bias in the derived clusters (Petrauskas & Rourke, 1979). Above all the variables must be reliable and valid (Morris et al., 1981).

In the present investigation the selection of variables for analysis was based on both clinical reports and experimental studies of children with movement difficulties. From the experimental literature it was predicted that perceptual performance might be used as a distinguishing feature among the children. Recent research has indicated that both visual (Hulme and colleagues) and kinesthetic (Laszlo and colleagues) difficulties are common in children with DCD although these results have been somewhat inconsistent (Doyle, Elliott, & Connolly, 1986; Elliott, Connolly, & Doyle, 1988; Hoare & Larkin, 1991). From the clinical literature it was hypothesized that subtypes based on visual–motor, manual dexterity, and gross motor dimensions might be present (Brenner & Gillman, 1966; Lord & Hulme, 1987a, 1987b; Sovik & Maeland, 1986; Stott, Moyes, & Henderson, 1984). Based on these hypotheses and personal clinical observation, six variables were chosen for inclusion in the cluster analysis.

Kinesthetic Acuity. To isolate a subtype that might be kinesthetically dysfunctional it was necessary to include a kinesthetic variable. The kinesthetic acuity test from the Kinaesthetic Sensitivity Test (Laszlo & Bairstow, 1985b) was chosen because of its recent use in the literature (Doyle et al., 1986; Elliott et al., 1988; Laszlo & Bairstow, 1985a, 1985b; Laszlo et al., 1988). The kinesthetic acuity test measures the ability to discriminate between the heights of two inclined runways. The protocol used for this test was as per Hoare and Larkin (1991).
Motor Free Visual Perception Test. Recent research has suggested children with DCD may experience difficulty with visual–perceptual tasks and this may contribute to their coordination problems (Hulme, Biggerstaff, Moran, & McKinlay, 1982). For this reason the Motor Free Test of Visual Perception (MVPT; Colarusso & Hamill, 1972) was included in the cluster analysis. As the name suggests this is a “motor-free” test of visual perception that provides an accurate measure of this ability without the contamination of a motor response from the child. Reported reliability has ranged between .71 and .84 (Colarusso & Hamill, 1972). The test consists of 36 multiple-choice plates that are individually administered. The plates are subdivided into those measuring figure ground discrimination, visual memory, visual closure, visual discrimination, and spatial relationships. The subject was required to indicate the response that she or he felt was correct. The child was given a score for the total number of plates correct out of 36.

Visual–Motor Integration. To enable the identification of a visual–motor subtype, the Beery (1967) Test of Visual–Motor Integration (VMI) was included. The VMI has been used extensively to assess children with coordination problems (Brenner & Gillman, 1966; Brenner, Gillman, & Farrell, 1968; Brenner, Gillman, Zangwill, & Farrell, 1967; Kimball, 1977). Reliability has been reported between .80 and .90 (Beery, 1967). The VMI requires the child to manually copy a series of 24 geometric drawings of progressively increasing difficulty. The final score given was the most difficult form the child successfully completed, providing the child had not failed three forms before this.

Purdue Pegboard. Given the frequent observation of manual dexterity problems in DCD children it was hypothesized that the group may be subdivided along this dimension. The Purdue Pegboard (Tiffin, 1968) was included to identify possible fine motor coordination problems. The Purdue Pegboard has had considerable use in both the psychological and motor development literature (Gardner, 1979). Reported reliabilities have ranged between .60 and .91 (Tiffin, 1968). The task consisted of a board with two parallel rows of 25 holes, with containers located above these rows. The child was required to place as many pins as possible into the holes on the same side as the preferred hand one at a time in a 30-s period. This was repeated on the other side with the nonpreferred hand. The results for these two tasks were summed to provide an overall score.

Static Balance. To determine if subtypes were present along gross motor dimensions, a test of static balance was included. Static balance tasks are often included in motor assessment batteries (Bruininks, 1978; Cratty, 1970; Stott et al., 1972, 1984). The protocol followed in this task was that of McCarron (1982) and had a reliability of .83. The child was required to balance on one leg for as long as possible to a ceiling time of 30 s. This was repeated with the nonpreferred leg. The subject was given a second attempt at any trial if the balance was held less than 10 s. The scores for the preferred and nonpreferred side were summed to give an overall score.

Run. The run task was included as a complex gross motor activity that has frequently been used as an assessment of motor development (Calder, 1979). Reliability estimates have been placed at .86 for a 50-yd dash (Fleishman, 1964). The subject was required to run 50 m as quickly as possible (each subject was given one trial). The score was the time taken to the nearest 0.1 s (Pyke, 1986).

Treatment of the Data
All scores were standardized within an age group to a mean of 0 and a standard deviation of 1. When variables are measured in different units standardization is strongly recommended (Milligan & Cooper, 1987). The standardized scores were then checked for outliers. This was deemed to be a score more than 3 standard deviations away from
the mean on any task (Tabachnick & Fidell, 1989). One outlier was found and was removed from the subsequent cluster analysis, as outliers have been found to distort clusters (Morris & Fletcher, 1988).

Following this, the scores of the 79 subjects on the six variables were subjected to a series of cluster analyses to determine how many clusters were in the group using the CLUSTER program in SAS. This is a hierarchical agglomerative procedure based on squared euclidean distances (Morris et al., 1981). Four clustering methods were used to determine the number of clusters: Ward’s minimum variance, average linkage, complete linkage, and centroid. The cubic clustering criterion and pseudo t statistic were used as indicators of the number of clusters (Milligan & Cooper, 1985). In addition the method suggested by Morris et al. (1981) of examining jumps in cluster coefficients was also used.

To test the internal validity of the clusters the data were then subjected to an iterative partitioning method of cluster analysis using the FASTCLUS procedure in SAS (Morris et al., 1981). This procedure is based on the K means method. The program sets up the initial cluster seeds such that they cover the range of profiles expected (Romesburg, 1984). Each observation is then temporarily assigned to the cluster it appears most similar to. With each iteration this process continues until the change in position of the cluster seeds is small enough that it terminates the program. This method allows continuous adjustment in cluster membership as the analysis continues. If a large number of subjects change clusters with each iteration the cluster solution is unstable (Morris et al., 1981). If a small number change clusters during iteration the cluster solution is stable.

As a further means of testing the internal validity of the clusters, Morris et al. (1981) suggest adding a group of subjects to the analysis with average or above average profiles. If the solution is stable it is expected that this group will form a new cluster with little change in the makeup of the other clusters. Therefore the scores for a group of 20 normally developing 9-year-olds were added to the analysis and it was reclustered to test its internal validity.

Results

NeuroDevelopmental Index (NDI)

The mean NDI of the subjects was 74.6 ± 10.5. This placed the group in the mild disability range according to the McCarron (1982) norms. The NDI scores for the subjects ranged between 49 and 89 with 64% considered mildly disabled (NDI score between 70 and 90), 31% moderately disabled (NDI score between 55 and 70), and 5% severely disabled (NDI score below 55). This indicates there was variability in the severity of movement dysfunction and that the test battery therefore satisfied the criteria for use in cluster analysis, because the sample contained subjects with a wide range of profiles (Milligan & Cooper, 1987).

Cluster Analysis

Of the four clustering methods used to determine the number of clusters present, three (Ward’s minimum variance, centroid, and average linkage) indicated there were five clusters in the data. In addition, the method of Morris et al. (1981) of examining jumps in cluster coefficients also suggested there were five clusters in the data.

Ward’s method was adopted for the subsequent analysis as it has been considered
the most appropriate (Milligan & Cooper, 1987). In the validation testing using the iterative method in FASTCLUS, 14% of subjects changed their cluster membership over all iterations. When Ward’s method was compared to the iterative method, a total of 70% of children were located in the same cluster. This included one cluster that had identical membership. One smaller group in the hierarchical method \((n = 6)\) became nested in a larger cluster in the iterative method. Thus, while these children were actually in a different cluster they still remained clustered together. With this considered, 77% of subjects remained stable in their cluster membership.

When the scores of a group of 20 normally developing children were added to the results to examine internal validity, a new cluster was formed containing 18 of the 20 non-DCD children and 8 DCD subjects. This represented a total change of 10% in cluster membership.

The FASTCLUS procedure provided cluster means for each variable. Figure 1 graphically shows the standard score profiles for each of the five clusters. The zero point represents the mean score of the DCD sample. This allows comparison between subtypes across the tasks used (Bender & Golden, 1990).

Cluster 1 had the largest membership—22 children. This group’s scores on the visual perception \((0.00)\) and visual motor \((-0.11)\) tasks were close to the mean. Purdue Pegboard was above average in comparison to the rest of the DCD sample \((0.46)\), as was static balance \((0.77)\). In contrast, this group had below average scores for the run \((-0.42)\) and kinesthetic acuity \((-0.41)\).

Cluster 2 consisted of 20 subjects. The primary characteristic of this group’s performance was above-average scores on the visual perception \((0.91)\) and visual motor \((0.94)\) tasks. Standardized scores relative to the remainder of the DCD sample on other tasks were \(-0.09\) (kinesthetic acuity), \(0.26\) (Purdue Pegboard), \(-0.18\) (static balance), and \(0.50\) (run).

Cluster 3 contained 15 members who experienced difficulty with the visual motor \((-1.06)\), visual perception \((-0.97)\), and Purdue Pegboard \((-1.02)\) tasks in comparison to the rest of the DCD group. Their scores for kinesthetic acuity \((-0.68)\) and static balance \((-0.55)\) were also below average, with only their ability to run close to the mean \((-0.07)\).

Cluster 4 consisted of 14 children whose performance was above average on kinesthetic acuity \((1.08)\) and to a lesser extent run \((0.72)\) and Purdue Pegboard \((0.57)\). Remaining scores were static balance \((0.27)\), visual motor \((0.10)\), and visual perception \((-0.30)\).

Cluster 5 was a smaller group of 8 subjects. Their scores for the six tasks were kinesthetic acuity \((0.76)\), visual perception \((0.05)\), visual motor \((-0.24)\), Purdue Pegboard \((-1.04)\), static balance \((-1.10)\), and run \((-1.21)\).

Discussion

Before the results obtained in the present study are discussed, it is important to note that the cluster solution that emerged was entirely dependent on the variables that were entered in the analysis. The inclusion of other variables might have altered the outcome. Despite this, however, the stability of the cluster solution was impressive as most children stayed in the same cluster when different methods of grouping were used. Also the internal validity of the five clusters was established through demonstration of stability when a nonimpaired group’s scores were added to the analysis. Given this stability and validity it is appropriate to discuss the clusters in terms of hypothesized subtypes, noting
Figure 1 — Cluster profiles for five subtypes of DCD children. The zero point represents the mean score of the DCD group. Task a = kinesthetic acuity; Task b = visual perception; Task c = visual motor; Task d = Purdue Pegboard; Task e = static balance; Task f = run.
of course that discussion of the clusters needs to take account of the fact that the task scores were standardized against the mean scores for the DCD group. Thus a score that is above average is only so relative to the DCD group.

The pattern of performance in Cluster 1 was interesting as there was a large difference in performances on the two gross motor tasks—static balance and run, suggesting that the notion of a subtype of DCD children with an overall gross motor difficulty might be too general. This finding also supports the separation of tasks requiring static balance from those requiring more gross body coordination or locomotor agility in assessment batteries (Bruininks, 1978; Stott et al., 1972, 1984).

Cluster 2 was distinguishable by the subjects' above-average skills in tasks requiring visual judgments relative to the remainder of the DCD sample. This provides evidence against the notion of generalized visual dysfunction in DCD children (Hulme, Biggerstaff, Moran, & McKinlay, 1982; Hulme, Smart, & Moran, 1982). Thus, when one is looking at previous research it is important to recognize that although the DCD population may perform poorly as a group, within the group there may be individuals who are visually competent.

Cluster 3 subjects had particular difficulty with both visual and kinesthetic tasks, suggesting a generalized perceptual dysfunction, supportive of the observations of both Hulme and Laszlo and colleagues. Interestingly, subtyping of learning-disabled populations has also frequently identified groups with visual-based difficulties (Bender & Golden 1990; Hung, Fisher, & Cermak, 1987; O'Brien, Cermak, & Murray, 1988; Satz & Morris, 1981). Of the 15 subjects in Cluster 3, 10 were considered learning disabled by their teachers, which provides further support for this relationship. It also suggests that the results of Hulme and colleagues, which have indicated a relationship between visual perception and motor problems in children with DCD, may have been due to the method of identification of the sample, because this was on the basis of academic failure. The identification of a subtype of DCD children with associated problems was also in line with the descriptive subtyping study of Henderson and Hall (1982).

Cluster 4 children were characterized by their particularly good kinesthetic processing relative to the rest of the DCD group. These children clearly do not have kinesthetic problems, as suggested by Laszlo and colleagues (1985a, 1985b, 1988). However, there was a large difference between their performances on the visual and kinesthetic tasks, suggesting there may have been a visual contribution to movement dysfunction. Rather than a generalized perceptual dysfunction as in Cluster 3, the inability was specific to one domain showing some separation of perceptual function.

Cluster 5 was the smallest group and the subjects clearly experienced execution problems. Their performances on motor-loaded tasks were well below average and lower than their scores for any of the perceptual tasks. This was especially so for the kinesthetic task, as the score for this was well above average in comparison to the rest of the DCD group. This subtype was hypothesized as representing the child with DCD who has greatest difficulty in executing motor tasks (Geuze & Kalverboer, 1987; Kalverboer & Brouwer, 1983; Schellekens, Scholten, & Kalverboer, 1983).

When the patterns of performance exhibited by the five clusters of children were compared, some interesting contrasts emerged. For example, the differences between the profiles on both aspects of perception support the idea that neither of these deficits is an essential component of the disorder. In the case of the visual tasks, one group of children (C2) clearly scored above average, while another group was well below (C3). Similarly for the kinesthetic tasks, there were differences in profile, and in three clusters
there was a dissociation between visual and kinesthetic performance. Thus, among a group of children who are equally impaired overall, one can find examples of perceptual deficits that generalize across modalities as well as examples that are highly specific. Such variation in profile was also evident among the other tasks included in the study.

Summary and Implications

The present investigation raises a number of issues regarding the characteristics of children with DCD from a research point of view. It is clear that the heterogeneity demonstrated here along with variation in definition and identification can in some part account for what appear to be inconsistent findings. Clearly, we need to move toward more universal definitional criteria in order to provide some consistency across investigations. In particular, the characteristics of DCD samples should be described in detail including how they were identified and assessed to facilitate comparison.

Although these findings are exploratory and need confirmation through subsequent analysis of additional perceptuo-motor tasks and DCD samples, the results are interesting from a practical point of view. For example, it would be of great interest to conduct an intervention study in which members of identified subtypes are given intervention specific to their deficits to determine if they respond differently to more specific training. Through such research it may be possible in the future to determine if particular teaching methods are more effective with given DCD subtypes.

References

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