Prediction in Ball Catching by Children With and Without a Developmental Coordination Disorder

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This study aimed to determine how predicting ability in ball catching changes with age and to explore this among children with developmental coordination disorder (DCD) as judged by performance on the Movement Assessment Battery for Children (Henderson & Sugden, 1992) and by clinical evaluation. In Experiment 1, participants were 157 non-DCD children, age 5–12. In Experiment 2, 46 participants (age 5–7) from Experiment 1 were controls for 40 same-age children with a DCD. In Experiment 1, younger children (age 5–6) did not predict ball flight as well as older groups at short viewing times, and girls did not predict as well as boys. In Experiment 2, DCD children predicted more poorly at most viewing times compared to non-DCD peers. It was concluded that age and gender are crucial factors in predicting ball flight and that predicting ability is a fundamental problem in catching for younger, female, and DCD children.

In many cultures, children with strong object-control skills have an advantage because playground games and physical education classes often include throwing and catching activities. Usually, children become increasingly competent in such domains with age and experience (Branta, Haubenstricker, & Seefeldt, 1984; Thomas & French, 1985; Ulrich, 1984). Yet, some children with developmental coordination disorder (DCD; American Psychiatric Association, 1987; Henderson, 1994) have considerable difficulty with ball-related activities (Hoare, 1994). Some authors have suggested that such problems are due to disturbances in visual perception (Hulme, Biggerstaff, Moran, & McKinlay, 1982; Hulme, Smart, & Moran, 1982; Lord & Hulme, 1987; Williams, 1983) or movement control (von Hofsten, 1980, 1982, 1983; von Hofsten & Lindhagen, 1979), or lack of experience (Wall, 1990; Wall, McClements, Bouffard, Findlay, & Taylor, 1985; Wall, Reid, & Paton, 1990). In this paper, we explore the development of ball trajectory prediction—an example of visual perception—with typically developing children, age 6–12 (Experiment 1) and by comparing children with and without DCD (Experiment 2).

Researchers have investigated catching from numerous theoretical and empirical perspectives. Studies with adults have explored expert and novice perform-

Research on how infants intercept moving objects indicates that interception has three aspects: perceiving the motion, starting hand movement, and moving the hand ahead of the object for accurate interception (von Hofsten, 1983, 1991; von Hofsten & Lindhagen, 1979). Young infants already possess a remarkable capacity to reach for stationary objects. By 4 months, they can reach and grasp them. Therefore, the infant is tracking the object and correctly perceiving velocity. By 4–5 months, babies can intercept moving objects, albeit with awkwardly controlled arm movements (von Hofsten, 1983, 1991; von Hofsten & Lindhagen, 1979). Arm control, more than perception, may be the major problem for infants. By 7–8 months, they show less deviation in reaching movements, suggesting greater arm control. However, considerable difference exists between catching an object fixed on a moving rod and catching one in free flight (von Hofsten, 1983, 1991; von Hofsten & Lindhagen, 1979). The skill level required to perform a rudimentary catching task takes 2 or more years of development. Numerous factors, such as ball size, color, speed, trajectory, distance, and height of interception point, can make the task simple or complex (Belka, 1985; Herkowitz, 1978; Isaacs, 1980; McConnell & Wade, 1990; Morris, 1976; Payne, 1985; Payne & Koslow, 1981; Strohmeyer, Williams, & Schaub-George, 1991; Wade, 1980). The individual is constantly required to make appropriate decisions based on changing situations. As the task becomes more complex, predictions are more difficult.

Viewing the entire ball trajectory is not necessary for successful catching (Sharp & Whiting, 1974, 1975; Whiting & Sharp, 1974), because subjects anticipate the final location of the ball. Research with adults also indicates that both total time to view a ball and the position of the ball when seen in its trajectory are very important in explaining catching behavior (Sharp & Whiting, 1974; Whiting et al., 1970; Whiting & Sharp, 1974).

Indeed, appropriate decision making in sport is important. Successful ball players may pick up cues earlier than novices. Many anticipation and prediction studies have attempted to isolate a perceptual basis for expert performance by simulating the field setting through use of film taken from a player’s perspective. The film can be manipulated to limit cues arising from specific time periods in the opponent’s movement (e.g., Abernethy, 1988, 1989; Abernethy & Russell, 1987; Buckolz et al., 1988; Goulet, Bard, & Fleury, 1989; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984) or from specific spatial regions of the display (e.g., Abernethy, 1988; Abernethy & Russell, 1987). The subject is asked to predict event outcome based on limited information. Not only are advanced cues useful and crucial to the decision-making process, experts can extract and use this information more effectively than less-skilled players (Abernethy, 1988, 1989, 1990; Abernethy & Russell, 1987; Buckolz et al., 1988; Goulet et al., 1989; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984). These findings support research by Whiting and colleagues (Sharp & Whiting, 1974, 1975; Whit-
ing & Sharp, 1974), who concluded that useful information is available early in the flight trajectory of an object.

These conclusions parallel the knowledge-based model of motor development (Wall, McClements, Bouffard, Findlay, & Taylor, 1985), which suggests that motor development is largely an accumulation of a sophisticated knowledge base. Thomas, French, and Humphries (1986) suggested that the knowledge base contributes to sport performance. Individuals who are highly knowledgeable about a sport are not only better able to make appropriate decisions, they can do so based on less information and more quickly than an individual with less knowledge (Allard & Burnett, 1985; French & Thomas, 1987; Starkes & Deakin, 1984). Thus, highly skilled individuals have the knowledge to make appropriate decisions in less time and with less information.

Catching performance can be used to differentiate young children from older ones as well as youngsters with and without DCD (Hoare, 1994; Thomas & French, 1985; Ulrich, 1984). However, is visual perception of minimal importance, as von Hofsten’s (1979, 1983, 1991) work with infants would suggest, or does it play a larger role, as argued by Hulme and colleagues (Hulme, Biggerstaff, Moran, & McKinlay, 1982; Hulme, Smart, & Moran, 1982; Lord & Hulme, 1987) and Williams (1983)? Simulating the field setting by using film and requesting children to predict the direction of ball flight may shed light on the role of visual perception. If age differences in predicting ball flight do exist, and children with DCD have difficulty predicting ball trajectory, then visual perception is likely an important limiting factor in catching performance.

One common indicator of DCD is delayed motor-skill development (Gubbay, 1975; Wall et al., 1985). Essentially, children with DCD do not acquire sufficient skills to handle the task demands of their environments. These difficulties often leave them open to ridicule from peers, which in turn contributes to poor self-esteem (Wall, 1982). Therefore, highlighting the differences between children with and without DCD is essential to understanding the disorder and increasing intervention effectiveness.

In our experiments, we aimed to explore the developmental phenomenon of ball trajectory prediction. Specifically, our purpose was to determine how predicting ability in a ball-catching task changes with age and to explore predicting abilities of children with DCD. Since most related research has been done with expert or novice adults, we first assessed how typically developing children progressed with the ball prediction task.

**Experiment 1**

**Method**

**Participants**

A total of 157 children (73 boys, 84 girls), age 5–12 ($M = 8.6$, $SD = 2.1$), participated in this study. Informed consent was obtained from parents or guardians. The sampling design was purposive. Children attended the same elementary school in a middle class, suburban area of a large Canadian city, and were largely Caucasian. The physical education teacher used the Motor Performance Rating Scale ($r = .75$), developed by Weir (1992), to confirm that children who would participate did
not have a DCD. The scale consists of 10 questions that evaluate the child’s performance level on commonly observed motor activities. In total, 12 children were excluded from the study. The remaining participants were subdivided into four age groups (see Table 1).

Instrumentation

Ball-tracking ability was assessed using a video that depicted softball trajectories. A 12-year-old boy, standing at a distance of 13 m, was seen throwing a ball overhand to the right, center, and left of the camera. The 13-m distance allowed sufficient time to view the ball and kept it in camera range, yet provided a clear view of the thrower. The ball was thrown to a 0.5-m² target, which was not visible on the video. The center of the target was 90 cm from the floor. This is considered the height where a 12-year-old child would catch a ball thrown at chest level. The target was placed in front of the camera for a center throw and at 0.8 m to the left and right for respective throws. This is the estimated distance required by a child to catch a ball with a small step.

In previous studies, average viewing times have been 20, 40, 60, 80, and 100% of total flight duration (e.g., Lamb & Burwitz, 1988; Nessler, 1973; Whiting, Alderson, & Sanderson, 1973). However, pilot work showed that the 60, 80, and 100% proportions made prediction too easy. Further, correct predictions are facilitated by advanced cues (Abernethy, 1989; Abernethy & Russell, 1987; Bulckolz et al., 1988), such as shifted body weight, eye movement, or subtle arm movements. Therefore, the three trajectories were divided into four viewing times: 0, 3, 6, and 9 frames from the moment of ball release (30 frames = 1 s), which is 0, 14, 28, and 42% of total flight time.

The experiment consisted of five trials for each location and four viewing time combinations, for a total of 60 randomly organized trials. Thus, the maximum score for each location and time combination was five correct responses. That is, the participant could score 1, 2, 3, 4, or 5, corresponding to the number of correct responses for each location and time combination. The number of correct responses served as the dependent variable. There were 12 practice trials, consisting of an example of each location viewed in full and at 42, 14, and 0% flight time.

Procedure

Testing was carried out individually in a quiet room, free of distractions, at the elementary school. Each child stood 1-2 m from the front of the monitor. Before each trial, the screen was black except for the word ready. This was followed by a

<table>
<thead>
<tr>
<th>Table 1 Number of Participants in Each Age Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group (years)</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>5–6</td>
</tr>
<tr>
<td>7–8</td>
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<tr>
<td>9–10</td>
</tr>
<tr>
<td>11–12</td>
</tr>
</tbody>
</table>
catching

3-s pause for preparing to view the boy as he arranged to throw and release the ball. A 5-s waiting period following each trial allowed participants to record an answer. Each child answered by lifting the right hand if it was predicted that the ball would go to the right, the left hand if the prediction was to the left, and both hands to the chest if the prediction was to the center. After 30 trials, each child had a 3-min rest before finishing the second half of the trials.

Treatment of the Data

Analyses of variance were conducted using the number of correct responses as the dependant variable. The design was a \( 4 \times 2 \times 3 \times 4 \) (Age \( \times \) Gender \( \times \) Location \( \times \) Time) factorial with repeated measures on the last two factors. Four-way ANOVAs were used to analyze the data. Significant differences were examined using one-way ANOVAs and Tukey’s HSD on between-subject factors to find the differences in third and fourth level factors. Simple contrasts were used for within-subject factors.

Results

Main effects for age, \( F(3, 149) = 9.37, p < .01 \), and gender, \( F(1, 149) = 20.51, p < .01 \), were significant. We also found significant main effects for location, \( F(2, 298) = 217.76, p < .01 \), and time, \( F(3, 447) = 945.66, p < .01 \). Time by age, \( F(9, 447) = 10.85, p < .01 \), and time by gender, \( F(3, 447) = 14.71, p < .01 \), interactions were significant, as were those between location and time, \( F(6, 894) = 186.93, p < .01 \), and location, time, and age, \( F(18, 894) = 2.65, p < .01 \). This triple interaction, which takes priority over other findings, will be discussed first, as anything said about “the main effects will be colored by the presence of the higher order interaction” (Keppel, 1973, p. 284).

The interaction for location, time, and age is shown in Figure 1. Descriptive statistics are presented in Table 2. One-way ANOVAs across age were performed for each location/time variable. Results revealed no significant effects for age at any viewing times for the left location. However, we found a significant main effect for age at the center location at 0%, \( F(3, 153) = 10.68, p < .01 \). Tukey HSD post-hoc comparisons revealed that the effect was caused by the 5- to 6-year-old group’s significantly lower score (compared to the others). We found no age effect for the center location at 14, 28, and 42% of total flight time. There was a significant effect for age for the right location at 0%, \( F(3, 153) = 7.39, p < .01 \), and 14% of total flight time, \( F(3, 153) = 5.96, p < .01 \), but not at 28 and 42%. Follow-up comparisons revealed that the difference for the right location, at 0%, was due to the youngest age group’s significantly lower score (compared to the others). We found no age effect for the center location at 14, 28, and 42% of total flight time. There was a significant effect for age for the right location at 0%, \( F(3, 153) = 7.39, p < .01 \), and 14% of total flight time, \( F(3, 153) = 5.96, p < .01 \), but not at 28 and 42%. Follow-up comparisons revealed that the difference for the right location, at 0%, was due to the youngest age group’s significantly lower score (compared to the older groups). HSD also showed that the significant effect for the right location, at 14% of total flight, was due to the youngest age group’s significantly lower scores (compared to the older groups). Thus, all groups usually scored better on the left location. The center and right locations were difficult only at the earliest viewing times and only for the youngest group.

Time also interacted with gender. Subsequent one-way ANOVAs across gender were performed for each time variable. Results revealed a significant difference between males and females only at 0%, \( F(1, 155) = 24.59, p < .01 \), and 14% of total flight, \( F(1, 155) = 8.29, p < .01 \). Thus, females differ from males only when the ball is in flight for the shortest time intervals.
Figure 1 — Number of correct predictions for time and age at each location.
### Table 2  Mean Scores for Age Groups Across Location and Time

<table>
<thead>
<tr>
<th>Age group</th>
<th>Location</th>
<th>Time (% of total flight)</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>Left</td>
<td>0</td>
<td>4.16</td>
<td>0.20</td>
<td>4.85</td>
<td>0.07</td>
<td>4.98</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td>2.89</td>
<td>0.23</td>
<td>4.76</td>
<td>0.08</td>
<td>5.00</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.33</td>
<td>0.27</td>
<td>3.92</td>
<td>0.19</td>
<td>4.96</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>7-8</td>
<td>Left</td>
<td>4.20</td>
<td>0.15</td>
<td>4.95</td>
<td>0.06</td>
<td>4.98</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td>3.80</td>
<td>0.18</td>
<td>4.88</td>
<td>0.06</td>
<td>4.96</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1.06</td>
<td>0.21</td>
<td>4.66</td>
<td>0.14</td>
<td>4.89</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>9-10</td>
<td>Left</td>
<td>4.19</td>
<td>0.15</td>
<td>5.00</td>
<td>0.06</td>
<td>4.98</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td>3.96</td>
<td>0.18</td>
<td>4.81</td>
<td>0.06</td>
<td>5.00</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1.34</td>
<td>0.20</td>
<td>4.52</td>
<td>0.14</td>
<td>4.93</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>11-12</td>
<td>Left</td>
<td>4.23</td>
<td>0.17</td>
<td>4.95</td>
<td>0.06</td>
<td>5.00</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td>4.31</td>
<td>0.20</td>
<td>4.82</td>
<td>0.07</td>
<td>4.89</td>
<td>0.03</td>
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</tr>
<tr>
<td></td>
<td>Right</td>
<td>1.99</td>
<td>0.23</td>
<td>4.48</td>
<td>0.16</td>
<td>4.82</td>
<td>0.07</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Maximum score = 5.
Discussion

We expected that all groups would predict poorly at 0% of total flight because very little visual information was available. However, the significant Age x Time and Gender x Time interactions indicate that this was not the case. Apparently, prethrowing cues—evident at 0% of total flight time—are used by some older catchers to predict effectively. The 5- and 6-year-old children are likely unaware of such cues and thus predicted poorly at 0% of total flight. By age 7 or 8, children have the knowledge to use these advanced cues.

A similar pattern was evident for gender. Females did not predict as well as males at 0 and 14% of total flight time. Apparently, young children and females cannot extract information that facilitates making appropriate decisions at early viewing times. This may be because they are just beginning to experience ball activities at school and on the playground. Males might participate more often in ball activities and therefore tend to have greater experience in and sensitivity for throwing cues that are available prior to ball release. In addition, males may have been more motivated to do well in our experiment.

Overall, these findings are consistent with and may shed some light on Thomas and French (1985), who indicated that, beginning in the elementary school years, boys’ catching performance exceeds that of girls. Apparently, young children and females require more time and thus more information to make accurate predictions.

When direction of ball trajectory was considered, more viewing time was required to accurately predict the right location compared to other locations, particularly for younger participants. The right location is likely difficult because the thrower’s arm moves across the body, and at the point of ball release, cues are only subtly different from those for the center location. This would hold true for a ball thrown to the left of a receiver by a left-handed thrower. Again, subtle cues are more accessible for older individuals, who may have more experience. Thus, data suggest that age is a crucial factor in predicting ball flight. This may be related to experience, which is congruent with previous studies on expertise (e.g., Abernethy, 1988, 1989; Abernethy & Russell, 1987; Buckolz et al., 1988; Goulet, Bard, & Fleury, 1989; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984).

Results of Experiment 1 indicated that even young children can predict ball-landing location based on limited visual information. Such data are similar to those found in previous studies with adults (Sharp & Whiting, 1974, 1975; Whiting & Sharp, 1974). However, consistent with Williams (1983), younger children did not predict the ball trajectory as accurately as older groups when viewing time was diminished. Children with DCD might have similar difficulties; problems in spatial prediction have been suggested as a cause of their motor problems (Hulme, Biggerstaff, Moran, & McKinlay, 1982; Hulme, Smart, & Moran, 1982; Lord & Hulme, 1987). Therefore, we conducted Experiment 2.

Experiment 2

Method

Participants

In Experiment 2, 46 children (age 5–7)—all of them participants from Experiment 1—served as a comparison group. Forty 5- to 7-year-old children with DCD were also included (see Table 3). As with Experiment 1, our sampling design was pur-
positive, and participants with DCD attended elementary schools in a socioeco-
omic area similar to that for the non-DCD children.

The children with DCD attended a remedial swim/gym program at a local
aquatics center, which was designed for "children who are unable to cope in physi-
cal activities due to perceptual, conceptual or gross motor co-ordination difficul-
ties" (Campbell, 1993, p. 2). Because DCD is difficult to identify (Henderson &
Hall, 1982; Hoare, 1994; Larkin & Hoare, 1992; Lazarus, 1990; Wall et al., 1990),
participants in this group had to meet three criteria:

1. A recommendation from the program director as having a DCD
2. A score in the lowest 15th percentile of the ball skills portion of the Move-
   ment ABC test (Henderson & Sugden, 1992)
3. No known neuromuscular problems

The program director identified 57 children (40 boys, 17 girls) as having a
DCD. This gender distribution is consistent with previous research, which has
shown that a higher percentage of boys than girls have a DCD.

The program director had access to the children's charts, which indicated
whether a child had any other disability. If this was the case, children did not
participate in the study. We also asked the director to identify children whom she
felt had a DCD. The director has shown her accuracy in this respect: Of the 23
children she recommended in Todd's study (1988), 16 were confirmed as DCD by
the Test of Motor Impairment (Stott, Moyes, & Henderson, 1984). The ball skills
portion of the Movement Assessment Battery for Children (Henderson & Sugden,
1992) was then administered individually to potential participants.

The Movement ABC is designed to identify DCD in children age 4–12. The
battery contains 32 items grouped under three headings: Manual Dexterity, Ball Skills,
and Static and Dynamic Balance. The battery identifies only the lower 15% of the
population. Since there are DCD subtypes (Hoare, 1994; Wright & Sugden, 1996),
some children may obtain a failure score in one portion of the Movement ABC and a
passing mark in others. Collective results may place the individual in a borderline
category or in the lowest 15%. However, for the purpose of Experiment 2, we only
needed children who had difficulty with ball skills, and thus, only this portion of the
ABC was used. A total of 40 children (25 males, 15 females) fell below the 15th
percentile in the Ball Skills subtest, and thus, only these individuals participated in
our study.

Instrumentation and Procedure

We used the same video in Experiment 2, with only one procedural modification:
Children were tested in a room at the aquatic center. Data collected in Experiment
1 were used for the control group in Experiment 2.

Treatment of the Data

Our major concern in Experiment 2 was identifying developmental differences in
ball prediction for the DCD and non-DCD groups. As in Experiment 1, analyses of
variance were conducted using the number of correct responses as the dependent
variable. The design for this study was a $2 \times 2 \times 3 \times 4$ (Group $\times$ Gender $\times$ Location
$\times$ Time) factorial, with repeated measures on the last two factors. Four-way ANOVAs
were used to analyze the data. All significant differences were followed up using
one-way ANOVAs and Tukey’s HSD on between-subject factors to find differences in the third and fourth level factors. Simple contrasts were used for within-subject factors.

Results

The pattern in this analysis was similar to results for Experiment 1. Main effects for group, $F(1, 82) = 62.13, p < .01$, gender, $F(1, 82) = 6.36, p < .05$, location, $F(2, 164) = 84.40, p < .01$, and time, $F(3, 246) = 401.45, p < .01$, were all significant. Interaction between time and group, $F(3, 246) = 8.80, p < .01$, was significant, as was that between location and time, $F(6, 492) = 49.85, p < .01$. We also identified two significant three-way interactions: location, time, and group, $F(6, 492) = 6.25, p < .01$, and location, time, and gender, $F(6, 492) = 2.89, p < .01$. As in Experiment 1, the triple interactions take priority.

To understand the three-way interaction of location, time, and group, means collapsed over gender are presented in Table 3 and depicted in Figure 2. The graphs show that the DCD group had more difficulty with the right-hand location. Subsequent one-way ANOVAs across group at each location/time variable were performed. Significant group effects were found at all location/time variables except at the right location, 0% of total flight, where both groups performed poorly (see Table 4). Overall, children with DCD scored more poorly (compared to non-DCD children) for ball flight prediction at all viewing times for the left and center locations.

Unlike Experiment 1, there was a three-way interaction between location, time, and gender. Subsequent one-way ANOVAs were performed. Results revealed a significant difference between males and females for the left location at 42% of total flight, $F(1, 82) = 6.84, p < .05$, and for the right location at 14%, $F(1, 82) = 10.20, p < .05$, and 28% of total flight, $F(1, 82) = 4.25, p < .05$. Thus, females differed from males at these location/time combinations.

Discussion

The non-DCD group predicted more effectively than the DCD group at all time periods. To further understand effects, we analyzed the three-way interaction. The DCD group predicted more poorly than the non-DCD group at all time/location combinations except for the right location at 0% of total flight. As in Experiment 1, the right location is quite difficult, and both groups had equally low scores.

Compared to non-DCD peers, children with DCD require more viewing time and perhaps more visual information to predict ball flight. We expected that both

| Table 3  Number of Participants per Group |
|---------|----------|----------|
| Group   | n        | Male     | Female   |
| DCD     | 40       | 25       | 15       |
| NDCD    | 46       | 17       | 29       |
Figure 2 — Number of correct predictions for time and group at each location.
Table 4  Mean Scores for Age Groups Across Location and Time

<table>
<thead>
<tr>
<th>Group</th>
<th>Location</th>
<th>0</th>
<th>14</th>
<th>28</th>
<th>42</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>DCD</td>
<td>Left</td>
<td>3.24</td>
<td>0.22</td>
<td>3.92</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td>2.19</td>
<td>0.25</td>
<td>3.85</td>
<td>0.16</td>
</tr>
<tr>
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<td>0.17</td>
<td>2.25</td>
<td>0.23</td>
</tr>
<tr>
<td>NDCD</td>
<td>Left</td>
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<td>0.21</td>
<td>4.93</td>
<td>0.15</td>
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<td>Center</td>
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<td>0.24</td>
<td>4.84</td>
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<td></td>
<td>Right</td>
<td>0.62</td>
<td>0.16</td>
<td>4.23</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Note. Maximum score = 5. DCD = developmental coordination disorder; NDCD = non-developmental coordination disorder.
groups would predict poorly at 0% of total flight. However, this was only the case for the right location. In all other situations, the non-DCD group predicted more effectively than the DCD group, even at 28 and 42% of total ball flight, which produced no age effects in Experiment 1. Therefore, we conclude that non-DCD children of all ages have the knowledge and ability to use cues to predict ball motion more effectively than children with DCD.

Again, the difficulty regarding location seems to be that more viewing time is required for accurate prediction for the right, hence, the significant Group × Time × Location interaction. As explained previously, the right location is likely more difficult because the arm moves across the body. At the point of ball release, cues are only subtly different from those to the center location. Cues for the right location are more subtle, and if very little viewing time is available, only individuals with catching experience are sensitive to these cues (Abernethy, 1988, 1989, 1990; Abernethy & Russell, 1987; Buckolz, Prapavesis, & Fairs, 1988; Goulet et al., 1989; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984).

**General Discussion**

Researchers have shown that catching a ball requires significant spatial and temporal prediction (Alderson, Sully, & Sully, 1974). Further, when the amount of viewing time decreases and landing location changes, the skill becomes more difficult (Belka, 1985; Herkowitz, 1978; McConnell & Wade, 1990; Sharp & Whiting, 1974; Strohmeyer et al., 1991; Whiting, Gill, & Stephenson, 1970; Whiting & Sharp, 1974). Results of the present study provide support for the above notions. As viewing time decreased, more prediction errors were made. This was also true when the ball was thrown to the right location. Moreover, the overall results from both studies reporting comparisons across developmental levels are similar to previous research on expert and novice predicting abilities in various sports. These studies state that individuals with more experience—and therefore knowledge—show superior prediction accuracy, even with very little ball-flight information (Buckolz et al., 1988; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984). The present findings support the conclusion that not only are early and preflight cues useful and crucial to the decision-making process in catching, older individuals, and perhaps males, can extract and use this information more effectively than less-skilled persons (Abernethy, 1988, 1989, 1990; Abernethy & Russell, 1987; Buckolz et al., 1988; Goulet et al., 1989; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984). Overall, the current findings converge toward a developmental explanation. As children age and gain more experience and knowledge in ball catching, they can better predict ball trajectory with less information.

Numerous hypotheses exist regarding causal factors of catching difficulties in children with and without DCD. Some believe that motor problems are due to difficulty with motor responses (Geuze & Kalverboer, 1994; Hoare, 1994), while others highlight visual perception (Hulme, Biggerstaff, et. al., 1982; Hulme, Smart, & Moran, 1982; Lord & Hulme, 1987). The present findings are consistent with an overall predicting problem for children with DCD. However, other variables, such as motor response, must not be excluded, since we did not manipulate this factor. Future research should aim to determine if the prediction difficulties reflect a distinct lack of knowledge of ball flight cues or a more general problem of visual perception.
Another possibility suggested by Eason and Surburg (1993) is a midline crossing problem, which might have been the case for throws to the right. Eason and Surburg found that individuals with mild mental retardation require more information-processing time for movements requiring midline crossing. In more practical terms, this research suggests that providing a child with an adequate amount of time to view ball trajectory might allow for better ball-catching performance. The child might benefit from learning to identify important visual cues, which may be as obvious as making arm and shoulder movements or as subtle as knowing where the thrower is looking. Determining which cues are useful is important, as is providing adequate instruction and much practice to young children, particularly those with DCD, thus allowing them to gain the experience and skill required to catch effectively.

Further work is required to investigate the developmental differences in spatial and temporal prediction between children with and without DCD. Researchers should consider conducting studies similar to those done on the predicting abilities of experts and novices (Buckolz et al., 1988; Jones & Miles, 1978; Salmela & Fiorito, 1979; Starkes & Deakin, 1984). Investigators should also assess expertise and experience levels to determine whether experience is the explanation for age, gender, and DCD/non-DCD differences. Experience could also be explored through training studies designed to improve catching performance.

References

Eason, B.L., & Surburg, P.R. (1993). Effects of midline crossing on reaction time and movement time with adolescents classified as mildly mentally retarded. Adapted Physical Activity Quarterly, 10, 269-280.


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