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GROEP BIOMEDISCHE WETENSCHAPPEN

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# THE CONTROL OF TIMING AMONG CHILDREN WITH DOWN SYNDROME

Thesis submitted in the fulfilment of
the Degree of Master of Adapted
Physical Activity

by Tjaša Planinšek

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# SUMMARY

TITLE: The control of timing among children with Down syndrome

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It has been shown that Down syndrome (DS) children have problems with interceptive action, and that their motor performance is slower in comparison with non-impaired children. In order to examine whether DS children have timing problems in one-handed catching, 11 children with DS and 16 with no impairment from 5 to 12 years old were required to catch three balls of different size (small, medium, large) under binocular and monocular viewing condition in the dark. The results in present research showed more misses for the DS children in comparison to control group. The kinematic analyses revealed that this is due to a late closing of the fingers. With respect to the visual information used in one-handed catching, no differences were found between DS and controls. Both groups missed more balls under monocular than under binocular condition. It appeared that besides the optical expansion (Tau), binocularly provided information about ball size and/or distance plays an important role in the timing of the catching. Since there were no differences between the two groups with respect to perceptual manipulations, it is suggested that the timing problem of the DS children is probably due to the slow motor apparatus of the children.

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Tjaša Planinšek

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# INTRODUCTION

Down syndrome (DS) presents a unique etiology that affects many areas of development. Of specific concern are the motor delays and deviations that can affect the development of such areas as fundamental motor patterns, physical fitness and the learning of complex motor skills. The effects of DS on motor development have been widely reported over the years, (Block, 1991; Thombs and Sugden, 1991; O’Brien and Hayes 1995; Henderson, 1985) but unfortunately, not many findings are provided with respect to timing in an ecological valid task as one-handed ball catching. It is this limitation which justifies the present research.

The theoretical paradigm is that of the coupling of perception and action developed by Gibson (1979; in Savelsbergh and Van der Kamp, 1993). Within this paradigm the animal actively samples the optic array in order to pick up the information needed to guide its action. Action and information (perception) are tightly coupled, namely information guides the action and through action new information becomes available to the actor. This is called the perception-action cycle (Figure 1).

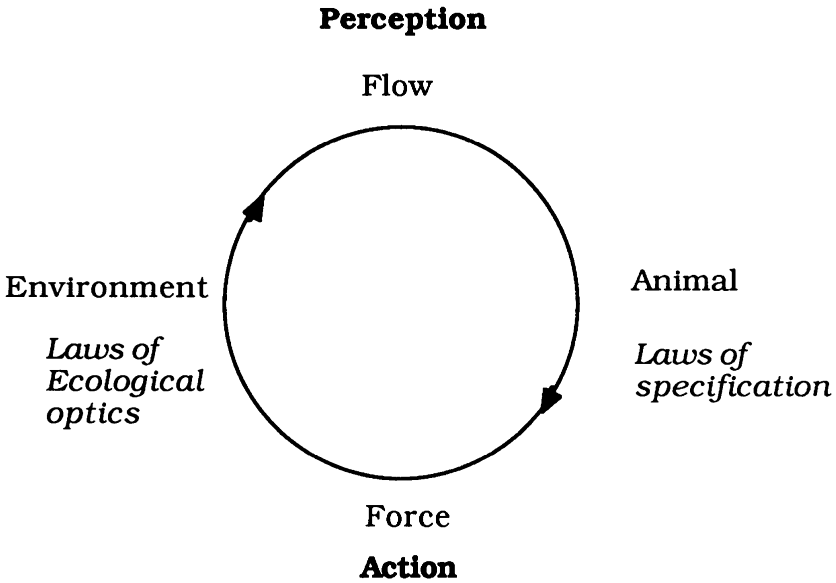

Figure 1: The perception-action cycle

Thus, the main idea is that action-relevant information (the kinematic optical flow field) is used to control and coordinate actions (the dynamics of motion). One of the important questions within this paradigm is: What is the nature of the information used in order to control and coordinate actions? For instance, Warren, Young and Lee (1986) showed that the optical variable Tau (perception) determined the step length (action) when somebody is running over an irregular surface. Therefore, in this thesis the coupling will be investigated by carrying out perceptual manipulations in a catching task.

Catching a ball is an important act which is presented in many sport activities and has a potential to provide many benefits to people of all abilities. Catching is both spatially and temporally highly constrained. Timing of a successful catch leaves little room for error and it is the nature of the task which might be the reason that there are not many studies in catching among Down syndrome children.

In this thesis an experiment is reported in which one-handed catching among children with DS and with no impairment will be examined, with two main goals, namely, to investigate whether and why DS children differ in a catching performance in comparison to normal children and furthermore, what is the nature of the information children use in one-handed catching a ball. To reach these goals, children with Down syndrome and children with no impairment will be examined in catching a ball. One might think that only motor aspects cause problems in interception action. However, it remains unclear whether this is a problem of action and perception or both, or a coupling of perception and action. Therefore, following the idea of inseparability of perception and action, the purpose of the present research study is to examine optical specification in the timing of an interceptive action in children with Down syndrome and children without impairment. In order to reach that goal in the first part the literature with respect to catching among adults (Chapter I), children (Chapter II) and children with DS (Chapter III) will be reviewed. Special attention is drawn to the information sources which are identified so far. In the second part the experiment is reported in order to find answers to the above mentioned questions.

# PART ONE. LITERATURE REVIEW

## CHAPTER I: CATCHING AMONG ADULTS

### 1. INTRODUCTION

The ability to catch a ball enables participation in a wide range of play and sport and leisure related activities which have the potential to provide numerous physical, psychological and social benefits to people of all ages and abilities (Williams, 1988). It is a fundamental gross motor skill which forces the person to rely heavily on environmental information and to adjust movements of hands, arm and upper body to this information in order to stop and hold an object that is travelling through the air (Wickstrom, 1983). More specific, in order to catch a ball successfully, the hand has to be positioned at the interception point in time. Next, a spatial adjustment of the hand has to be made such that the ball hits the hand in the metacarpal region, and the grasp has to be initiated and completed within a defined time-window, depending on the speed of the approaching ball. Failure to fulfill the gross and fine orientation results in spatial and temporal errors (Alderson, Sully and Sully, 1974). High speed film analysis of adult catching by Alderson et al. (1974) suggested a gross spatial orientation of the catching hand some 200 milliseconds (ms) prior to the catch, followed by a fine orientation some 50 ms later. The grasp and hold action begins some 32-50 ms before the completion of the catching action (Figure 2). Further, Alderson et al. (1974) suggested that the best range of accuracy for timing the flexion phase of a one-handed catching would be in the range of 16 ms before, to at most, 30 ms after optimum. Closing the hand too early will result in the ball being deflected off the fingers, while closing too late will result in the ball bouncing off the palm of the hand. It is worth to say that in Alderson et al. (1974) only one ball velocity was used, namely, 10m/s.

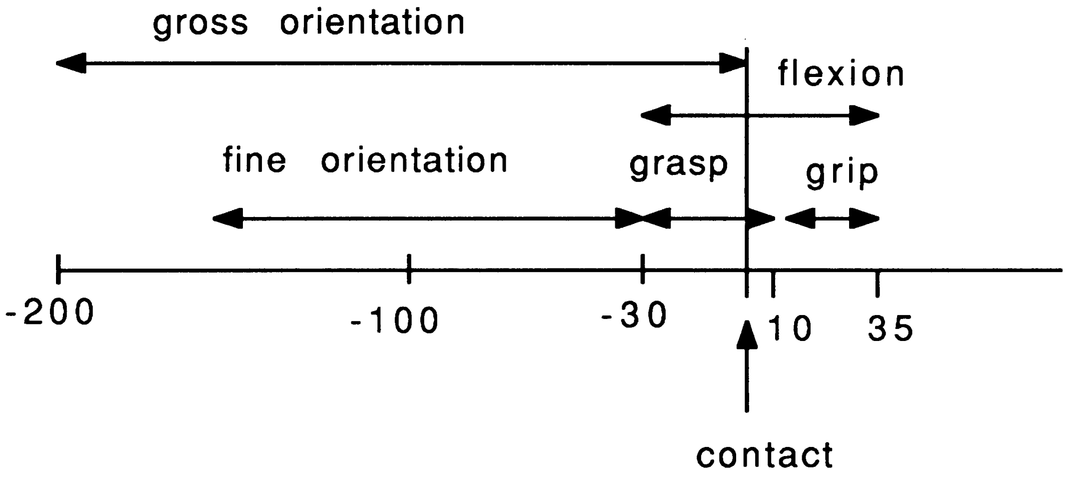

Figure 2: Components of the catch (in milliseconds; adapted from Alderson, Sully and Sully, 1974)

In order to perform an action such as catching a ball different types of information are necessary. Humans are able to perform a whole range of finely timed interceptive acts (catching, kicking, striking) by integrating exteroceptive and proprioceptive information.

The most important source of exteroceptive information for humans is vision. That is, if we want to catch a ball, we need information where the ball is and where it is going to be and moreover we need information about the catching hand relative to the ball (at least for the unskilled catcher). Proprioceptive information is the information about the movements or position of body parts relative to one another and is necessary for coordinated actions. It is gained through mechanical receptors in the joints and in the vestibular system. Of course information of the body or its parts can be perceived also through vision. This kind of information is called exteroproprioceptive information (Lee, 1980).

Catching behavior is difficult to study because of the number of variables influencing the performance. Some of the major variables are: size of the ball, the distance the ball travels before it is caught, the method of projecting the ball, the direction of the ball in relation to the catcher, the speed of the ball, etc. In addition, there are age related sensory and perceptual factors. Some of these variables are illustrated in the following section that provides an overview of the current level of understanding of catching performance. Some of the results will serve as a comparison to the results of children catching.

The next paragraphs will focus on the literature in order to identify the important information sources which are used in the control of catching among adults. That is, the main emphasis will be on the amount and nature of the visual information needed in catching.

## 2. THE AMOUNT OF THE VISUAL INFORMATION NEEDED IN CATCHING

In an early experiment (Whiting, 1968) adult subjects were trained to perform a task which required them to first throw, then catch a ball when sight of different sections of the ball's circular trajectory was occluded. The experimental design included full-light and total dark conditions. The results showed that information about the trajectory of the ball is essential to successful catching but it is not necessary to view the entire ball trajectory. It seems that prediction on the basis of prior information of the flight path of the ball plays an important role. In a follow up study (Whiting, 1970) subjects controlled the amount of time that they were able to view the trajectory of the ball by switching on and off the illumination apparatus. Results suggested that the grasp phase of the catch is not visually monitored, at least by the experienced adult subject. The shortcoming in this experimental design was that the ball was propelled and caught by the same person.

Further research by Whiting, Gill and Stephenson (1974) was undertaken on this topic by modifying the task so that the ball was projected to the subject by a mechanical device on a relatively unpredictable path. Results showed that catching performance was a function of the amount of time available for viewing the ball. Namely, a longer viewing time led to a better performance. With a viewing period (defined as the viewing time before the ball-hand contact) of

100 ms-150 ms subjects reached a remarkably good performance level. This level was improved when viewing time was extended to 200 ms. Further extensions of the viewing time to 300 and 400 ms had little affection catching performance (Whiting et al, 1970). Later experiments showed that it was the 'total time' (a

combination of viewing time and occluded period - time for which the ball was occluded in flight) that was important for the determination of optimal catching performance (Sharp and Whiting, 1974). The viewing time and occluded period are presented in the schematic illustration (Figure 3).

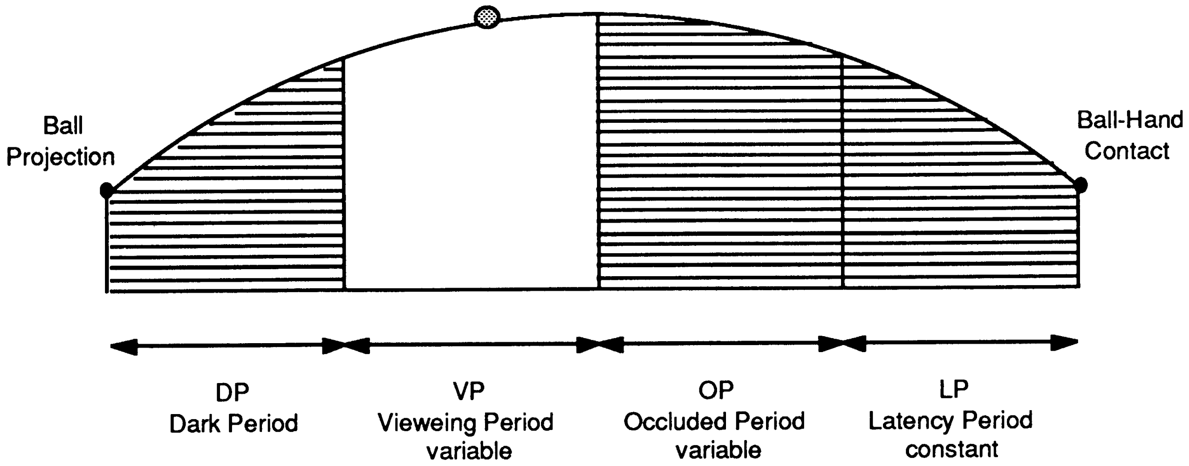

Figure 3: Schematic illustration of the experimental paradigm (adapted from Sharp and Whiting, 1974)

## 3. THE EFFECT OF SIGHT OF THE CATCHING HAND

Information about the position of the hand which can be visual and/or proprioceptive is important for catching. Theories of perceptual motor skill acquisition have suggested that visual control of effectors is important early in learning, but this monitoring of limb movements is delegated from vision to proprioception as learning proceeds, or central pre-programming decreases the need for ongoing control and frees vision to attend to other aspects of the task (Smyth and Marriot, 1982). Both of this views suggested that skilled catchers do not need vision in order to know where their limbs are. With respect to this topic several studies were done in the past, namely a number of experiments demonstrated that when vision of the catching hand is prevented, novice catchers make more errors in positioning their hand in the flight path of the ball than skilled catchers do (Savelsbergh and Whiting, 1988; Smyth and Marriot, 1982; Whiting, Savelsbergh, Faber, 1988).

Fischman and Schneider, (1985) also found that the absence of viewing the catching hand led to more temporal errors in skilled and novice subjects. The catching errors of the skilled subject were caused by mistimed grasps rather than inaccurate positioning, while the novice catchers make more errors in positioning of the hand as well as in the timing of the grasp.

As noted above, longer viewing time and sight of the catching hand led to more accurate performance in catching. Both, visual and proprioceptive information are important for a successful catch, but skilled catchers rely more on propriceptive information. On the other hand, unskilled catchers depend heavily on the visual information.

## 4. THE NATURE OF THE VISUAL INFORMATION NEEDED IN CATCHING

Temporal and spatial information are provided by different sources of information. Information about the timing of the catch can potentially be provided by the ball, the perceptual system (i.e. binocular vs. monocular vision) and the environment. These different information sources will be discussed below.

### a) Timing information provided by the ball

The approaching ball provides retinal expansion information that is related to the optical variable Tau. A number of experiments showed that the optical variable Tau plays a major role in temporal organisation of adult catching (Savelsbergh, Whiting and Bootsma, 1991; Savelsbergh, Whiting, Pijpers, Van Santvoord, 1993). The optical variable Tau is a variable which specifies time to contact, that is the time the ball needs to reach the hand. It is independent of ball speed and size and essential to a monocular information source. In order to understand the optical variable Tau a short discussion will be taken upon in the next lines.

## Explanation of the optical variable Tau

It was Lee (1976, 1980) who demonstrated that the pattern of optical expansion of approaching objects on the retina contained predictive temporal information. The optic flow field is a field that affords a wealth of information about the layout of the environment and about the organism's movement. To explain the geometry of the optic flow field (Figure 4) the schematic eye is considered to be stationary and the environment moving towards it with velocity V in the direction Z to O, P denotes a texture element on a surface in the environment (size R). Light reflected from P passes through the nodal point of the lens, giving rise to the moving optic texture elements P' on the retina. The position P' distant r(t) from O, moves outwards with optic velocity v(t). The position of P relative to the eye at time t is defined by the distance coordinates Z(t).

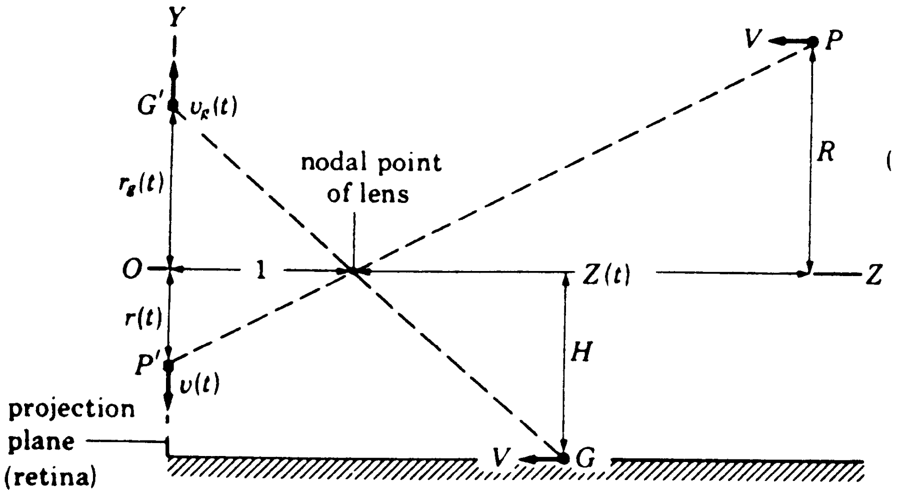

Figure 4: Geometry of the optic flow field (adapted from Lee, 1980)

$Z(t)/R = 1/r(t)$ (1)

Differentiating (1) with respect to time

$V/R = v(t)/r(t)^2$ (2)

substituting (1) by (2),

$$\text{Tau} = \text{Time to contact} = Z(t)/V = r(t)/v(t) \qquad (3)$$

The quantity $Z(t)/V$ is the time to contact of element P with the plane through the nodal point of the lens and parallel to the retina, given that the approach velocity V remains constant. The time to contact can be perceived without perceiving distance or speed (Schiff and Detwiler, 1979), which indicates that the optic variable Tau is perceived directly. For controlling action, the Tau-margin can be used (Lee and Young, 1986). The Tau-margin is a particular Tau-value at which subject starts an act. According to Lee and Young (1986) it can be used whether or not the velocity of the approach objects is constant. The Tau-margin value is subject/task specific and is probably learned. Thus, if Tau-margin is 300 ms, then subject starts to act when Tau specifies that the ball only needs 300 ms to hit the ball. This should be the same for different ball velocities and since it is the *relative rate of expansion*, Tau specifies the same time for different ball sizes. Moreover, because optical expansion can be picked up monocularly, no differences in Tau-margin are expected when monocular and binocular viewing are compared. Thus, subjects should start their act at the same time to contact independently of ball velocity, ball size and monocular vs. binocular vision.

The inverse of the relative rate of dilation, denoted Tau (Lee, 1976, 1980), has shown to be useful also in examples such as the regulation of gait during the run up phase of the long jump (Lee, Lishman & Thomson, 1982), the folding of the wings by gannets diving into the sea (Lee and Reddish, 1981), the jumping up to punch a falling ball (Lee, Young, Reddish, Lough and Clayton, 1983). Of special interest is the Lee et al. (1983) study, because there it was demonstrated that the behaviour of the subjects was consistent with their gearing their action to Tau and not to the real time-to-contact in the case of a discrepancy between the two, brought about by a non-constant relative approach.

In the study of Savelsbergh, Whiting and Bootsma (1991) a direct manipulation of the optical pattern was carried out. The most important question was what happens to the timing of the grasp movements involved in catching a ball when optical expansion information is not veridically provided. They used 2 luminescent balls of constant size and a luminescent ball that changed its diameter during flight. By this they directly manipulated the rate of optical expansion. The results of two experiments (binocular and monocular vision) shows that the time of the maximal closing velocity of the hand was later for the deflating ball than for the balls of constant size as is specified by Tau. That confirms that subjects were using retinal expansion information. This study also showed that in the last 200 ms before the contact of the hand and ball (particularly in the monocular condition) adjustments of the hand aperture still took place, contrary to what was found by Whiting (1970).

Thus, Tau appears to control the timing of the opening and closing the hand in ball catching. As the ball approaches, its image on the retina expands and the inverse of the relative rate of dilation directly specifies time-to-contact and this can be used to determine when to initiate the grasp.

### b) Information provided by binocular vision

Since Tau is essentially monocular, a question arises whether also binocular vision also contributes to the timing of the catch. That is, when looking with two eyes, disparity specifies distance and change in distance between the observer and the approaching object (Bruce and Green, 1995; Rock, 1995). This distance information might be used to control the timing in interceptive action.

One study in which the role of binocular vision was examined is the study conducted by Judge and Bradford (1988). One-handed ball catching was used to study the effect of the disturbance of depth judgement induced by telestereoscopic viewing (i.e., viewing with increased effective interocular separation). These researchers studied the recovery of performance with experience in the telestereoscope, and the errors that arose when the telestereoscope was removed. As stated earlier in order to catch a ball both the position and the hand timing of the grasp has to be controlled. In the beginning wearing the telestereoscope, subject closed the hand much too early, but after about 20 trials subjects closed the hand at approximately the correct time and place. Then, when the telestereoscope was removed an after effect appeared: subjects closed the hand too late, again. The existence of this effect shows that the process of adaptation involves revaluation rather than neglect of the misleading binocular information. However, binocular information seems to influence the timing of the catch.

Another study reported by Van der Kamp, Savelsbergh and Smeets (1995, 1996) examined the role of the distance information as specified by disparity. In the first experiment subjects were asked to estimate the size of different sized balls and in the second to catch these different balls. The experiments were conducted in a completely dark room where only the luminous balls were visible. The subjects estimated the balls to be smaller in the monocular condition in comparison to the binocular condition. This effect was most pronounced for the larger balls. In alignment with this results, the researchers found differences with respect to the temporal aspects of the catch. Namely, subjects started to open and close their hand earlier when monocular viewing is provided (Figure 5 and 6) and again these differences were most pronounced for the larger balls.

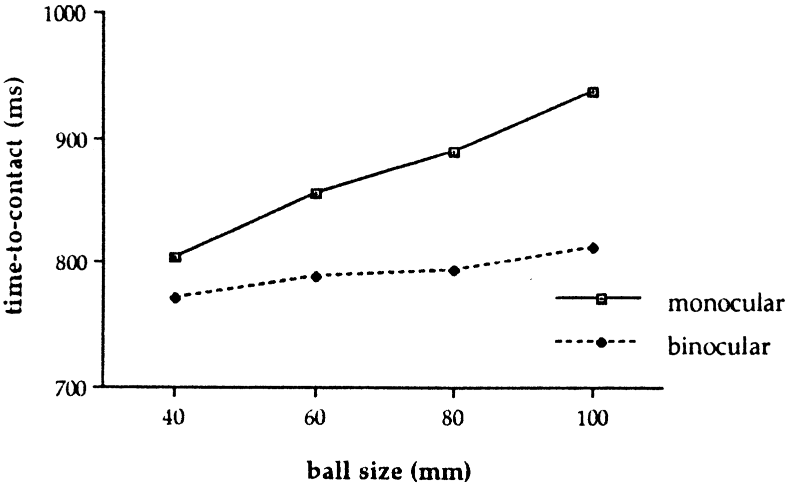

Figure 5: Timing of the opening of the hand (adapted from Van der Kamp, Savelsbergh and Smeets, 1995)

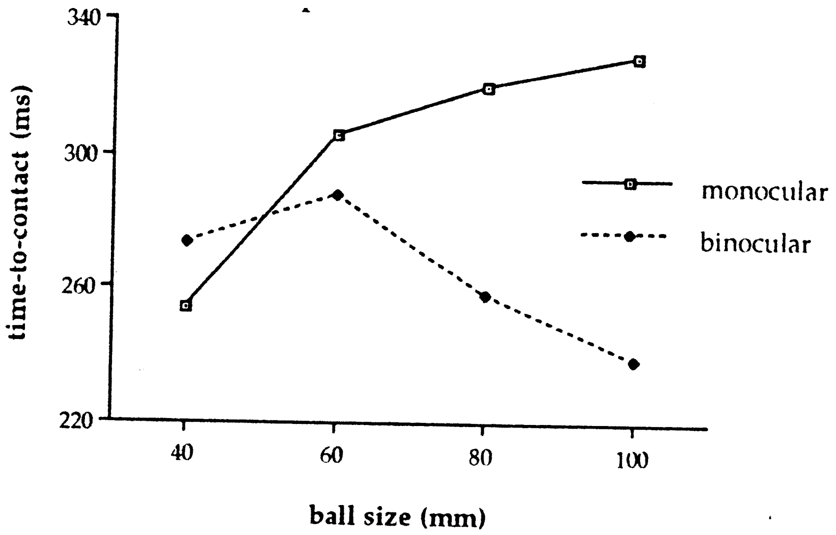

Figure 6: Timing of the closing of the hand (adapted from Van der Kamp, Savelsbergh and Smeets, 1995)

No Tau-margin was found in the monocular condition for the different ball sizes, suggesting that not only Tau was used. However, when binocular information was provided the differences disappeared (i.e. they started to act at the same time).
The results from Van der Kamp et al. (1995) support the findings of the Judge and Bradford (1988) study and also the assumption that beside information from the ball also other sources, such as binocular vision, seem to be important in catching. That is, not only Tau information but also perceived size of the object plays a role in the guidance of the timing of interceptive action.

### c) Information from the environment

Studies by Rosengren, Pick and Von Hofsten (1988), Savelsbergh and Whiting (1988) and Whiting, Savelsbergh and Faber (1988) demonstrated that degrading of the environment by reducing the information available, leads to an increase in catching errors. Under conditions in which only the ball was visible in a dark room, more spatial and temporal errors were made (Savelsbergh and Whiting, 1988). It is not clear why subjects make more timing errors in the dark when the ball is visible and the optical expansion pattern can be perceived. A possible explanation could be a less accurate perception of the ball size (Van der Kamp et al. 1996).

Despite of this, Rosengren et al. (1988) demonstrated that the presence or absence of a luminescent visual frame in a total dark room improved body stability and, therefore, catching performance. However, Savelsbergh (1990) found a negative effect of a luminous frame (background) on the catching performance, namely subjects made more spatial errors. So, there is also evidence that background structure affects the spatial prediction, but it remains unclear whether it improves or detoriorates the performance.

## 5. CONCLUSIONS

From the literature review which was briefly presented and discussed above, some conclusions can be drawn.

Catching a ball is an important act which is presented in many sport and leisure activities. It is both spatially and temporally highly constrained. Timing of a successful catch leaves little room for error, namely closing the hand too early or too late will result in missing the ball. To perform an action such as catching different types of information are used. With respect to vision, information sources such as the ball, binocular vision and the environment can provide information for the timing of the catch.

Most research in the field of timing in adult catching focused on the amount and type of visual information needed in catching. Experiments with respect to the amount of visual information needed in catching show that a longer viewing time improves the performance. Further, information about the position of the catching hand is important and improves the performance. Preventing to see the catching hand leads to both spatial and temporal errors.

With respect to the temporal organisation of adult catching, the optical variable Tau that specifies time to contact, appears to control the timing of the grasp in ball catching. However, it was found that also binocular vision, presumably by providing information about the size or distance of the ball size are of importance.

In this chapter experiments which focused on adult catching were presented. In the remainder of the report the focus will be on findings with respect to the development of catching.

# CHAPTER II: CATCHING AMONG CHILDREN

## 1. INTRODUCTION

There is a dearth of studies with respect to catching behaviour in the age period 1 to 12 years in literature. Especially studies of one-handed catching and development of timing accuracy in children are conspicuously absent. The reason may be that one-handed catching is a difficult skill to study developmentally, because many variables influence its performance (different speed and ball size, distance of projection, angle of projection, Chapter I). The child's first important precatching experience requires him to deal with a rolling ball. He may sit with his legs spread and, when a ball is rolled slowly toward his central axis, he attempts to grasp it. Controlling a ball rolled directly towards him at a slow rate of speed is his easiest and earliest catching related experience. From this rudimentary beginning, his perception of time-space relationships improves, and he becomes able to attempt more challenging tasks (i.e. attempt to catching an aerial ball), (in Payne and Isaacs, 1995)).

Catching skill develops from an early age. The maturation of the nervous and the visual system imposes the most severe constraints on the development of reaching and grasping in the first year (Von Hofsten, 1984; Trevarthen, 1974). From Von Hofsten’s experiments (1983) it can be concluded that the capacity to time and coordinate one's movement in the catching of a moving object is an early developing skill. As young as 4 months, babies start to develop skill and will successfully reach for both stationary and moving objects, and by 9 months can achieve 50 ms precision.

However, it was found that the development of reaching reflects also a changing interaction between organismic and environmental constrains (Savelsbergh and Van der Kamp, 1994). In this study authors demonstrated that changes in the development of the quality and quantity of reaching are influenced by body orientation to gravity in 12 to 27 week infants.

In the following text, a review of literature in the field of children's catching will be presented. The aim of this chapter is to find some related motor skill studies that can help to understand the nature of the ball catching. Therefore, factors that influence catching performance will be taken into consideration.

## 2. SPATIAL ACCURACY IN CATCHING AMONG CHILDREN

In the following discussion the most important studies with respect to spatial accuracy will be presented. The goal of those studies was largely descriptive, and documented in terms of what and when. Anyhow, those studies might be interesting for the present research. Fischman, Moore and Steele (1992) for instance, investigated the influence of age, gender and ball location on children's one-handed catching. Boys and girls (n=240) ranging in age from 5 to 12 years old attempted to catch tennis balls, tossed from 3 meter distance. Tosses were directed to four locations: waist, shoulder, above the head and out to the side. Results showed that catching performance improved with age, boys caught more balls than girls, ball location influenced catching success (balls tossed above the head and out to the side elicited the use of correct hand orientation), and in general, the location of the toss constrained the child's selection of an appropriate spatial orientation. With the exception of the shoulder location for girls, even very young children are sensitive to the perceptual aspects of the toss and respond with an appropriate spatial orientation.

In a study by Laszlo and Bairstow (1985) researchers focused on two-handed catching of children in the age range of six to twelve years. It was found that catching ability reached adult level at the age of ± 11 years. Additional evidence is provided by the high-speed film analyses of Alderson (1974) which showed that at the age of 10 years, positioning of the catching hand in the path of the ball (spatial accuracy) had reached adult level. The ability to catch different types of objects in a reasonable variety of situations is attained between the age of 7 and 9 years in both boys and girls. Starkes (1986) and Alderson (1974) reported an increase in catching ability between 7 and 13 years. Alderson's results (1974) showed that, with increasing age, children's ability to position the hand - as indexed by percentage of correct location - becomes more accurate. Williams (1992) observed and described adaptation in the way 28 children between four and ten years of age use their perception and hands to catch a ball. Observation was made for one and two handed catching. Ball catching was studied by examining videotaped recordings of their action of catching. In this study three modes of perception (retrospective, concurrent, predictive) and hands movement (cradling, clamping, grasping), (spaced along a maturity continuum) were used (Williams, 1992). Results show that only the ten year old children caught the ball with the strategy of perception and hand usage as skilled adult catching. Success in two handed catching improved with age from 77% to 96%. For one-handed catching the success rate was 40% at age 4, 5 and 6, at 7 and 8 years 30% and at 10 years 92%. At 7 and 8 years the drop in performance coincided with the highest incidence of mixed strategies. No gender differences on either strategy or performance were evident.

Strohmeyer, Williams and Schaub-George (1991) investigated the validation of the hypothesised two handed catching sequences and examined the importance of task constraints on catching performance. Seventy-two subjects (5-12 years old) were videotaped as they attempted to catch a small ball (10 cm). The ball was tossed to three locations: directly to the body, at the forehead, and to various other locations. Trials were categorised using developmental sequences including four components: arm reception, arm preparation, hands and body. Movement sequences for hand and body components were comprehensive and age-related for the groups studied. Task conditions differently constrained children of different age. As has already been mentioned, the studies presented above are mainly descriptive data that are focused on spatial accuracy which increases with age. Only few studies in the past focused on temporal accuracy (e.g. Bruce, 1966; Williams, 1968, Isaacs, 1983). Since temporal aspects of catching will be the main focus of the present research, temporal constrains and factors that influence catching performance will be discussed in the next paragraph.

## 3. FACTORS THAT INFLUENCE CATCHING PERFORMANCE

In the past several studies were conducted in order to examine factors that may influence catching performance. Researchers focused mainly on the effects of ball size, trajectory angle of the ball, the environment and the effect of instruction. The main findings are presented below.

### a) Effect of the ball size

The effect of ball size in catching has received much attention (Isaacs, 1980; Payne and Koslow, 1981; Payne and Isaacs, 1985; Strohmeyer et al, 1991). Initial studies demonstrated that children's performance improved when catching larger balls. Explanation of these findings were often based on the premise that young children are far sighted and would thus profit from using the larger ball, which would be easier to visually track. Another explanation based on neurological considerations was that the young child was assumed to have insufficient fine motor control for grasping the smaller object. It has to be mentioned that the conclusion, that larger balls are more easy to catch, was made on a pass-fail basis, namely child caught or did not catch the ball. The balls were tossed to the subject by the experimenter.

More recently, researchers tried to implement more sophisticated methods such as statistical analyses, the mechanical projecting of ball and using rating scales to evaluate catching performance. A recent study by Payne and Koslow (1981) showed that larger balls were more easily caught by children. In this study 60 subjects, who were randomly selected from a kindergarten, caught four different balls (15, 23, 25 and 33 cm in diameter). There were 28 trials (seven attempts per ball per subject). A special apparatus was designed to roll the ball consistently into the subject's arms from a horizontal distance of approximately 1.20 m. The quality of each attempted catch was evaluated using a five-point scale, which is presented below (Table 1). The main effects of ball size, grade and sex were significant. A linear trend described the relation of ball size and grade. The over-all quality of the catching performance improved from kindergarten to second grade, and what is the most important, from the small ball to the larger ones. Thus smaller balls were caught earlier in development.

Table 1: Product oriented rating scale (adapted from Payne and Koslow, 1981)

| POINTS | MOTOR BEHAVIOUR |
|---|---|
| 1 | failure to react |
| 2 | one hand contacts, ball dropped |
| 3 | two hands contact, ball dropped |
| 4 | uncontrolled catch (bobbled) |
| 5 | controlled catch |

On the other hand, some studies where a different rating scale was used, found smaller balls to be more conductive to successful catching (Isaacs, 1980). In his study, 45 males and 45 females between 7 and 8 years of age were required to catch rubber playground balls which varied in both size and colour. He presented (Table 2) a process oriented ratings for the skill of catching and the analysis indicated that smaller balls (15.2 cm in diameter) were caught significantly better than were bigger balls (24.5 cm in diameter).

Table 2: Process oriented rating scale (adapted from Isaacs, 1980)

| POINTS | MOTOR BEHAVIOUR |
|---|---|
| 0 | initial body contacts: the subjects makes no attempt to contact the ball |
| 1 | arm and/or body contact, miss: initial attempt to contact is made on the arms and/or body but the ball is missed |
| 2 | arm and/or body contact, initial contact is on the arms or body and the ball is retained |
| 3 | hand contact, miss: initial contact is made by the hands but the ball is dropped then immediately or dropped following arm or body contact |
| 4 | hand contact, assisted catch: initial catch is made by the hands; the ball is juggled but retained by using arms and/or body assistance |
| 5 | hand contact, clean catch: the ball is contacted and retained by the hands only; the ball may be brought into the body on the follow through after control is gained by the hands |

From this review of studies about the size of the ball it is still not clear which size of the ball is more conductive to successful catching. Clearly, we need more information on this topic. In the present research, the effects of ball size in one-handed catching will be examined.

### b) Effect of the trajectory angle of the ball

Bruce (1966) showed that angle of projection (i.e. 30 or 60 degrees) did not significantly affect the child’s catching ability. However, Williams (1968) used nine skilled and nine unskilled children to find out the effects of trajectory angle on judging speed and accuracy of a moving object. Results indicated that the unskilled catchers performed better when balls were projected at a 34 degree angle, while the group as a whole performed better when the balls were projected at a 44 degree angle.

### c) Effect of ball velocity

Bruce (1966) determined that ball speed is also an influential factor in accurate children's catching. In his investigation with 7, 9 and 11 year old children, he found that the catching performances of the 7 and 9 year old children declined as ball speed increased from 8 to 10 meters per second. Isaacs (1983) supported this assumption that more slowly the ball is projected to the child, the greater is the likelihood he/she will be able to time grasping of the hand around the ball. A Bassin Anticipation Timer was utilised whereby the subject attempted to grasp a ball at the instance they anticipated the illumination of a target lamp. That is, a row of lights was provided, which illuminated successively such that the light seemed to approach the subjects. Subjects had to grasp a ball at the moment the light reached the subject. The ball was positioned at the end of the row of lights. Children (n=128) from 5 to 12 years old responded more accurately at the slowest (2.25m/sec) of the two velocities in his study, (i.e., the second speed was 4.40m/sec). Thus, there seemed to be an effect of velocity on the timing of the catch. This is not predicted from a Tau perspective (independent of velocity). However, the task in Isaacs (1983) study was not a real catching task and no optical expansion pattern was provided. In the present research, a real ball will approach the subjects such that an optical expansion pattern is available.

### d) Effects from environmental information: ball and background colour

In a study of the effect of ball colour and background on young children's catching Morris (1976) found that blue and yellow balls were caught significantly better than white balls and children performed their highest catching scores when blue balls were projected against a white background. Isaacs (1980) indicated that a child's preferred colour of the ball can also be influential in catching performance. In his study children were required to choose their favourite colour. Results showed that both boys and girls caught their preferred colour ball significantly better than their non preferred colour ball. Isaac' s explanation is that children in this study focused their attention on the ball for a longer time when catching their preferred colour ball and they were able to obtain more critical information about the ball flight. Again, however it remains unclear what is this critical information.

### e) Effect of the instruction

Only one study has examined the influence of catching instruction on children's one-handed catching. Williams (1992) made a single subject study of an 8 year old child. He wanted to find out the effects of practice and instruction on ball catching. An eight year old boy practiced one-handed catching. He was given 30 minutes instruction each day on seven separate days. The child was provided performance feedback by means of videorecordings. Catching behaviour was classified in two levels: percentage success (ball caught or dropped) and percentage of observed maturity of the catching action (immature/child like, transitional, mature/adult like). Results showed changes in both maturity of catching and success in action. An adult like catching action (both hands) emerged in the second session and was exclusively used thereafter. Catching success at the second and third assessment improved from 40% (preferred hand), 30% (non preferred hand) and over 90% (both hands) on the final assessment. It seems that the program of instruction and practice influenced the skill level of the subject, however it is difficult to make any conclusions about the effect of instruction because only one subject participated in the study.

## 4. CONCLUSIONS

Catching skill develops from an early age. The maturation of the nervous and the visual system, and the changing interaction between organismic and environmental constraints impose the most severe constraints on the development of reaching, grasping and catching in the first year of life. From the research just reviewed, it is apparent that relatively little is actually known about the factors involved in catching behaviour in children. Many questions are still open, but some conclusions can be made.

Researchers found, mainly in descriptive studies, that speed, size and colour effects catching performance. It is difficult to compare these studies because they vary as to type and size of the ball, distance of projection and type of evaluation system used. In this thesis, there is a special interest in the timing of the catch, which might be influenced by the size and speed of the ball and by different types of information sources available. On basis of the optical variable Tau, which specifies time to contact, it is not expected to find differences in timing performance between different sizes and speed of the ball. Except for Isaac (1983) research, which has some important shortcomings, there were unfortunately no studies in the past on this matter. Hence, this will be one of the objectives of the present research.

Nothing is known about temporal versus spatial errors in children's catching and the nature of the information used in catching. It seems that catching performance is mainly considered by looking at what happens when there is spatial uncertainty, but not when there is temporal uncertainty. There were no studies where researchers tried to use kinematical analyses to study the temporal characteristic in catching a ball.

Therefore, the present research will try to find whether the different types of information found and used in adults' catching are also used in children's one-handed catching (e.g., Tau, ball size). In the following discussion the most important findings with respect to movement control in topics in DS children will be described, especially topics which are close to the present research topic.

# CHAPTER III: CATCHING AMONG CHILDREN WITH DOWN SYNDROME

## 1. INTRODUCTION

Children with Down syndrome (DS) have a chromosomal disorder which has far-reaching effects on their cognitive and physical development. Karyotyping of chromosomes in most persons with DS shows an extra chromosome number 21, indicating the condition referred to as Trisomy 21. Down syndrome is the largest single chromosomally determined intellectually handicapping condition. The effects of DS on cognitive and motor development have been widely reported over the years. The goal of early work was largely descriptive, and documented in terms of what and when, the differences between retarded and normal individuals. Recently, the more theoretical question of why and how the DS children differ from normal and other mentally retarded peers has received at least as much attention. In this chapter several aspects related to motor performance in DS children will be discussed. First, some characteristics of medical, health and perceptual problems that are often present in DS children will be described. Second, a short overview will be presented with respect to discrepancies between motor development in DS children compared to motor development in normal children. Finally, the main topic of this thesis, catching, will be elaborated upon. Again special emphasis will be laid on timing aspects of catching.

## 2. MEDICAL AND HEALTH PROBLEMS AMONG CHILDREN WITH DS

There is a great individual variability among children with DS. Each child can present a unique medical history but some general characteristics can be pointed out (Block, 1991; Henderson, 1985).

### a) Cardiac problems

It has been reported that nearly half of the children with Down syndrome have congenital cardiac abnormalities which are detrimental to their growth and fitness. The most common defect is ventricular septal or multiple cardiac abnormalities. Heart defects in children with DS are generally treated early in life with surgery or medications.

### b) Skeletal problems

DS individuals often have skeletal problems. The most significant of these abnormalities is atlantoaxial instability, which is a result of increased laxity of the transverse ligaments between the atlas and axis of the upper cervical spine. About 12-20% of children with DS have clinical findings of atlantoaxial instability with no apparent over manifestation. Another 1-2% of children with DS have a more critical defect of symptomatic atlantoaxial subluxation. These individuals often display signs of subluxation of the joint resulting in muscle weakness and increasing loss of motor co-ordination which have significant effects on movement and posture (Block, 1991).

### c) Hypotonia

Hypotonia is one of the most common and most significant conditions found in DS. It is defined as an increase in the range of motion of the joints and results in unusual postures such as the frog-like position of the legs in the supine position. Hypotonia is probably linked with the motor delays and abnormal movement patterns exhibited. The exact cause of hypotonia is still unknown. Some researchers (Davis and Kelso, 1982; Davis and Sinning, 1987) have suggested that hypotonia may actually be a manifestation of problems in the control of muscle stiffness and recruitment.

### d) Obesity

One final medical condition that is found in some studies is a strong tendency for children with DS to be overweighted in comparison with nonhandicapped children. The propensity for obesity is more closely common among girls than among boys with DS, as well as among children reared in institutions compared to children reared at home (Cronk, Chumlea and Roche, 1985). It would be interesting to know the effects of exercise and dietary control on overweight among children with DS.

## 3. PERCEPTUAL PROBLEMS AMONG CHILDREN WITH DS

As Henderson (1985) pointed out most of the studies that have attempted to analyse the perceptual attributes of children with DS have had varying degrees of methodological problems. While perceptual problems most likely do exist among children with DS, the success or failure of children with DS in tasks requiring the analysis and interpretation of sensory information may reflect more the task condition and strategies used rather than specific perceptual deficits. Hearing, visual and kinesthetic problems that are associated with perception among children with DS will be briefly discussed below (Henderson, 1985; O'Brien and Hayes, 1993; Block 1991).

### a) Hearing problems

It has been found that almost 55-60% of children with DS exhibit significant hearing impairments. The most common type is a bilateral mild to moderate conductive loss in the high-frequency ranges. Children may exhibit auditory perceptual deficits such as an inability to locate sounds or distinguish between the sounds.

### b) Visual problems

Many children with DS have ophthalmologic disorders, such as cataracts, strabismus, and nystagmus. All these disorders are found more frequently among children with DS as compared to the general population. Furthermore, visual perception problems may be present among children with DS. However, Stratford (1980) showed that apparent visual perceptual problems among children with DS were due to deficit in the children's ability to physically reproduce a display rather than to problems in correctly perceiving the display visually. Thus, visual perceptual problems found among children with DS may in fact be problems in visuo-motor performance rather than in visual perception.

### c) Kinesthetic problems

Children with DS have problems to obtain information regarding the position and movements of the body in space, and the nature of objects that come in contact with the body (Block, 1991). Researchers (Knights, Atkinson and Hyman, 1967) have found that only few DS children were able to perform tactile and kinesthetic discrimination tasks (e.g., to discriminate between objects by texture, size and weight while blindfolded) as compared to children without DS, matched for age and IQ, although the inclusion of visual input improved tactile performance for these children.

Evidently, Down syndrome presents a number of medical, health and perceptual problems. Researchers should take into consideration these conditions when planning a study. Extreme heterogeneity of the DS population makes traditional statistical analyses difficult. Clearly, more research is needed to understand the exact nature of these perceptual problems.

In the next chapters the characteristics in motor development of DS children will be presented and compared with other retarded children and children with no impairment. Later on, this chapter will focus on literature that is more close to the topic of this thesis. That is, how children with DS respond to tasks that involve timing and anticipation. As it will be seen in the following discussion, not much was done in the field of timing in catching a ball among children with DS. Therefore, the purpose of the present overview will be to find some questions/ hypothesis/

assumption/ answers to explain timing problems among children with Down syndrome.

## 4. MOTOR SKILL DEVELOPMENT AMONG CHILDREN WITH DS

Children with Down syndrome are often delayed or abnormal in their physical and gross and fine motor development (Block, 1991; Thombs and Sugden, 1991; O'Brien and Hayes, 1995). Three points which characterise the motor development of individuals with Down syndrome emerge consistently throughout the literature. Henderson (1985) gives a summary of these findings.

### a) Children with DS perform less well than their nonhandicapped peers at all stages of motor development

While a great deal has been studied and written on the early motor development of children with DS, there is little information on the motor development of children as they reach school age (5-12 years old). Two recent studies focused on motor development among DS children and will be presented here.

Connolly and Michael (1986) used the Bruininks-Oseretsky test where they compared the motor skills of 24 mentally retarded children (age 7.6 to 11 years). 12 children were children with DS and 12 without DS. Results of this study indicated differences between the groups in both gross and fine motor skills, with the non-DS group scoring superior in running speed, balance, strength, visual motor skill control and overall gross and fine motor skill performance. Further analysis revealed no differences between the boys of both groups but did show significant differences between the girls. Henderson, Morris and Ray (1981) found differences between 10-years old with DS compared to an age-and IQ-matched group of children without DS on the Cratty Six-Category Gross Motor Test. They found that the children without DS were superior in balance and locomotor agility as compared to the children with DS, but they found no other differences between the two groups on other areas of the test, which includes body perception, ball throwing and ball tracking. On the other hand, LeBlanc, French and Shultz (1977) found no differences between children with and without DS (other retarded) who were matched by age and IQ on the Cratty Six-Category Test. The children averaged 12 years of age and thus were older than in the previous study's sample. Reporting results from the balance subtests only, LeBlanc et al. (1977) found no differences in static balance between the groups but significant superiority in dynamic balance for the children with DS. Taken together with Henderson's et al. study (1981), these results appear to further confuse the issue of differences between children with and without DS who have similar mental functioning. More studies are needed to find whether there are differences in motor development between children with DS and other mentally retarded children, and whether different habilitative motor teaching is warranted.

### b) Children with DS tend to fall further and further behind their nonhandicapped peers as they get older (in terms of both motor and intellectual development)

It has been suggested with respect to motor development that DS children do not progress with age in the same way as normal children. If one simply looks at the IQ scores given in various studies, the average DS baby seems to score around 70 in the first few months of life but then the scores drop quickly thereafter. This does not mean that the child with DS makes no progress. It might be that there are periods when the infant manifests no apparent progress and periods when development is rapid and many new skills emerge (Cunningham, 1979).

### c) There are tremendous inter-individual and intra-individual differences in development within the DS group

Intuitively, one might expect Down's individuals form a more homogeneous group than normals. However, this is not the case. For example, whereas a normal child starts walking between 9 and 17 months of age, for DS children the range is 13 to 48 months, or even more (Cunningham 1992, in Henderson, 1985). While some have speculated about the origin of this variability, few studies have attacked the questions directly. As Gibson (1978) pointed out, the origins of motor developmental differences are likely to include the variable effects of karyotype, secondary organic processes, physical nurture, health status, stimulation level, sex and the morphological factors peculiar to the syndrome. Furthermore, besides inter-individual differences there are often intra-individual differences or within subject variability. DS children perform very differently from trial to trial. That is, one trial they perform at a good level, but the next is absolutely under good level. This variability should be a concern for the researchers who are trying to design a study with homogenity and control.

From this short review of the literature, it is evident that children with DS have deficiencies in sensory-neurological, integrative-perceptual and motor learning control processes. They have a delayed reflex development (Block, 1991), low muscle tone (hypotonia: Davis and Kelso, 1982; Davis and Sinning, 1987), slow movements (Henderson, 1985; Block, 1991), problems in integrating sensory information and in organising a movement response (in Henderson, 1985), and controlling the force of their movements (Henderson, 1985). These problems seem to be a reason for lower performance in movement tasks and also the reason for falling further and further behind in terms of motor and intellectual development as compared to normal peers. DS individuals form a very heterogeneous group with inter- and intra-individual differences within the DS group, which should be of concern in research studies and in physical education as well. Up to now, only general patterns of motor development and skills are discussed. Therefore, in the remaining of this chapter grasping and catching patterns will be pursued.

## 3. GRASPING AMONG CHILDREN WITH DS

Despite the importance of grasping in every day living, few research have analysed grasping patterns of Down syndrome subjects. An exception is the work of Moss and Hogg (1981) and Hogg and Moss (1983). The result of their studies suggested that both Down syndrome subjects and age matched controls (age range of 15 and 44 months) demonstrated an increasing use of precision grips (adult digital and transverse digital) with age. However, the oldest Down syndrome subjects did not advance to the same level of precision versus power grip as found in the oldest subjects without Down syndrome. Power grips involve the use of all the digits while the precision grips generally involve only the thumb and index finger. Moss and Hogg (1981) also noted that children without disability showed an increasing use of the adult digit grip with decreasing size of the rod, but the children with Down syndrome did not. They suggested that this latter finding 'may be partly accounted for by anatomical factors' (Moss and Hogg, 1981). It is well known that hand-size differences due to shorter finger in persons with Down syndrome exist in comparison with other persons of the same age (e.g. Chumlea et al., 1979) and has an effect on perceptual-motor coupling (Savelsbergh, Davis, Van der Kamp, Sing Badhan, 1994). In a study of Thombs and Sugden (1991), 40 DS children between 6 and 16 years of age were examined using qualitative and quantitative methods on a range of manual tasks. These involved a variety of hand actions during peg displacement, transportation, manipulation and relocation. A number of age related changes were reported. With an increasing age there was an almost linear increase in the use of precision as opposed to power grips, offering the older children a greater range of responses. In general older children were more consistent in their approach than younger children, although this was not a linear increase and was also dependent on the type of task. On a number of speed measures, the older DS children were faster in performing the task.

Based upon the above findings, it is reasonable to expect that hand-size differences might account for some of the differences in grasping patterns found when comparing Down syndrome to subjects without impairment. Therefore, when examining catching, ball size as related to hand size should be taken into consideration, particularly when using children between 5 to 12 years of age. The following discussion will focus on catching performance and temporal characteristic in DS children, which is closely related to the present research and will be important for further discussion.

## 6. CATCHING AMONG CHILDREN WITH DOWN SYNDROME

The only known report in the literature with respect to catching performance in DS is the report by O’Brien and Hayes (1995). They found that the Down syndrome children performed worse as compared to other mental and non-handicapped children. One of the possible reason might be that skills such as ball catching, where failure is so obvious, are considered to be unsuitable for mentally retarded children and DS children as well (e.g. Henderson et al, 1981). As has already been mentioned in the Chapter I, to catch a ball successfully the hand has to be positioned at the interception point, followed by a spatial adjustment of the hand such that the ball makes contact with the hand in the metacarpal region, and the grasp has to be initiated and completed within a defined time-window depending on the speed of the approaching ball. Failure to fulfill the gross and fine orientation results in spatial and temporal errors.

The Down syndrome children have problems with interceptive action (e.g. O'Brien and Hayes, 1995). From this study it is unclear whether this problem is due to spatial or temporal errors or both. Moreover, it also remains unclear whether this problem is due to perceptual (e.g., do they perceive time-to-contact and what kind of information do they use) or motor problems (are they more clumsy, slow). Since, motor control under temporal constrains is the main interest in the present paper, special attention in the lines below will be on the control of timing in children with DS.

### 6.1 Timing among children with DS

Studies on motor impaired children have indicated that children with Down syndrome may have deficiencies in controlling the timing and spatial parameters of a movement and that they would be unable to maintain accuracy of their movement (Henderson, 1985). However, it should be mentioned that very little is known regarding how children with DS respond to tasks that involve timing and anticipation. Two of experiments that are closely linked to each other are of special interest in this respect. In both, Frith and Frith (1974) and Henderson, Morris and Frith (1981) subjects were required to perform a task under temporal constraints.

In the experiment of Frith and Frith (1974) the subjects were required to perform two simple motor tasks: pursuit rotor tracking and finger tapping (a single plate tapping task). The results from DS children (n=17) were compared to normal (n=23) and autistic children (n=19). There were two major differences in the performance of the DS group in comparison with the other two groups. Firstly, the DS children failed to show an improvement in tracking after a five minute rest while normal and autistic children did show a marked improvement. Secondly, DS children tapped abnormally slowly. It is hypothesised by Frith and Frith (1974) that DS is associated with specific difficulties in using feedforward motor programmes (i.e. planning and producing movement without feedback) and that DS children may therefore be dependent on simple feedback processes to perform motor tasks.

Furthermore, also of special interest is the study from Henderson et al. (1981). Although Henderson et al. (1981) did not choose catching a ball as the experimental task, they were primarily interested in temporal constraints in motor behaviour. Henderson et al. (1981) considered young children learn to catch a ball:

> He must learn *where* the ball will arrive and *when* it will arrive within reach. In other words, he must learn to predict the final location of the ball from its trajectory and its arrival time from the speed at which it is approaching. It is not uncommon to find that these two components do not develop synchronously. The young child may make the correct sequence of movements and may be in the right place but be too late to successfully catch it. There are two possible reasons for his failure to arrive in position at the correct time. First, he may be unable to make the perceptual judgements necessary to plan the correct sequence of movement. Alternatively, he may know when he should arrive but be unable to make the required movement fast enough. This problem of timing, whatever its sources, is common in many children with movement difficulties. The

> specific problem in the programming of movements apparently shown by the DS children may only reside in this timing component, but not in the spatial component. This hypothesis would allow us to explain the sometimes contradictory findings relating to movement control in DS children (Henderson et al. 1981: 234).

Thus, according to Henderson et al. (1981) DS children have no more difficulty than their retarded peers when success depends on the accurate performance of a particular movement pattern, provided the task is free of time demands. When the child, however, is required to complete a sequence of movements in a set time, or time his movement to coincide with external events, his difficulties would become evident. Henderson et al. (1981) sought to find a task which would allow them to examine responses to a highly predictable input over a reasonable period of time. They found a skill such as ball catching, where failure is so obvious, unsuitable. Therefore, they adopted a tracking task where they investigated possible differences in performance in four related timing tasks among 10-year-old mildly mentally retarded children with (n=17) and without (n=17) DS as well as a group of 5 and 6 year old children without mental retardation (n=12). Each child performed two tracking tasks (the sinusoidal track and accelerating track), and two subsidiary drawing tasks (drawing from memory). The tracking task was introduced as a driving game in which the subjects would pretend to drive a vehicle of their choice along the ‘road’. The children traced with a pencil a curved path on a slowly moving piece of paper and were tested on their ability to anticipate changes in the path of the road by copying the movement. In the subsidiary drawing tasks subjects were tested how they draw the paths they had been tracing with the pencil from memory.

The main aim of this study was to find differences in the temporal components in the tracking tasks between the DS children and their matched retarded controls. Henderson et al. (1981) defined timing as how a subject controlled his movement. This was examined by looking at the accuracy of copying (hitting) the peaks of the sinusoidal track. A second measure of how well a subject can 'keep up' (i.e. time) with the target is simply to measure the total amount of time he remains in contact with it. In order to hit the peaks exactly it is necessary to slow down when approaching the turn, subsequently change the direction of the movement and speed up again on the sides (Henderson et al. 1981). It was shown in this study that the non-handicapped children had no difficulty following the moving path in the pencil and paper task. The children with mental retardation did not perform as well in this task as the nonhandicapped children but better as children with DS. Both groups of children (with or without DS) were able to draw the path from memory fairly accurately. Children with DS were not able to accurately match this knowledge to the act of moving the vehicle along the road. Therefore, Henderson et al. (1981) concluded that problems in DS children associated with anticipatory movement tasks are due to temporal rather than spatial errors.

What is interesting in this study is that Henderson et al. (1981) found catching a ball a too difficult task to find information about temporal characteristics in motor behaviour in DS children. Probably Henderson et al. (1981) could not find a solution how to exclude spatial umcertainty such that only temporal aspects can be examined in catching. Timing in tracking and catching differ with respect to the available information sources. As discussed in adult catching the approaching ball provides retinal expansion information that is related to the optical variable Tau. Tau, which specifies contact and appears a very likely candidate for the control of timing in catching. With respect to the Henderson et al. study (1981), it can be argued that the information about the temporal aspect in the tracking task differs from that in catching: that is, no retinal expansion information is available. To find which type of information is used in tracking, the researcher should manipulate the constraints on timing (e.g. different speed, binocular or monocular condition, dark or light condition). The second problem in the Henderson et al. study (1981) is whether the accuracy in following the peaks of the track, is really a timing measure, or it is a spatial measure. However, this study will serve as a kind of starting point for the present study. It gives possibilities for a comparison of the results in two different tasks such as tracking (Henderson et al. 1981) and catching a ball, where the interest of the research is in the same domain; timing.

A study from Kerr and Blais (1985) showed that while children with DS have problems in tasks involving coincidence timing they could improve their performance with training. In their study 37 male subjects (12 with DS, 10 mentaly retarded without DS and 15 nonretarded) performed eight trials on a subject-paced pursuit tracking task. The main findings was that subjects with DS did not respond to directional probability in the same manner shown by the retarded or the nonretarded subjects matched for chronological and functional age. This difference in strategy was also reflected in their greater emphasis on accuracy rather than speed. Finally, these effects were consistent across the subjects with DS despite the large intersubject variability seen in their performance. In a study by Sugden and Keogh (1990), it was argued that central processing limitation specifically related to memory may be associated with DS children's inability to utilise accumulated knowledge in anticipatory tasks. It might be argued that visual problems play a role in timing problems, especially given that most coincidence-timing task involve visual tracking. However, there is a need for more research in this area. Finally, it may be possible that children with DS can perform anticipatory task at some levels but not at others. On possible paradigm for exploring this notion is to manipulate the environment so that the children are tested in different anticipatory situations.

To follow this ideas, the information that is used in ball catching by DS children and children with no impairment will be examined. As discussed in adult catching there are some studies where manipulation of different information sources was carried out. There it was found that the optical variable Tau (time to contact) and disparity (ball size) are important information for timing (Savelsbergh et al. 1991; Van der Kamp et al. 1995). To turn to children’s catching, unfortunately not much is known about temporal characteristic of catching and the information used. To find whether some temporal characteristics as found in adult catching can also be found in children’s catching, spatial constraints will be excluded and some of the studies presented above will stand as a comparison.

## 6.2 Reaction and Movement time among Children with DS

Perhaps the most consistent finding in the literature on mental retardation is that mentally handicapped individuals perform more slowly than their normal peers (Block, 1991; Henderson, 1985). Furthermore, the bulk of the evidence seems to suggest that DS individuals perform even more slowly than other retarded subjects of the same mental age. Berkson (1960) was one of the first authors to report systematic differences in reaction times between DS and other mentally retarded subjects. Using a series of tasks of increasing difficulty, he found that the DS subjects were not only generally slower, but also fell more and more behind as the task became more complex.

In a review of simple and choice reaction time experiments (Henderson, 1985) it has been reported that children with Down syndrome of the same chronological age as intellectually disabled children have a slower premotor reaction time (Henderson, 1985).
The movement time data (i.e. speed of the actual movement, once the movement is initiated) showed that children with Down syndrome had significantly longer movement times than either normal, clumsy or intellectually disabled children. Such a finding helps to explain observed slowness in movement of these children (e.g. Connolly and Michael, 1986).

From the review of the motor control under temporal constraints it is suggested that children with DS have deficiencies in controlling timing parameters. Compared to other mentally retarded peers they fail to perform at the same level. Henderson (1985) reported significantly slower movement and reaction times which help to explain observed slowness in movement of these children. Unfortunately, not many findings can be discussed about timing in a task such as catching. Most researchers (e.g. Henderson et al. 1981) found catching too difficult for DS children. However, spatial uncertainty can be excluded in catching tasks (see Savelsbergh et al, 1991; Van der Kamp et al. 1995), and using such a set up, where timing constraints in a task as catching can be taken upon. This will be examined in present research.

## 7. SUMMARY AND CONCLUSION

Down syndrome presents a unique etiology that affects many areas of development. Of specific concern are the motor delays and deviations that can affect the development of such areas as fundamental motor patterns, physical fitness and the learning of complex motor skills. The effects of DS on motor development have been reported over the years, particularly with the profusion of research in the past 10 years. The most important conclusions and a brief summary are given here.

Firstly, while it is often stated that children with DS exhibit normal but delayed course of motor development, there is evidence that they have many unique motor problems. Hypotonia, abnormal reflex development, instability and obesity present the greatest boundaries in the acquisition of motor skills of children with DS (Block, 1991).

Medical and health problems such as congenital heart defects, atlantoaxial subluxation and joint hypermobility as well as sensory-motor problems affect motor development in children with DS (Block, 1991).

Children with DS have problems in controlling the timing and spatial parameters of a movement and they are unable to maintain accuracy of their movements. Unfortunately, not many findings are reported with respect to timing of children with DS. Henderson et al. (1981) concluded that problems associated with anticipatory movement tasks are due to temporal rather the spatial errors. Additionally, it was found that children with DS have longer reaction and movement times as normal children, and that they are slower in reaction time compared with other mentally handicapped children, but equal in movement time.

Catching and temporal constraints were not examined among children with DS yet. Thus, the central issue of the present study is the optical information that is used in the control of the temporal aspects in one-handed catching. Results from DS children will be compared with non-impaired children.

## SUMMARY AND MAIN CONCLUSIONS OF THE LITERATURE REVIEW

Before reporting the experiment, the literature review with respect to adult, children and Down syndrome catching is summarised and the main conclusions will be pointed out. The aim of this part is to outline those aspects that are linked with the present research.

From adult catching it is known that successful one-handed catching requires temporal and spatial predictions based on visual, proprioceptive and exteroproprioceptive information. The optical variable Tau and disparity are visual information sources which are used by adults.

Concerning children, there are some descriptive studies, but not much is known about temporal versus spatial errors in catching. Some factors as size, speed and colour of the ball play an important role in children’s catching. However, nothing is known about the nature of the visual information needed (only vision of the hand is shown to be important). In sum, the nature of information in children’s catching is still unknown and to uncover these will be a challenging task for further research in this field of motor performance.

Studies with Down syndrome children report, besides many medical and health problems, motor performance problems. DS are slower in comparison to the normal children and other children with mental retardation. It was suggested that children with Down syndrome have problems with interceptive action, especially in the temporal domain. However, it is still unclear whether this is a perceptual, motor or a perceptual-motor problem. As stated in the introduction, perception and action can not be separated and this will be the focus at the experiment. As for children with no impairment, also for DS children nothing is known about the nature of information needed in the control of the timing. This present research might shed some light on these issues.

# PART TWO. RESEARCH STUDY

## 1. INTRODUCTION

In several studies with Down syndrome children, it is has been reported that motor performance is slower in comparison with normal children and other children with mental retardation (Chapter III). In particular, it has been suggested that children with Down syndrome have problems with interception actions (Henderson, 1985; Block, 1991). Therefore the main goal of this research is to examine whether and why DS children perform worse compared to children with no impairment in a motor task such as one handed catching.

More specifically, it is examined whether the worse performance in catching, as found in O'Brien and Hayes (1995), is due to different or worse temporal judgements (timing). Although the generalisation of Henderson et al. (1981), from a tracking task to catching performance is arguable, it could be hypothesised that it is a timing problem that explains the differences in catching between DS and children with no impairment. In addition, because perception and action are strongly connected, it is important to know whether this is due to a perceptual or motor or perceptual-motor problems (Introduction, part one).

Studies in adult catching, examining the nature of the visual information, showed that optical variables Tau and disparity (probably providing information about perceived size of the object) play an important role in the guidance of interceptive action (Chapter II). However, the visual information sources used by children are still unknown (Chapter II), especially not among children with DS (Chapter III). Therefore, in the present experiment, the children were required to catch balls of different size under binocular and monocular viewing conditions. From the literature overview several hypotheses follow.
Firstly, since the optical variable Tau can be perceived monocularly, it is hypothesised that if children use the optical variable Tau in order to steer their timing, no differences should be found between monocular and binocular vision

conditions. Secondly, since Tau (i.e. the *relative* rate of expansion) is independent of ball size, no differences in timing for the different ball sizes are expected. If, however, perceived size and/or disparity are important, differences between monocular and binocular condition and differences between ball sizes should be found (Van der Kamp et al., 1995). Furthermore, differences as a result of these visual conditions between DS children and children with no impairment will show whether the timing problem is a perceptual problem.

## 2. METHOD

### a) Subjects

The research involved 27 children in the age range between 5 and 12, of which 11 were subjects with Down syndrome (8 male, 3 female) and 16 had no impairment (7 male, 9 female). Characteristics of these 27 children are described in the Table 3.

Table 3: Characteristic of the children: number, sex, average and standard deviation of age

| group | number | sex | average age (X) | standard deviation of age (SD) |
|---|---|---|---|---|
| DS | 11 | 8 boys<br>3 girls | 8.3 years | 3.1 years |
| Control | 16 | 7 boys<br>9 girls | 7.1 years | 2.2 years |

All children participated with their own and their parents’ consent, and had normal or concluded to normal vision.

**b) Apparatus**

Subjects were required to catch balls which were presented by the Ball Transport Apparatus (BallTrAP: Figure 7). The BallTrAp is a large (305 cm x 110 cm x 15 cm) wooden box, supported by two fixed aluminium columns, 155 cm above the floor. Within this box there are two iron wheels (diameter 80 cm) with their centres 200 cm from each other. These wheels are connected to each other with a rubber belt (651 cm) on which an aluminium rod (length 58,5 cm) is fixed. One of the iron wheels is driven by a Micron MT30r4-58 Servo-Motor (maximal torque 3,5 Nm and maximal 2500 Rpm) that is controlled by a Galil DMC-700 Motion Controller. The Motion Controller receives its instructions from FAMS-lab software installed on a PC (Lijn 80486Dx-33). All of this allows the distance, velocity, acceleration and deceleration of the rod to be specified precisely. Balls are fixed onto the rod. In the present experiment the balls had a diameter of 3 cm (small ball), 5 cm (medium ball), and 6 or 7 cm (large ball). The size of the large ball was adapted to the hand size of the child and determined by multiplying hand size by the dimensionless factor .6 (Van der Kamp, Savelsbergh, Singh Badhan, Davis, 1996).

The subjects were seated in the chair, next to the table and below the wooden box, at the end of the 200 cm straight path. The right wrist of the subject was fixed in the armrest, positioned on the table, such that only movement of the fingers was possible. Distance between the eyes and the hand was about 30 cm.

Positioning of the hand ensured the hand to be in the path of the ball, so that the ball on the rod always swung into the hand of the subject. No spatial uncertainty with respect to the trajectory of the ball was present and therefore only temporal judgements were required to catch the ball. Figure 7 illustrates the design of the apparatus.

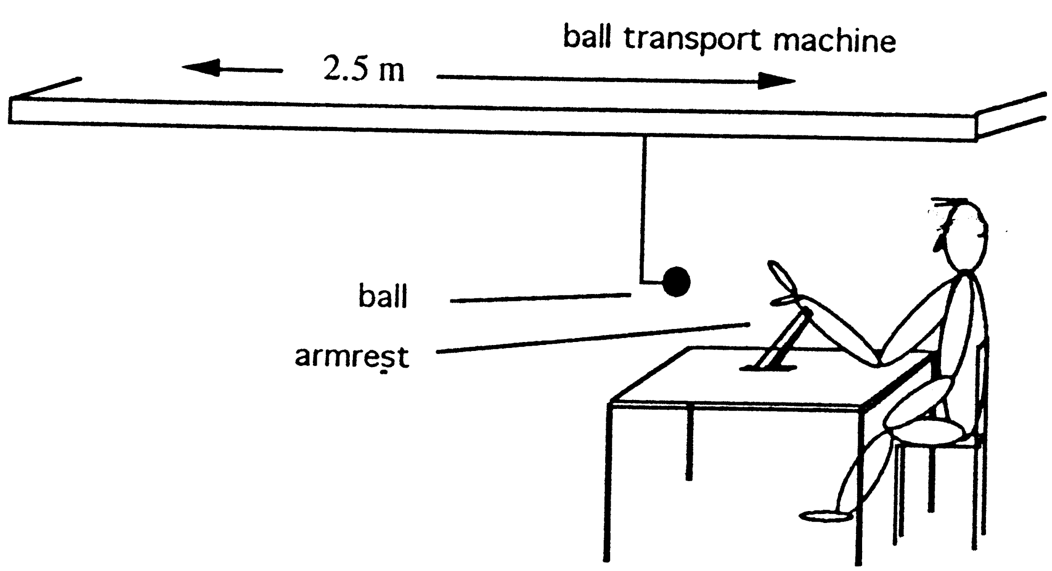

Figure 7: Design of the apparatus

Kinematic characteristics of the catch were measured with the Selspot system. The camera was placed at a 110 cm distance, laterally from the subject, at the height of 110 cm. The Selspot system recorded the position of four light emitting diodes (LED's) positioned on the end of the rod (‘ball-LED’), on the wrist at the anatomical snuffbox (‘wrist-LED’), and on the tips of the thumb and the index finger. Four reference LED's with known distance were in the same plane as the experimental LED's on the hand and were used to calculate the distance between the experimental LED’s. The position signals of LED's were sampled with a frequency of 156,4 Hz, and filtered by a second order Butterworth filter with a cut-off frequency of 10 Hz.

### c) Procedure

Subjects were required to catch 45 balls. The balls were 3 (small), 5 (medium) and 6 cm (large) in diameter. The balls were painted with luminous paint and were visible in the total dark.

Every ball was caught 5 times under binocular light, monocular dark and binocular dark condition. The first, light binocular condition was used only as a practice. In the dark conditions only the ball was visible. In the monocular condition children wore an eye patch ('pirate patch') on the left eye, which prevented binocular vision. In total nine conditions were carried out. Note, that the first 15 balls in a light binocular condition were used as practice. Three different sized balls were randomly ordered within the three conditions. Before each trial, the ball was loaded with a light bulb and transported to the subject. Subjects were required to catch the ball between thumb and the other fingers. Each trial the subject started with the thumb and index finger contacting each other. The experiment always started with the binocular light condition, the second and the third condition were counterbalanced in order to control for learning effects. After 15 trials there was a short break of approximately 2 minutes. Each subject spent approximately 30 minutes to complete the experiment.

To find out whether the experiment was indeed suitable for 5 to 12 year old children, a pilot study was carried out in which a 5 year old boy and a 7 year old girl participated. The results from this pilot were also used for the final analyses. However, only the video data (i.e. the number of misses) of the boy were used due to technical failure of the kinematic recordings, while from the girl, video as well as kinematical data were included. The pilot study showed that the experiment was convenient for the children, indeed.

### d) Analysis of the Data : Dependent Variables

Analysed were the catching failures, (i.e. the number of misses), and several kinematic variables, which were of importance with respect to timing. The moment of ball-hand contact was defined as the moment at which the distance between the ball LED and wrist LED is minimal. Referring to this moment the occurrence of the following temporal characteristics are determined:

- The moment of opening the hand or the *initiation of the catch* (i.e., the distance between the thumb and index finger starts to increase)
- The moment of closing the hand or the *maximal aperture* (i.e., the moment the distance between thumb and index finger is maximal)
- The moment of catch or the *time of catch* (i.e., the moment the distance between thumb and forefinger is at minimum (depending on ball size or the way the ball is caught)

These three kinematic landmarks are presented in the Figure 8.

To complete the kinematical analyses of the catch, also the results of the *maximal aperture of the hand* (i.e., the maximal distance between the LED's on the thumb phalanx and index finger) and *peak closing velocity* (i.e., maximal closing velocity) were analysed and taken into consideration (Figure 8 and 9).

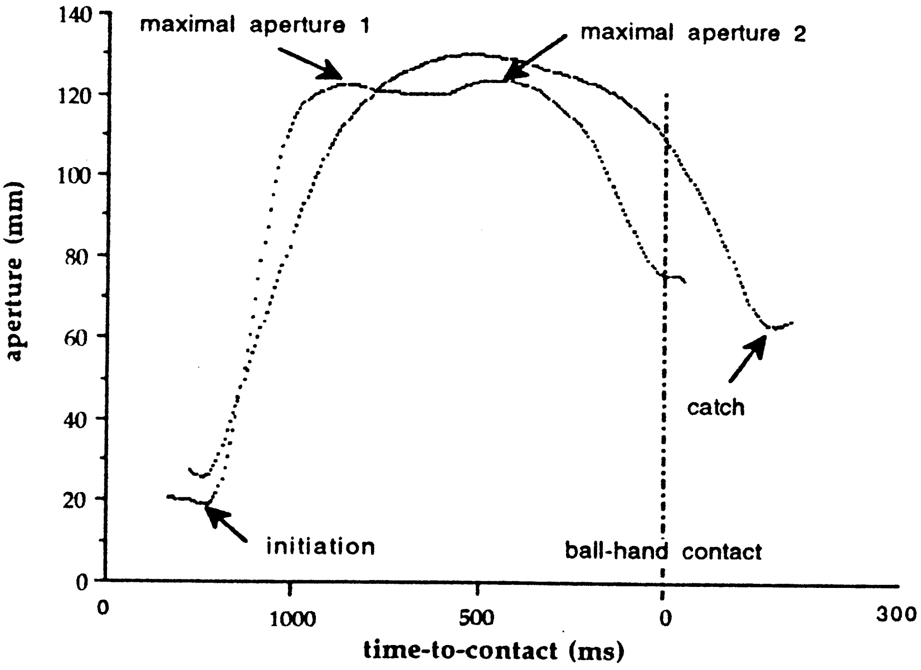

Figure 8: The kinematic landmarks: time of initiation of the catch, maximal aperture (represented by maximal aperture 1), time of maximal aperture (represented by maximal aperture 2), time of the catch (indicated by arrows: adapted from Van der Kamp et al., 1995)

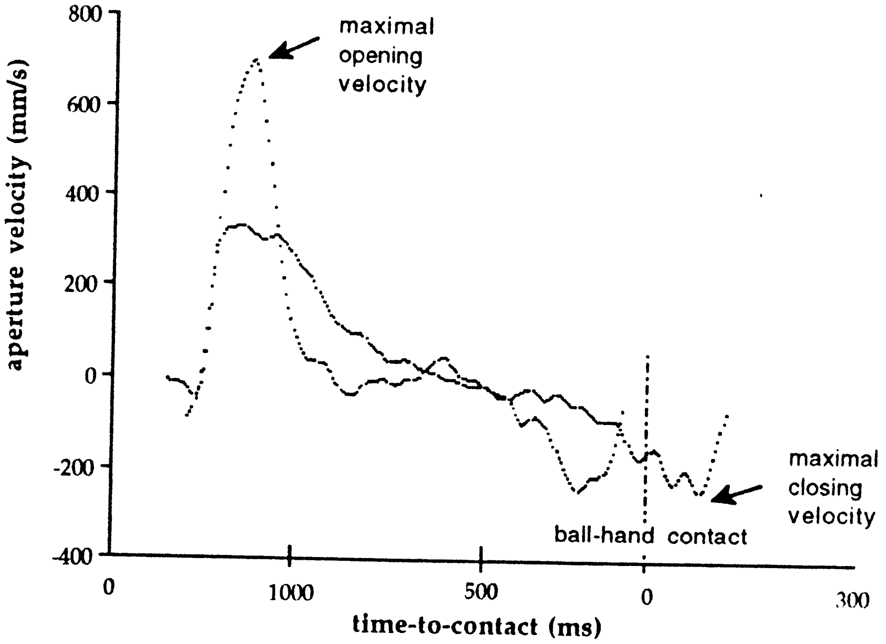

Figure 9: The kinematic landmarks: maximal opening velocity and maximal closing velocity (indicated by arrows: adapted from Van der Kamp et al., 1995)

## 3. RESULTS

Most subjects understood the task, however four DS children caught balls only in the light binocular condition, and they were not used for further analyses. One young DS and one control subject caught only 9 balls in each viewing condition in order to conduct the experiment in a shorter period of time.

The results of the study will be presented following the questions pursued above, namely firstly, the differences between DS as compared to control, will be pointed out (misses and kinematic analyses) and secondly, differences with respect to factors Viewing and Ball Size for all the children together. For each dependent variable, a separate 2 (Group; DS vs. control) x 2 (Viewing; binocular vs. monocular) x 3 (Ball Size; small, medium, large) analysis of variance was carried out with repeated measures design on the last two factors. To identify differences between means, Newman-Keuls post-hoc comparisons were carried out
(with $p < .05$).

### 3.1 Differences between DS and Control Group

#### a) Percentage of catching failures - misses

To answer the question concerning the differences in catching performance in children with Down syndrome and children without impairment, the percentage of misses were compared.

For the *percentage of misses*, a significant main effect of Group was found, (F(1, 20) = 20.30, p < .001). DS children missed more balls than control group; DS missed 30% of the balls vs. control 7% of the balls.

An interaction effect of Ball Size by Group was found, F(2,40) = 9.907, p<.001, (Figure 10). Post-hoc comparisons indicated that both groups showed more misses for the small balls compared to the other two sizes. In addition, the DS showed more misses for the small ball compared to the control children.

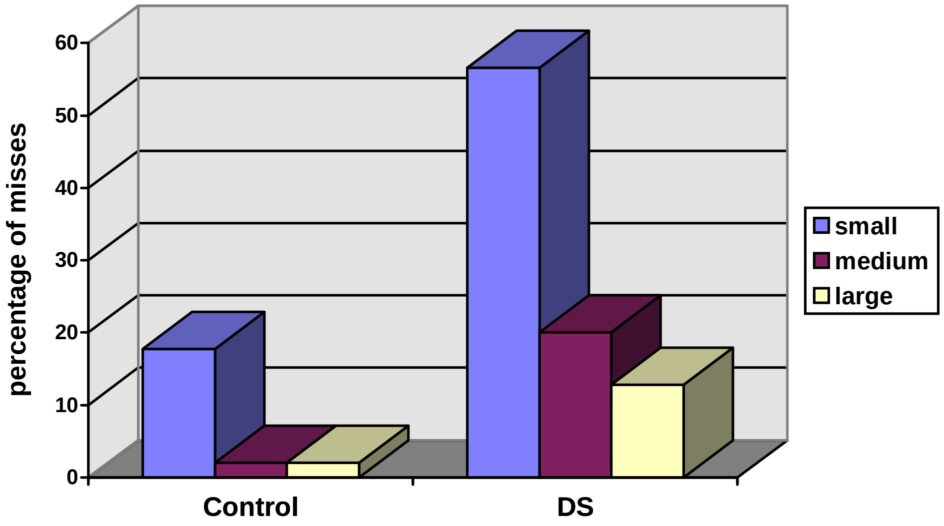

Figure 10: Interaction effect Ball Size * Group for the misses

No interaction effect of Viewing by Group was present, F(1, 20) = 0.057, while the third order interaction effect of Viewing by Ball Size by Group, tended to reach the level of significance, F(2, 40) = 2.56, p = .09 (Figure 11).

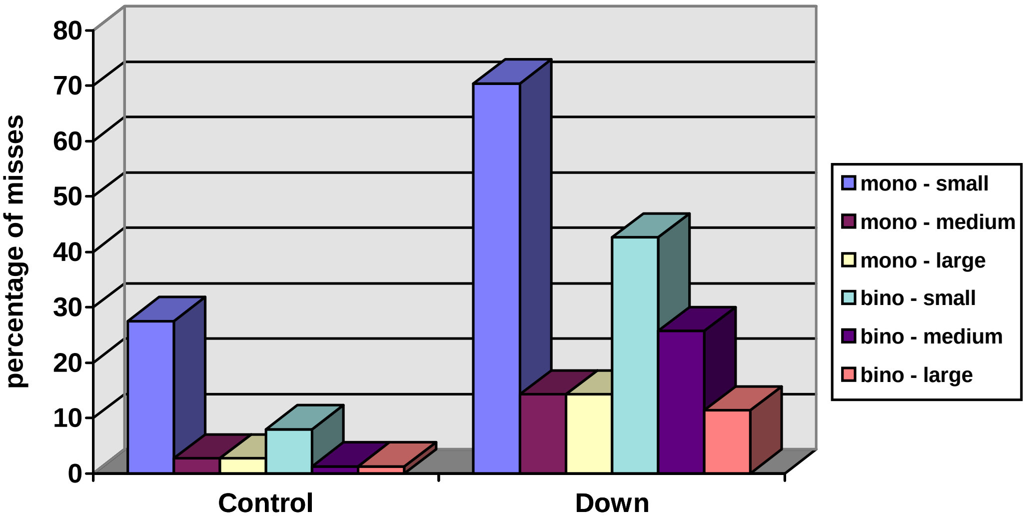

Figure 11: Interaction effect Viewing * Ball Size * Group for the misses

**b) Kinematical analysis of the important temporal characteristics of catching**

With respect to temporal characteristics of catching, results of the *time initiation of the catch,* the *time of maximal aperture* and the *time of catch* will be discussed. Additionally, to complete the kinematical analyses results of *closing velocity* and *maximal aperture* will be presented in this section. In Table 4 the kinematic data is reported.

Table 4: The means and standard deviations (in parentheses) of dependent variables as a function of Group

| DEPENDENT VARIABLE | DS GROUP | CONTROL GROUP |
|---|---|---|
| Time of initiation of the catch | -702 (166) | - 789 (152) |
| Time of maximal aperture | -241 (96) | - 270 (83) |
| Time of the catch | 57 (91) | 21 (74) |
| Maximal hand aperture | 66 (24) | 56 (10) |
| Peak closing velocity | -395 (156) | -281 (110) |

Note: Time of initiation of the catch, time of maximal aperture and time of the catch are in milliseconds (ms), while maximal hand aperture is in millimetres (mm) and time of peak closing velocity is in mm/s. The minus sign indicates that the time is *before* the catch.

With respect to the temporal variables, that is, the *time of initiation* (F(1,17) = 2.0), the *time of maximal aperture* (F(1,19) = .95) and the *time of catch* (F(1,19) = 2.65) no significant main effects for Group were found, although the *time of catch* approached significance (p = .11). From Table 4 it can be seen that the DS children tended to complete their catch later than the control children. Since also the variance is higher for the DS group, a t-test for the time of catch was conducted. This (unrelated) t-test showed that the difference was almost significant, t(19) = 1.63, p = .06. Figure 12 illustrates that the DS tended to complete the catch later compared to the control children. This was confirmed with a Mann-Whitney rank order test, which was found to be significant, U(19) = 78, p < .05. This significant effect indicates that DS were indeed late catchers in comparison with controls. When plotting means of all trials together in the time window (Figure 12), and adding twice the standard deviation (Figure 13), it is clear that this tendency in DS to catch the ball later, might result in more misses in catching. From Figure 12 it can be seen that DS subjects closed their hand later (the ball almost has left the hand already, about 100 ms after contact) in comparison with controls. Only one DS subject closed his hand early. Figure 13 shows that when the time region (i.e. mean plus or minus 2 SD) within which DS caught the ball is plotted, with the tendency of DS children being later, indeed explains the higher frequency of catching failures. That is; the ball is often gone before they finished the catch.

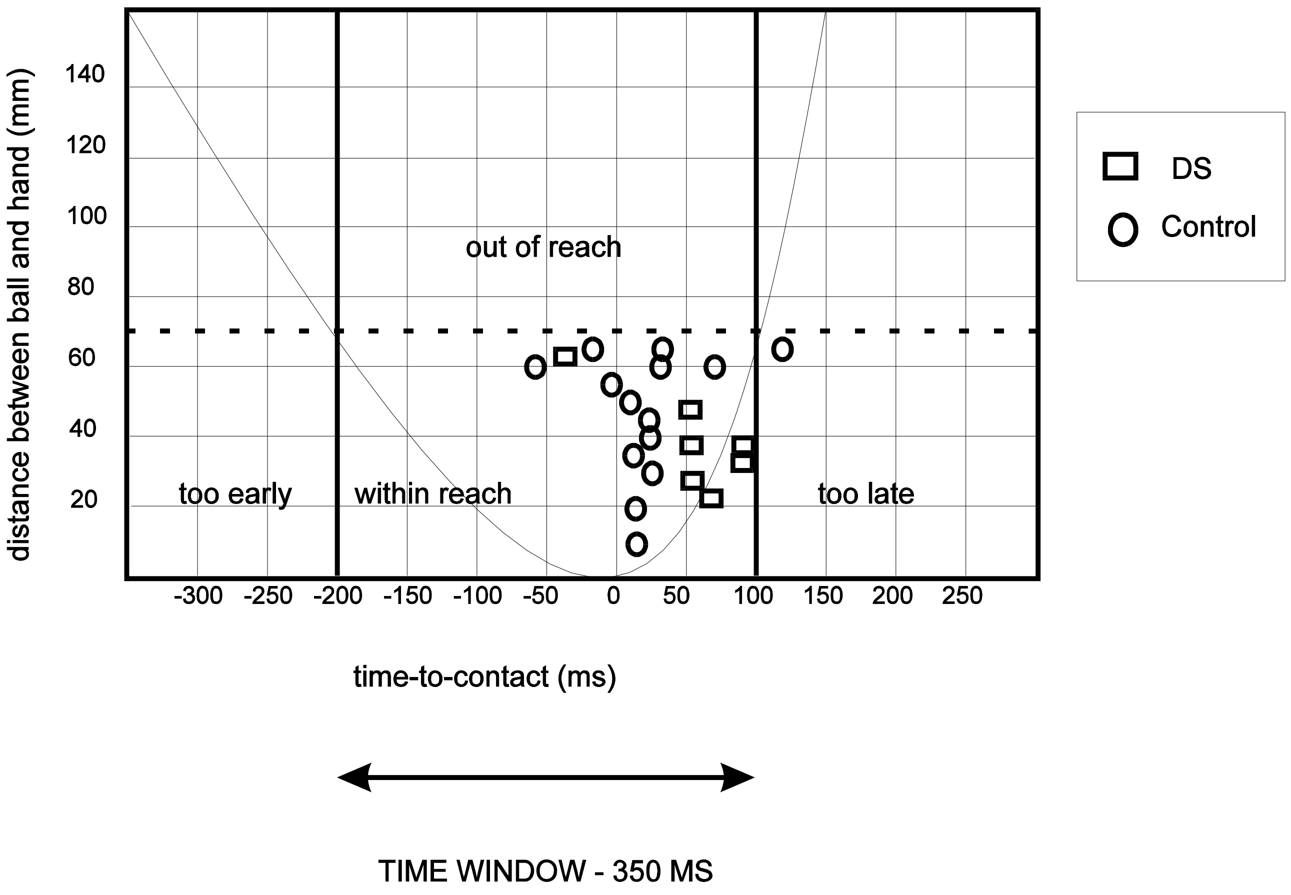

Figure 12: Means of the time of catch (7 DS and 14 Control subjects) in the time window

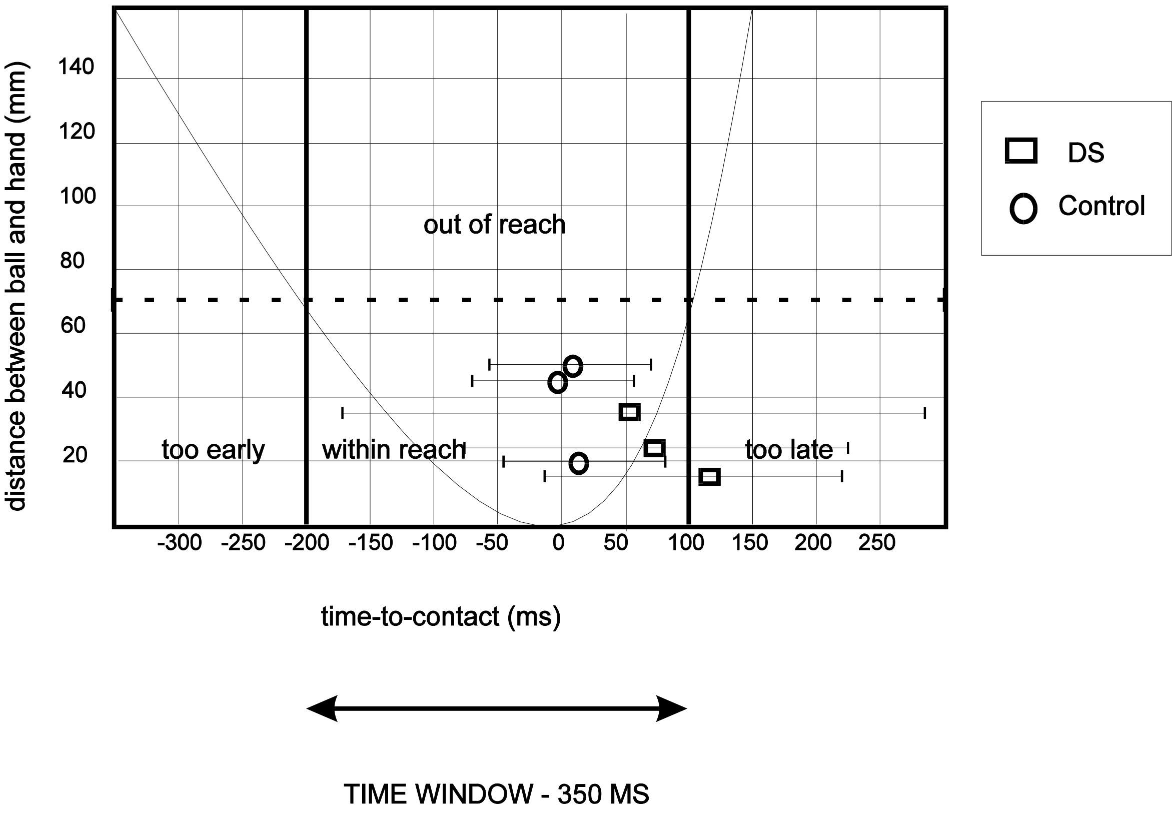

Figure 13: Means and twice the standard deviation of the time of catch (3 DS and 3 Control subjects) in the time window

Three DS and three Control subjects are presented in the Figure 13. It is seen that all three DS are out of the time window (too late) with two standard deviations (SD) compared to control subjects (they are within reach).

A significant main effect of Group was present for the *closing velocity*, F(1,18)=8.544, $p < .01$. DS closed their hand significantly faster compared to normal children (Table 4).

For the *maximal aperture*, an interaction effect of Viewing by Group was found, F(1, 15) = 4.65, $p<.05$. Post-hoc comparisons revealed that DS opened their catching hand significantly more in the binocular condition than control group. This was not the case in the monocular viewing condition (Figure 14).

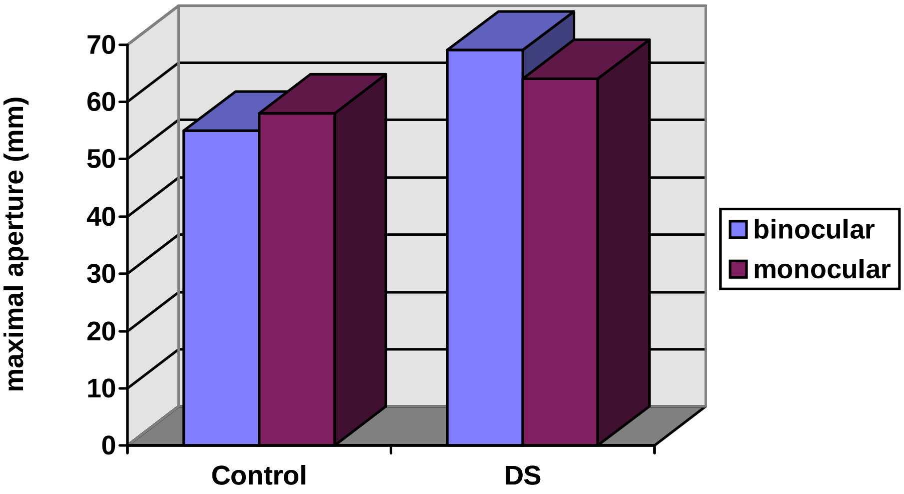

Figure 14: Interaction effect Viewing * Group for the maximal aperture

It can be concluded at this point, that DS group missed more of the small, medium and large balls in comparison with the control group. With respect to timing characteristics in one handed catching, the results show that DS completed the catch too late, but did not start to open and close the hand later.

### 3.2 View and Ball Size

#### a) Percentage of catching failures - misses

A significant main effect was found for Viewing, F(1, 20) = 9.49, $p < .01$. The children missed 10.9% in binocular and 17.9% in monocular condition. Moreover, a significant main effect for Ball Size was found, F(2, 40) = 49.416, $p < .001$. Post-hoc comparisons indicated that the children missed significantly more small balls than medium and large ones, but not significantly more medium balls than large ones. An interaction effect of Viewing by Ball Size was found, F(2,40) = 20.088, p < .001 (Figure 15). Post-hoc comparisons indicated that the children missed significantly more small balls than medium and large balls both in the binocular and in the monocular condition. Furthermore, the children missed significantly more small balls in the monocular than in the binocular condition. No such differences were found with respect to the medium and large balls.

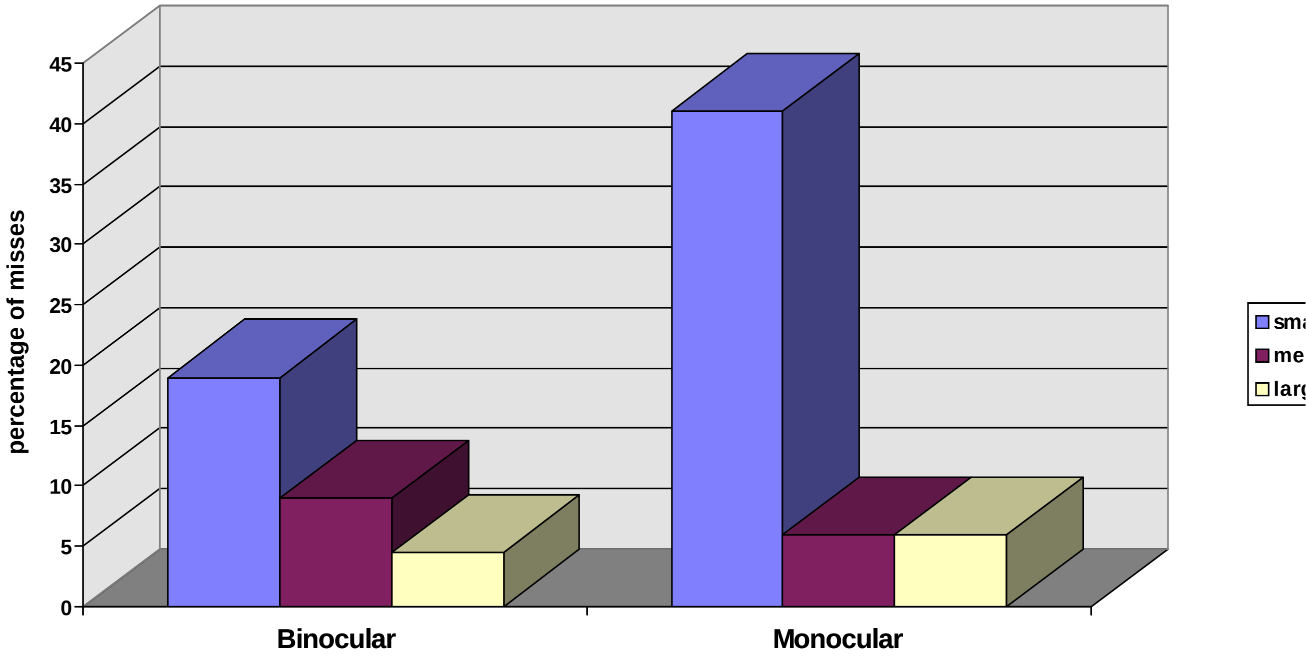

Figure 15: Interaction effect Viewing * Ball Size for the misses

**b) Kinematical analysis of the important temporal characteristics of catching**

The data with respect to Ball Size and Viewing condition are reported in Table 5.

Table 5: The means and standard deviations (in parentheses) of several dependent variables as a function of Ball Size and Viewing

| DEPENDENT VARIABLE | Ball size | Monocular condition | Binocular condition |
|---|---|---|---|
| Misses | small | 41 (32) | 19 (25) |
| | medium | 6 (13) | 9 (17) |
| | large | 6 (11) | 5 (9) |
| Time of initiation of the catch | small | - 679 (172) | - 765 (141) |
| | medium | - 762 (189) | - 792 (157) |
| | large | - 793 (176) | - 782 (114) |
| Time of maximal aperture | small | - 215 (89) | - 254 (74) |
| | medium | - 290 (115) | - 239 (68) |
| | large | - 300 (89) | - 266 (69) |
| Time of the catch | small | 114 (76) | 56 (72) |
| | medium | 17 (64) | 19 (73) |
| | large | -11 (73) | 6 (73) |
| Maximal hand aperture | small | 55 (13) | 54 17) |
| | medium | 60 (18) | 59 (14) |
| | large | 65 (18) | 65 (16) |
| Peak closing velocity | small | - 432 (133) | - 349 (114) |
| | medium | - 307 (129) | - 333 (132) |
| | large | - 245 (117) | - 263 (106) |

Note: Misses are in percent, time of initiation, time of maximal aperture and time of the catch are in milliseconds (ms), while maximal hand aperture is in millimetres (mm) and peak closing velocity is in mm/s. The minus sign indicates that the time is *before* the catch.

For the *time of initiation* of the catch only a main effect was found for Ball Size, F(2, 34) = 5.659, p < .01. Post-hoc comparisons revealed that all children started initiating the catch significantly later for the small compared to medium and large balls, but not significantly later for the medium compared to the large balls. No other main and interaction effects were significant (Viewing, F(1,17) = 1.0, p = .32; Viewing by Ball Size, F(2, 34) = 2.44, p = .10, Figure 16).

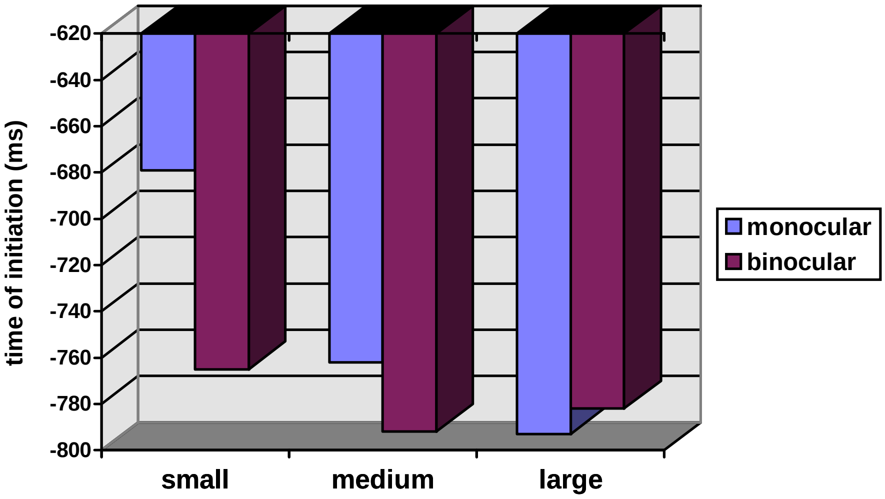

Figure 16: Interaction effect Viewing * Ball Size for the time of initiation

For the *time of maximal aperture* of the catch only a main effect was present for Ball Size, F(2, 38) = 7.94, p < .01, (Figure 17). Post-hoc comparisons indicated that the children reached the moment of closing the hand significantly later for the small compared to the medium and large balls, but not significantly later for medium compared to large balls. For the *time of maximal aperture* an interaction effect was found for Viewing by Ball Size, F(2, 38) = 8.86, p < .01. Post-hoc comparisons revealed that the children reached the moment of closing the hand significantly later when they caught small balls in the monocular condition in comparison with medium and large balls in the same viewing condition, but not significantly later for medium compared to large balls. In contrast, in the binocular condition no significant effect was found with respect to ball size. Moreover, the children reached the moment of maximal aperture significantly later when catching small and medium balls in the monocular in comparison with the binocular condition.

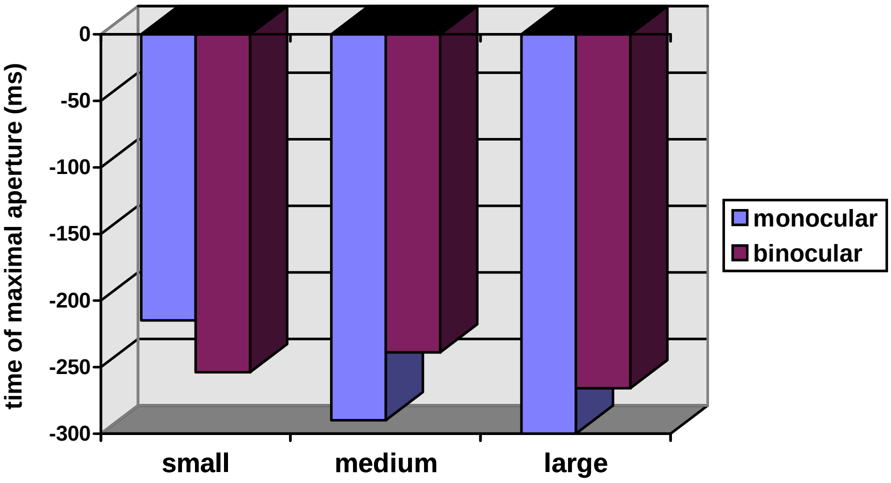

Figure 17: Interaction effect Viewing * Ball Size for the time of maximal aperture

For the *time of the catch*, a main effect was found for Ball Size, F(2, 38) = 3.23, p < .01. Post-hoc comparisons indicated that the children reached the time of catch significantly later for the small balls compared to the medium and the large ones, but not significantly later for the medium compared to the large balls. There was no main effect of Viewing, F(1, 19) = .303. With respect to *time of the catch* an interaction effect was present for Viewing by Ball Size, F(2, 38) = 8.97, p<.01. Post-hoc comparisons revealed that children in the monocular condition reached the time of catch significantly later for the small balls compared to the medium and large balls, but not significantly later for medium compared to large balls. In the binocular condition, only the small balls were caught significantly later compared to the large ones. In addition, the children reached the time of catch significantly later when catching small balls in the monocular compared to the binocular condition, but not significantly later when catching medium and large balls in the monocular compared to the binocular condition (Figure 18).

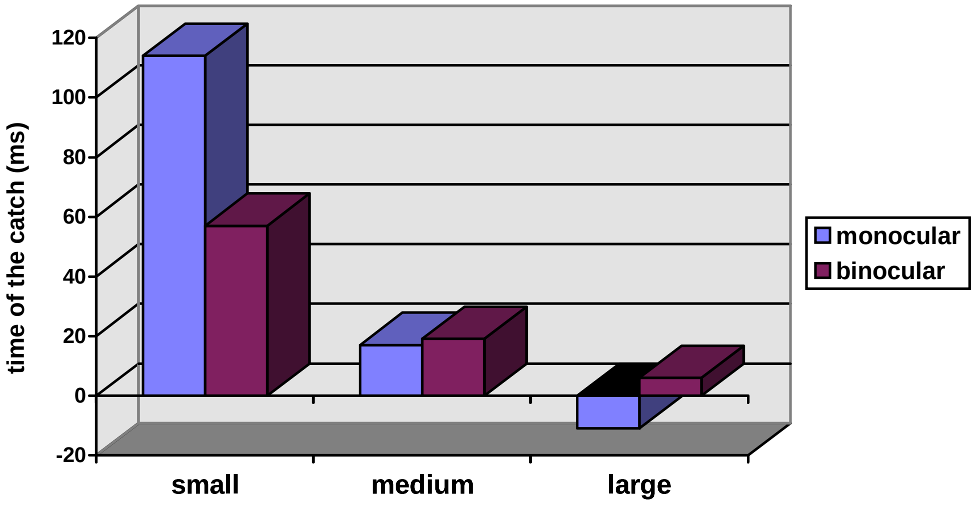

Figure 18: Interaction effect Viewing * Ball Size for the time of the catch

For the *maximal aperture*, a main effect was found for Ball Size, F(2, 30) = 9.01, p < .001. Post-hoc comparisons revealed that the children opened their hand significantly more for the large balls (65 mm) as compared to the small balls (54 mm), but no significant differences were present between the medium ball (60 mm) and the large and small balls.

For the *peak closing velocity,* a main effect was found for Ball Size, F(2, 36) = 18.22, p < .001. Post-hoc comparisons revealed that the children closed their catching hand significantly more slowly for the large balls compared to the small and medium balls. The same was found for the medium compared to the small balls. An interaction effect was present for Viewing by Ball Size, F(2, 36) = 6.97, p < .05 (Figure 19). Post-hoc comparisons revealed that in the monocular condition, children closed their catching hand significantly faster for small balls compared to medium and large balls, but not significantly faster for the medium compared to the large balls, while in the binocular condition for the small balls the hand was closed significantly faster compared to the large but not to the medium balls. In addition, a significant difference was present between medium and large ball in the binocular condition.

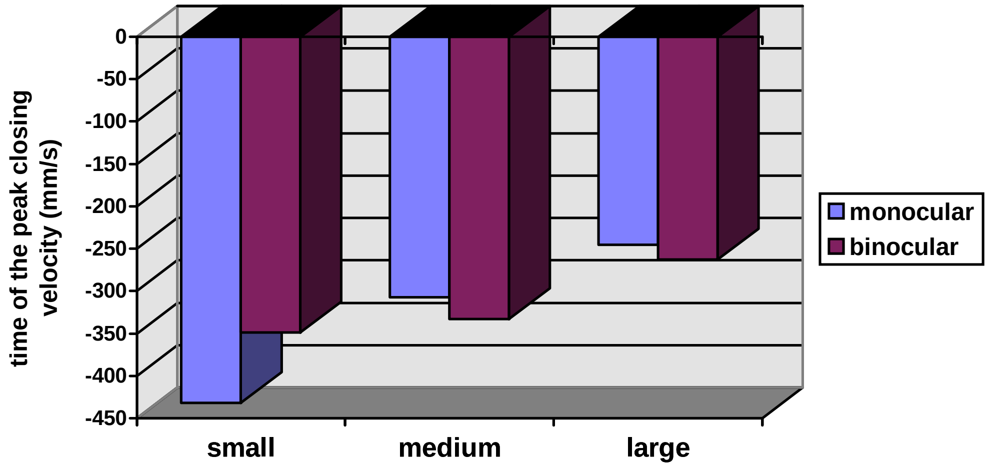

Figure 19: Interaction effect Viewing * Ball Size for the peak closing velocity

### 3.3 Summary of results

The main findings of the experiment are:

DS children showed more misses, due to a later time of the catch. No differences were found between DS and the control group for the other temporal variables. In addition, no interaction effects of Group were found for viewing condition and ball size.

Under binocular viewing DS children showed a larger maximal aperture than the control group. Under monocular viewing condition no differences were apparent between the DS and the control group. Furthermore, differences in peak closing velocity were present between the two groups of children.

Both, the DS and control group made more catching mistakes for the small balls under the monocular condition in comparison to the binocular condition.

These misses were reflected in the kinematic analyses, namely the time of maximal aperture and time of catch, both groups were significantly late for the small ball under monocular viewing condition, but not in the binocular condition.

## 4. DISCUSSION

The general purpose of this study was to give an answer to the question whether Down syndrome children differ from children with no impairment in a motor task such as one handed ball catching where temporal predictions have to be made. More specific, the two questions were whether and why DS children differ in a catching performance compared to normal children and furthermore, what is the nature of the information that the children use in one handed ball catching.

### a) Differences between DS and Control group

The results revealed that DS children made more misses than normal children and, therefore, it can be stated that they are less successful in a motor task with temporal constraints compared to their non-impaired peers. It should be stressed at this point that these findings are not surprising and are in line with the suggestions of other researchers (Henderson, 1985; Block, 1991; O'Brien and Hayes, 1995; Thombs and Sugden, 1991; Connolly and Michael, 1986), who pointed out that children with Down syndrome perform less well than their non-handicapped peers at all stages of motor development as a result of deficiencies in sensory-neurological, integrative-perceptual and motor learning control processes. DS children have a delayed reflex development, a low muscle tone (hypotonia), slow movements, problems integrating sensory information and organising a movement response, and problems in controlling the force of their movements. These problems seem to be the reason for such motor performance and also the reason for falling further and further behind in terms of motor and intellectual development compared to normal peers. More specifically, with respect to the temporal nature of the task examined, the findings are in agreement with Frith and Frith (1974), Henderson et al. (1981) and Kerr and Blais (1985), who indicated that children with Down syndrome have deficiencies in controlling the timing of their movement. However, it should be recognised from the outset that our approach differs somewhat from the one taken in the recent literature. Namely, researchers (Henderson et al., 1981) found the task of catching of a ball too difficult for DS children, and were not able to find information about temporal characteristics in this specific motor behaviour task among DS children. Therefore, they used a different kind of task, that is a continuous tracking task. With respect to timing and the information of timing in motor behaviour, tracking and catching tasks differ. As discussed in adult catching, the approaching ball provides retinal expansion information that is related to the optical variable Tau. Tau is an optical variable that specifies time to contact and controls timing. In this respect, it can be argued that information about timing in a tracking task is different from that one in catching, since no retinal expansion information is available. What kind of information is used in a tracking task remains unclear. However, to find which information is used in a tracking task researchers could manipulate the perception (e.g. different speed, binocular or monocular conditions, dark or light conditions). The second aspect with respect to the Henderson et al. (1981) study, is whether the accuracy of following the peaks of the track, which was used as an index for timing, is really a timing measure or more a spatial parameter of the tracking task. However, this study did present a kind of starting point for the present study. It gave possibilities for the comparison of results in two different tasks: tracking (Henderson et al. 1985) and catching a ball, where the interest of the research is in the same domain. Unfortunately, there are no other studies reported with respect to catching a ball, but the data reported by Henderson et al. (1981) support our conclusions, namely that problems associated with anticipatory movement tasks are due to temporal errors.

In order to find an answer why DS differed in catching performance, the kinematical analyses of the catch were carried out. It is seen that the DS children started initiating and closing the hand almost at the same time as the normal children, but they showed a later time of catch for all three ball sizes, especially for the small ball. This is probably the reason why the DS children missed more as the control group. This finding is consistent with the existing literature and clinical observations. Namely, DS individuals perform slower than their normal peers with respect to reaction and movement time (Berson, 1960; Connolly and Michael, 1986 in Henderson 1985). Another explanation for the finding of a later moment of the catch might be the larger opening of the hand in the binocular viewing condition; DS opened their hand more, maybe as a result of lack of precision. The Henderson et al. study (1981) concluded that DS are impaired in using predictability in timing in order to control their movements by pre-programmed sequences. With the respect to the late catch found in DS, the question arises whether this is indeed a case of worse anticipatory control or a problem of slowness of movement. When examining the time of the catch in relation to the time window (Figure 12 and 13), it can be seen that the most DS children, in contrast to the non-impaired children, tended to finish their catch too late. Since differences in timing were not found for the time of initiation and the time of maximal aperture, the present experiment suggests that it is not so much the anticipatory control but a slowness of movement that causes the higher percentage of catching failures in DS children.

In the literature it is found that there exist hand size differences due to shorter fingers in person with DS in comparison with other persons at the same age. When examining the grasping patterns of Down syndrome, Moss and Hogg (1981) and Hogg and Moss (1983) indicated that children with no disability showed an increasing use of the adult digit grip with decreasing size of the rod, but the children with DS did not, which might be partly accounted for by shorter fingers which have an effect on perceptual-motor coupling (Savelsbergh et al. 1994). Based upon these findings, it is reasonable to expect that hand size differences might account for some of the differences in grasping patterns and therefore also in the performance during catching. This issue (smaller hands lead to a smaller time window) was touched in the present research, namely the DS children compared to the control group caught in particular significantly less of the small balls. Therefore, the size of the fingers might be the reason for worse performance. Further empirical research is needed in order to find evidence whether this is the case.

### b) The nature of the information

The second goal of the research was to identify the visual information sources which control the timing of the catch among the DS and the children with no impairment. To reach this goal, the research was designed in a way that binocular vs. monocular vision was manipulated. It is worthwhile noting at this point that no similar studies were conducted with respect to catching in children. On the other hand, there were some interesting studies which examined the nature of the information needed in adult catching. In the study of Savelsbergh et al. (1991), it was shown that catchers do gear their action to the optical variable Tau, which specifies the time to contact. In this study, a direct manipulation of the optical pattern was carried out, namely balls were deflated while they approached the observer. The results of the two experiments (binocular and monocular vision) show that the time of the maximal closing velocity of the hand was more late for the deflated ball than for the balls of constant size. Other researchers (Judge and Bredford, 1988; Van der Kamp et al., 1995), examined other sources of information in adult one handed catching by manipulating disparity. These studies showed the importance of binocular information in the timing of catching. With respect to the temporal aspects of the catch, Van der Kamp et al., (1995) found differences between the monocular viewing vs. binocular condition. Namely, subjects started to open and close their hand earlier when monocular viewing was provided and furthermore, in the monocular, but not in the binocular condition there were differences in timing for the different ball sizes. These findings support the assumption that besides information of the ball also other sources (e.g. disparity), seem to be important in catching. Thus, not only Tau but also disparity plays a role in the guidance of timing of this interceptive action.

The present findings show a difference in viewing condition. That is, children missed more balls in the monocular compared to the binocular condition. The same effect was more pronounced among DS children, namely, they missed more balls in the monocular compared to the binocular condition, although they missed more balls in both conditions compared to control group. With respect to the temporal characteristics (i.e. time initiation of the catch, time maximal aperture and time of the catch) there is no difference between the DS and control group for the different ball sizes and viewing conditions. This indicates that, while the DS children were slower (i.e. main effect for Group for time of the catch), they probably did not use different types of information (monocular vs. binocular), compared to children with no impairment.

The second important finding is, taken all children together, that no main effects for viewing were found. This is in contrast with Van der Kamp et al. (1995) who showed that adults started to open and close their hand earlier when monocular viewing was provided. However, in the present study, the interaction effect of viewing and ball size was found. Namely, the children timed differently for different ball size in the monocular condition, but not in the binocular condition, like the adults did. It seems, that the children used binocular vision, and thus, disparity information specifying the size and distance of the ball is used for the timing of the catch. Furthermore, also monocular information can be used for timing of the catch, because not all balls were missed. However, it is difficult to conclude that Tau is used, since this was not really tested. From a Tau perspective, the timing should be independent of the ball size, but there was an effect of ball size in this experiment. Compared to adults, however, one could argue that monocular sources of information are more important among children, since no main effect for the monocular and binocular condition for timing was present, in contrast to adult catching where such a difference was present.

Anyhow, based on these findings, it can be stated at this point that DS children used the same visual information as the controls did, and moreover the difference in catching with respect to temporal judgement might be due to motor problems and not due to problems in the perception of the information. It seems that both DS children and children with no impairment used different types of information, (i.e., Tau, disparity) to perform an interceptive action such as one-handed catching.

## 5. CONCLUSION

The current study examined if and why children with DS (n=11) performed less well than their non-impaired peers (n=16) in one-handed catching task. It was found that DS children perform less well, that is, they missed more balls. It can be stated that they are less successful in a motor task with temporal constraints compared to their non-impaired peers. The results of the kinematic analyses revealed that children with DS were only late at the time of catch that indicates a slowness of movement, as found in the literature and clinical observations, that is probably due to motor problems and not to perceptual problems.

This conclusion is furthermore confirmed by the fact that there were no differences between the DS children and controls with respect to the perceptual manipulations carried out in the present experiment. Namely, children with DS and non-impaired children missed more balls in the monocular compared to the binocular condition. Therefore, it appeared that DS children used the same visual information as the controls did. It seems that both (children with DS and non-impaired children) used different types of information (i.e., Tau, disparity) to perform an interceptive action such as one-handed catching.

## 6. GENERAL CONCLUSION

The effects of Down syndrome on motor development have been widely reported over the years. It has been shown that DS children have problems with interceptive action, and that their motor performance is slower in comparison with non-impaired children. In order to answer the question whether DS children have timing problems in one-handed catching, 11 children with DS and 16 with no impairment aged between 5 and 12 years, were required to catch three different balls (small, medium, large) under binocular and monocular viewing conditions in the dark. The results in present research showed more misses for the DS children in comparison with the control group. The kinematic analyses revealed that this is due to a late closing of the fingers. With respect to the visual information used in one-handed catching, no differences were found between DS and controls. Both groups missed more balls under monocular compared to binocular condition. It appeared that besides the optical expansion (Tau), binocularly provided information about ball size and/or distance play an important role in the timing of the catching. Since there were no differences between the two groups with respect to perceptual manipulations, it is suggested that the timing problems of the DS children are probably due to the slow motor apparatus of the children as found in the literature and clinical observations.

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