



DEPARTAMENTO DE EDUCAÇÃO FÍSICA E DESPORTO

**THE UTILIZATION OF VISUAL INFORMATION
BY CHILDREN IN A CRICKET TASK**

Angelino Sabino Lira da Silva Gonçalves

2008



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*Dissertação apresentada com vista à obtenção do
grau de Mestre em Educação Física e Desporto*

Orientação: prof.dr. G.J.P. Savelsbergh

Co-orientação: dr. G.J. van der Kamp

Angelino Sabino Lira da Silva Gonçalves

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VRIJE UNIVERSITEIT, AMSTERDAM

FACULTEIT DER BEWEGINGSWETENSCHAPPEN

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1) GENERAL INTRODUCTION

“We continuously receive high quality information from the environment that can be used for direct perception” (Gibson, 1979).

a) INTRODUCTION

In this section we begin by summarizing what is known about cricket in general and specifically what are some of the constraints for adults when batting. We then report on what is known about age related differences in children especially in interceptive actions, describe how humans use visual search and motor control in a variety of actions including cricket and look at recent theories in natural and biological systems. Next we see how sport is helping to strengthen these theories through the perception-action system, what is expertise and how does it come about. A description follows of what is known about interceptive actions and movement coupling and how they are accomplished, and the ecological constraints on these actions. Finally we review other studies that have looked at children’s ability to anticipate in cricket and other fast ball sports.

b) CRICKET

The game of cricket (see appendix a) is an ideal sport for scientists to utilize for research in many different fields as it is unique in many ways; games lasting five days, played at day and night, bowlers bowling fast, spin, seam and swing, and with the batsmen having to contend with a ball that swings through the air and can also change direction after bouncing on the pitch. It is a sport that is characterized by a predominance of low-intensity activities, including standing and walking. The game is replete with relevant movement models such as dynamic interceptive actions like catching, batting and locomotor pointing (running toward a target in space) (Davids *et al.*, 2005). Cricketers require skill in a variety of complex, multi-joint, interceptive actions when batting, bowling, and fielding. The spatiotemporal task constraints of cricket are very demanding. When fielding, players perform one- and two-handed catches of the ball, with error margins for timing the grasp phase of approximately 16ms.

I. MOTOR SKILLS: PERCEPTION AND ACTION IN CRICKET BATTING

Batting has been classified by Whiting (1969), along with other dynamic actions where a ball is received and sent away in the same movement, in the second most

complex category of skills. The batsman has to use his motor and psychological skills to play the best shot from a wide repertoire of attacking and defensive strokes against bowlers of different types, hitting the ball in such a way as to avoid it going to one of the 11 fielders especially through the air (or the batsmen, if caught, will be out). When batsmen face fast bowlers, who bowl from a distance of about 18m (from wicket to wicket is 20.12m), at bowling speeds of up to 160km/h, they need to discriminate perceptually the spatial trajectories in depth of balls to a precision of 0.5° . Precision timing has been estimated to have margins of failure of approximately 2.5ms at the point of movement execution (Regan, 1997), making cricket batting a useful tool for studying the relationship between perception-action in goal directed behaviour. Batsmen can execute these actions successfully because they develop a continuous link between perceptual and action systems which allows them to make ongoing adjustments late into the stroke. This is a resource that all humans have and that is simply fine-tuned with context specific practice (Williams *et al.*, 1999). However, for children it is much more difficult to coordinate actions when trying to displace moving objects in real-world tasks such as intercepting a ball than for adults (Bard *et al.*, 1990; Williams, 1986). They have these greater difficulties due to an inability to correctly estimate arrival time of the moving object at the position where contact will occur (Schiff & Oldak, 1990).

c) AGE DIFFERENCES IN ESTIMATING ARRIVAL TIME

Age differences in estimating arrival time were studied by various scientists in tasks that consisted in presenting a moving object that was occluded just before it reached the observer or a specified position, and the observer was required to make a simple response (e.g., press a button) that coincided with the moving objects immediate arrival time at the observer's position or another specified position in space, they showed that there is a linear relationship between estimates of arrival time after the occlusion and actual arrival time.

According to Yakimoff *et al.*, (1993) this linear model is applicable for occlusions ≥ 200 ms but this assumption is unwarranted if the visuo-motor delay during which information about the time remaining before the arrival of the moving object could not be used to coordinate the response is < 200 ms in coincidence timing actions as various authors have suggested (e.g., Lee *et al.*, 1983; Whiting *et al.*, 1970; Bootsma &

Vanwieringen, 1990; Savelsbergh *et al.*, 1991). When Dorfman (1977) occluded the final part of the trajectory, he noted that it had more effect on younger children than on those with ages between 14-15 and 18-19. He concluded that the cognitive processes that were involved in compensating for the disappearance of moving objects were likely to develop later than those processes that were required when the displacement of the moving object was not occluded. These results have been corroborated by Ripoll (1994) when he showed that children of 11 and 13 years have the same response accuracy across conditions and that the response times were slightly overestimated. He therefore concluded that the accuracy of arrival time improves mainly between the age of 7 and 11 years. Thus, there seems to be no difference between children and adults in short occlusions where processes are supposed to be perceptually driven. However there is a large difference for occlusions of longer duration, where extrapolation mechanisms are necessary (Benguigui *et al.*, 2004). They also confirmed that 200ms is the threshold where extrapolation mechanisms come into play.

Children therefore, in the course of their development, produce arrival time estimates that are progressively more in accordance with the linear model. There could be one of two reasons for this progression towards the linear model. Firstly, children have difficulty mastering cognitive temporal extrapolation processes (only at around 11 years). Secondly, they have difficulty using cognitive motion extrapolation (Benguigui *et al.*, 2004). It has also been noted that children utilize different strategies of control depending on the requirements of the task at hand, alternating between feedforward and feedback components of action (Gachoud *et al.*, 1983; Hay, 1984). Carson *et al.*, (1995) and Rosenbaum (1980) also noted that when children pre-cue the spatial dimensions of direction and/or amplitude of movement their reaction times decrease. Also, the reaction time has been seen to be a function of the number of pre-cued parameters. This shortening of reaction time is an inverse function of stimulus-response uncertainty and not a function of the nature of the pre-cue. An increase in reaction time is therefore a function of the number of alternatives as it introduces more uncertainty (Fairweather & Hutt, 1978).

Further support for this comes from Olivier & Bard's (2000) kinematics data, where peak velocity shows a larger increase when two dimensions instead of one dimension are pre-cued. It is considered a reliable measure of movement programming that reflects proactive processes, and also increases significantly with the pre-cueing of

a single dimension, either direction or amplitude, for all the age groups. It thus argues for the existence of advance movement preparation. Pre-cueing of direction and/or amplitude will result in an increase in peak velocity during the ballistic phase, without affecting the online control of this phase. Therefore pre-cueing shows that the effects on response time do not only result from the processes of the response selection time although it was used to enhance the functioning of processes involved in the response programming stage. An additive effect on peak velocity in addition to the shortening of time to peak velocity and movement time suggests that the two spatial parameters induce separate processing constraints. This result in children is in total agreement with a behavioural observation that is already well established which states that direction and amplitude are specified independently but not in parallel (Bonnet *et al.*, 1991; Lepine *et al.*, 1989). These results further support the role of pre-cueing on the efficiency of motor programming and execution. Children's accuracy at peak velocity is influenced by pre-cueing. This influence apparently does not occur in adults, who seem to be able to specify direction completely before movement initiation (Olivier & Bard, 2000).

d) VISUAL SEARCH AND MOTOR CONTROL

Although there are many limitations as has been described before, the batsmen can instantaneously predict a ball trajectory to within 0.5° of the visual field and can perceive TTC (Time-to-contact) information to within 2-3ms (e.g., Regan *et al.*, 1998). To be able to do this the expert batsmen fixate the bowling hand and ball until the bowler is in a side-on position in the delivery stride. They then fixate the anticipated area of ball release with a time lag of around 0.94s. It has been suggested that this temporal delay occurs so that the eyes are stationary when the hand appears (Barras, 1990). Thus sport performers must be able to identify the most information-rich areas of the display which is saturated with both relevant and irrelevant information, direct their attention appropriately, and extract meaning from these areas efficiently and effectively. Knowing where and when to look is crucial for successful sports performance (Williams *et al.*, 1999). To be able to retrieve this information it is necessary to have relatively prolonged quite eye periods, since saccadic eye movement reduces the ability of the visual system to extract information (Duchowski, 2002). It has been shown that this general rule applies across a wide variety of sports, where experts seek the most information-dense areas of a display and have longer fixation periods than the non-experts (Williams *et al.*, 1993). The number of fixations varied across sport type, with

the smallest margin of expert/non-expert difference occurring across interceptive sports (Mann *et al.*, 2007).

According to Martenuik (1976) perceptual-cognitive skill refers to the ability to identify and acquire environmental information for integration with existing knowledge in a way that the appropriate responses can be selected and executed. Investigators trying to understand visuo-motor control have described, using the planning versus control model, two separate processes which follow two separate and independent visuo-motor pathways. When planning the visual system operates before the initiation of movement and accommodates for the initial kinematics of the movement. The system takes into account a broad range of visual information which is then coupled with other non-visual factors such as memories of the past experience with the object, for example, its weight and its fragility. After the movement has begun, the visuo-motor system will come under the influence of the on-line visual control system. The visual control system will only take into account information about the spatial characteristics of the object, e.g., its orientation, size, and position. Therefore its influence will be limited to the spatial parameters of the movement such as the trajectory and the orientation of the hand. However this model still has to be verified in interceptive actions because they are constrained both spatially and temporally (Caljouw *et al.*, 2006). This means that the path that is followed by the effector must intersect the path of the moving object and they have to arrive at the interception point simultaneously.

The cricket players' eyes receive light after it has been reflected off surfaces and moving objects. After information about the bowler's movements and ball flight has been encoded, transformed and perceived a motor response is selected to intercept the ball (Tyldesley & Whiting, 1975). This response can be pre-programmed to coordinate the many degrees of freedom of the motor system (Bernstein, 1967). This means that after many years of repetition and systematic practice the individual components of the movement system do not have to be controlled individually by the brain. Expert performance of dynamic interceptive actions only demands attention to the input and decision components of performance. Therefore playing a shot in an interceptive sport can be reduced to the timing initiation of the movement (Tyldesley & Whiting, 1975).

e) CHARACTERISTICS OF NATURAL AND BIOLOGICAL SYSTEMS

Biological movement systems are characterized by dynamical systems and ecological psychology as complex, dynamical systems, revealing how the composite motor system degrees of freedom are coordinated and controlled during interactions with the environment according to Jirsa & Kelso (2004). In natural and biological systems, coordination emerges between components of dynamical movement systems through processes of self-organization which are ubiquitous (Davids *et al.*, 2005). As a consequence of this there are three key ideas which can be articulated on the ecological approach to perception and action during interceptive actions. The first idea is that optical information from the ambient light which arrives at the eye has enormous structure because it has been reflected off surfaces and objects and is available to be perceived directly by all organisms that possess a suitable visual system (Gibson, 1979). These optical variables are characterized by the action possibilities and affordances that they offer the sport performer. The affordances that an athlete receives from his adversary, as well as from ball flight, can be exploited as reliable sources of information to constrain his actions. The second idea is that this information is unambiguous and can be perceived directly by the sport performer. With experience and practice of the actions in specific performance contexts they merely attune existing sensitivity to optical sources of information to constrain their actions (Michaels & Beek, 1995). The third idea is that of compensatory variability. The experts' ability to precisely modulate ongoing dynamic interceptive actions is predicted on a functional role for movement variability. It is a functional type of variability. It is an important means by which skilled performers in dynamic environments can produce a tight fit between the current state of the action system and the task goal at the all-important endpoint of execution, through modulating movements on the basis of ongoing perceptual information (Bootsma & Vanwieringen, 1990).

f) PERCEPTION-ACTION

The use of sports and physical activity in recent models has provided much insight into how processes of perception-action support movement control and coordination. According to Davids *et al.*, (2005) earlier motor behaviour studies did not use multi-joint actions because of a perceived dichotomy between experimental rigor and ecological validity. However this is now recognized as a continuum because of the

recent advances in technology and theory of movement coordination and control, dominated by ecological psychology (Jacobs & Michaels, 2002) and dynamical systems theory (Jirso & Kelso, 2004). Davids *et al.*, (2005) have stated that there are a number of reasons for the changes that have taken place when selecting movement models for studying coordination and control using sports and physical activity. Some of the reasons are that sports and physical activity exemplify how processes of perception-action are mutually enabling, are embodied within the performer-environment system, function in a task specific manner and are dependent on nested, interacting constraints inherent to particular performance contexts. A significant role is attributed to specific movements of the performer and the relevant objects in the environment when detecting perceptual information. There are lawful changes to the energy flow that provides information on the environmental properties to the performer when movement occurs. Therefore, the nature of perceptual information that is used to constrain action and the inextricable relationship between information and movement in specific performance contexts can be retrieved from sport. The traditional experiments that have been performed have provided useful information to identify lower-order variables (target location, velocity and acceleration) when investigating perception under controlled laboratory conditions. However, the latest tendency is for movement models from sport and physical activity which emphasize a more functional view characterizing the intrinsic and inescapable link that exists between perception and control in natural environments. This new perspective focuses on the higher-order perceptual variables at the level of the actor-environment system, thus increasing the different ways in which perceptual processes function during natural movements (Schöllhorn, 2003).

In traditional theory the perceptual activity will predetermine the spatiotemporal characteristics of the interception point so that the movement can be parameterized (Saxberg, 1987; Regan, 1997). The temporal constraints that will permit any final adjustments to be made to correct errors of the initial prediction due to the multiple parameters involved must be taken into account. These control strategies are called predictive (Tresilian, 1995). When a person tries to produce a goal directed action such as when one tries to intercept a moving object, it is necessary to coordinate the movement and information constraints that are involved. In the ecological approach the perceptual flow (information) and a movement parameter (force) must be continually related and updated during the interceptive action (Warren, 1988). This process of

perception-action coupling is considered in psychology as the basis of skilled interceptive timing behaviour (Savelsbergh & Bootsma, 1994). This coupling is ongoing and permits experts to update interceptive actions continuously, with concurrent perceptual information, until a very late stage of performance (Bootsma & Vanwieringen, 1990; McLeod & Dlenes, 1993). This does not require knowledge of spatiotemporal characteristics of the point of interception (McBeath *et al.*, 1995). Thus, according to Williams *et al.*, (1999) actions need information for initiation, completion and ongoing guidance.

The skilled performer is the one who exploits advance information from the opponent's movements to 'buy' time for decision making and response preparation. This explains why expert performers never seem to react to unexpected events but rather seem to always be one step ahead. We can therefore agree with Whiting (1991) when he stated that acting is not reacting. Experts use what has been called anticipatory mode of action. It has therefore been shown that decision making is the product of a sequence of events that occur before overt movement will be required (Abernethy, 1991). In this way experts maintain a perceptual advantage over non-experts that facilitates the accuracy of their response. The model of required velocity derived by Peper *et al.*, (1994) and Bootsma *et al.*, (1997) links the property of perceptual flow to the movement pattern. The model states that the actor controls the amount of acceleration produced according to the difference between the required velocity and the present velocity of the effector (*any muscle, organ etc. that can respond to a stimulus from a nerve.*) segment as is specified by perception.

It has also been shown that experts are superior to non-experts not only in perception but also in stroke production. It is thus plausible that the common coding mechanism also explains their advantage on anticipation tasks as those used by Abernethy & Russell, (1987). Therefore, using the common coding system, one might predict that heightened sensitivity to kinematic changes will be a hallmark of expert perception and anticipation (Abernethy & Zawi, 2007).

g) EXPERTISE

Differences in perceptual-cognitive skill have been seen using a multitude of research protocols (anticipation, decision making, recall, task performance, spatial and temporal occlusion, and eye-movement registration). They have shown that experts

have the ability to consistently exhibit better athletic performance. According to Ericsson & Kintsch, (1995) experts have qualitatively different cognitive mechanisms and strategies that facilitate anticipation which permits reduced response time and increased response accuracy. They are better at making decisions and are much more proficient at resolving the task at hand (Holyoak, 1991). Abernethy & Russell, (1987) have stated that they use enhanced perceptual-cognitive skills, such as attention allocation and cue utilization, which gives them the ability to know where and when to look for the information that is available. This is believed to be at the core of perceptual anticipation during time-constrained interceptive actions (Abernethy & Russell, 1984).

In reactive skills, experts have the ability to use advance visual information from an opponents' movement patterns to anticipate behavioural events (Abernethy *et al.*, 2001; Williams *et al.*, 1999). Experts have the ability to extract advance perceptual cues which can then be used to alleviate the temporal constraints imposed by reaction time alone (Buckolz *et al.*, 1988). However, according to Pollick *et al.*, (2001) the nature of the visual information that players use, is in most cases, still unknown. Recently, with the intention of changing this, researches have tried to determine the sources of this information using, for example, three dimensional motion analysis, analysis of the observer's visual patterns, and the occlusion of specific regions of display. In a variety of racquet sports researches have used temporal occlusion of vision of the opponents' hitting action to determine the skill related differences that are used in advance pickup of information (Abernethy & Zawi, 2007).

Researches do now have some explanations for how skilled performers in natural tasks can commence their movements earlier and thus alleviate the usual processing constraints that reaction time and movement time impose (Salthouse, 1991) and give us the impression of "having all the time in the world" (Bartlett, 1947). After they have received the necessary information they can then use their procedural and declarative knowledge to anticipate and predict future events (e.g., McPherson, 2000). It is then seen as their ability to anticipate their opponents' intentions much quicker and more accurately than less skilled athletes. Jackson & Mogan (2007) have concluded from responses to free-recall tests that skilled performers are aware of the knowledge that they use to make their judgements. Using this information they can then anticipate future events early and accurately.

In the game of cricket it has been shown that the foot movements of skilled batsmen have been completed before the point of bat-ball contact because they are more able to infer ball flight characteristics from advance information from the bowler's body during batting (Abernethy, 1982). For example, their eye movements are characterized by fewer fixations of longer duration. This supports the interpretation that they retrieve more task relevant information from each fixation than do the lesser skilled performers (Williams *et al.*, 1993). It has also been seen elsewhere that these advanced perceptual cues facilitate sport performance by means of aiding in the anticipation of the adversary's actions and therefore decrease the overall response time. However, Regan *et al.*, (1998) have shown that early ball flight information that is retrieved by the human visual system is unreliable, because our visual system has difficulty in estimating absolute distance and absolute speed of an approaching object beyond a few meters and it is therefore necessary to make on-line adjustments when the ball reaches the batsman.

h) INTERCEPTIVE ACTIONS AND MOVEMENT COUPLING

For an interceptive action to be successful, the limb or implement has to be at the right place at the right time. Savelsbergh & Bootsma (1994) found that for this to take place, the following three task constraints should be fulfilled. The projectile should be contacted in the environment, it should be contacted with the intended velocity, and finally, it should be contacted with the intended spatial orientation. Therefore, there has to be good coordination between the relevant parts of the movement system and there has to be good coordination between relevant motor system components and the projectile to be intercepted. This last requirement is the most difficult to accomplish (Regan, 1997). However, there is evidence from neural mechanisms in the visual system to support the evolutionary basis of smart mechanisms for interceptive timing (Regan, 1997; Regan *et al.*, 1998). At a constant time before contact during perception of information from looming objects specific neurons in the brain respond with heightened electrical activity (Wang & Frost, 1992). McLeod & Jenkins (1991) have shown, that without any particular practice, ordinary people can produce fine tuned interceptive actions.

When dealing with rapid interceptive actions actors have very little time to make online adjustments due to neurophysiological delays. However, several studies have shown how humans can make spatial adjustments during the very short time in which

the movement is being executed, based on the visual information obtained from the moving object (Caljouw *et al.*, 2006). The performer, therefore, establishes a relationship with key perceptual variables that are available from the environment to regulate his actions continuously, as is described in prospective models of interceptive actions.

So how do we learn to use the information available in the environment for movement? Jacobs & Michaels (2002) argued that there are two processes involved when learners assemble information–movement couplings. First, learners educate attention by becoming better at detecting the key information variables (TTC and place of contact) that specify movements from the myriad of variables that do not. During practice, they narrow down the minimal information needed to regulate movement from the enormous amount available in the environment. Second, learners calibrate actions by tuning movement to a critical information source (TTC and place of contact) and, through practice, institute and sustain information–movement couplings to regulate behaviour. It is therefore apparent that the earlier account from indirect perception, claiming that cricket batsmen need to somehow encode and transform information before selecting a pre-programmed response is overly complex.

i) ECOLOGICAL CONSTRAINTS

All dynamical systems exploit environmental constraints to allow functional, self-sustaining patterns of behaviour to emerge in specific contexts. This process modifies the number of biomechanical degrees of freedom that are regulated by the performer through temporary assemblage of muscle complexes called coordinative structures. There is variability in movement patterns which are exemplified by fluctuations in stability, and permit flexible and adaptive motor system behaviour. The paradox between stability and variability explains how skilled athletes can produce a subtle blend of persistent and adaptive movements during successful performance (Davids *et al.*, 2003; van Emmerick & van Wegen, 2002). According to ecological psychologists in a systems perspective, the organism-environment system is the unit of analysis for studying perception-action in the natural environment. Beek *et al.*, (2003) emphasize that biological organisms are surrounded by a huge array of energy that can provide information to constrain movement behaviour, including decision making, planning and organization. The use of the information which is carried in the energy,

and that is specific to certain contexts and which is available to be perceived directly requires, as stated by Davids *et al.*, (2005), a law of control that will continually relate the state of the individual to the state of the environment.

Actions are constrained by a variety of mechanisms including visual information, biomechanics, required outcome of the task, and the neurophysiological processes involved. When studying the time constraints in skills such as tennis, badminton, or squash shot; striking a cricket or baseball; and making a penalty save in soccer, the importance of making decisions before unambiguous ball-flight information is available has been noted by Jackson & Mogan (2007). However, Abernethy & Zawi (2007) have stressed that due to limited understanding of what perceptual information provides to the performer, there are still some obstacles to be overcome in the design of practice methods that can systematically enhance anticipatory skill. According to Caljouw *et al.*, (2006) movement characteristics are planned and/or controlled mainly by the outcome needs of the task. In self-paced actions the spatial characteristics are usually more defining than the temporal ones. Here online control will primarily consist of spatial characteristics. In interceptive actions the temporal constraints will be just as important as the spatial characteristics. They will therefore also be adjusted online for a successful interception to be possible. There is evidence to support this from the fact that participants were able to increase acceleration of an interceptive movement due to the sudden acceleration of the target object (Brenner & Smeets, 1997). However, different adjustments will take longer than others depending on the process that is being controlled. It is thought that this is because of the type of information that is required for control and the fundamental neural substrate. This is due, according to Brenner & Smeets (2003), to the fact that determining an object's velocity will take longer than determining its position. It therefore seems clear that different types of constraints regulate different aspects of an action and that these different processes depend on functionally different neural systems, ranging from long-term processes that take into account a larger amount of information to processes that function at a fast time scale outside of conscious awareness.

The game of cricket, especially batting, has some of the most severe temporal constraints that can be found in sport (Regan, 1997). It was calculated that the minimum time required for visual feedback to influence the initiation of an interceptive action when the ball deviates off the pitch, either forward or laterally in the latter part of flight

was 200ms (Mcleod, 1987). However, later studies have shown that this cannot be justified outside the laboratory, particularly during natural actions when visual information was used primarily to adapt or modify ongoing movement (e.g., Bootsma & Vanwieringen, 1990). Recently temporal constraints on the pick-up and comparison of perceptual information with ‘cortical memories’ have been modelled at around 80-100ms, based on what is now known about firing times for neurons and local circuitry in the brain (Ballard *et al.*, 1998). The speed of response is limited however by the nature of the task, that is, it is influenced by the sport type, with the largest expert/non-expert differences evident for interceptive sports (Mann *et al.*, 2007). Each environment has its own specific energy flow patterns. They can act as sources of invariant information which can be picked up directly by performers to constrain their actions.

Ecological psychology has given its theoretical foundations to prospective control models according to Davids *et al.*, (2003). The latter emphasize that an essential task constraint is the information that is available in specific performance contexts for actors to use for the coordination of their actions with respect to the environment. Davids *et al.*, (2005) concluded that learning in sport is essentially the attunement to information in specific contexts. This leads to the construction of functional relations between movement and information that provide information-movement couplings underpinned by laws of control. Other studies have revealed how perceptual variables from the motion of a ball are coupled to the movements of the athlete and how this is used to regulate the spatiotemporal patterning of the most rapid of interceptive actions continuously (Caljouw *et al.*, 2006). It has been shown that higher order constraining perceptual variables that are available for prospective control of action during catching and batting include TTC and place of contact (Beek *et al.*, 2003).

j) ANTICIPATION IN CHILDREN

Although Bartlett (1947) established that anticipation was one of the important parameters of expert performance in time-constrained activities, very little is known today about how expert anticipation is developed through childhood to adulthood. Fast ball sports like cricket can have a very important role in resolving how and when the experts’ anticipatory skill is developed and what developmental and practice experiences may contribute to this development. The few studies that have been carried out using age as an independent variable have implied that visual perceptual skills, like

anticipation and pattern recognition, that have been shown to be critical for expert performance in adults, improve not with maturation or chronological age alone but with experience and exposure to vast amounts of task-relevant practice.

Côté *et al.*, (2007) have suggested that there are likely to be multiple pathways to expert performance. In their Developmental Model of Sports Participation (Côté, 1999; Côté & Hay, 2002) they proposed a pathway toward elite performance that consists of three distinct stages: the sampling years (childhood; age 6-12), the specialising years (early-adolescence; age 13-15) and the investment years (late adolescence; age 16+).

Abernethy (1988) investigated the effects of skill and chronological age on anticipatory performance in badminton using experts and novices in different age groups ranging from 12 years of age to adult. He showed that the experts demonstrate a progressive increase in the use of early movement pattern information as they got older unlike the novices, although it was only at the adult level that the anticipatory performance of the experts was significantly superior to that of the age-matched controls.

Tenenbaum *et al.*, (2000), in a comparable study of anticipatory skill in tennis, have suggested that enhanced anticipatory capability may enable young and skilled athletes to exhibit the anticipation superiority which they assume to represent procedural knowledge. “Knowing how” under extreme temporal constraints is not a sufficient condition to make the correct decision. Anticipation, particularly pronounced in older high skill athletes, enables them to implement the correct decision needed at the certain time and that the magnitude of skill-related differences was greatest after some 6-7 years of accrued experience in the young age categories.

Ward & Williams (2003) examined the relative contribution of visual, perceptual and cognitive skill to the development of expertise in soccer. They found that the emergence of skill and/or age differences appeared to be dependent upon the type of task used to measure anticipation. Accurate prediction appears to be a consequence of integrating contextual information with situational probabilities or expectations stored in memory. As they grow older, elite players became more adept at predicting and confirming or adapting their typical response (Williams, 2000).

In a recent study on anticipation in cricket by Weissensteiner *et al.*, (2006) it was shown that all batsmen below the age of 20 years, including highly skilled batsmen, did not provide systematic evidence to indicate ability to pick-up advance information. However all groups, including the highly skilled adults, were able to improve their prediction accuracies dramatically once ball flight information was available. They suggested a number of possible reasons to why well-developed anticipatory skills do not emerge until adulthood, even for highly skilled batsmen. Firstly, anticipatory skills may be relatively un-important in junior competition levels where bowling speeds are generally slower and may not impose sufficient time constraints to make advance judgements on the basis of pre-release information necessary for success. At this age batsmen may rely only on early ball flight information which may be sufficient to allow interceptive movements to be planned and executed in time and other factors such as physical size and strength may consequently be more important contributors to batting success than anticipatory ability. Secondly, junior players may be capable of anticipating the movement patterns of bowlers of similar ages to themselves but not of adults and may therefore have been unable to display their anticipatory skills in this experiment because the task only presented vision of an adult bowler. Thirdly, while anticipation may be potentially important for batting even in the junior age groupings, the ability of players to detect subtle postural information from the bowler may require large amounts of practice to develop.

While the highly skilled junior age cricket batsmen were not able to provide strong evidence of an ability to effectively use advance information, it was noted that for both the prediction of ball type and ball length, accuracy levels in the release condition showed a systematic relationship to age, with the mean accuracy of the skilled adult group being greater than that of the U20 skilled group which was, in turn, greater than that of the U15 skilled group. This is consistent with the observations on anticipation in badminton (Abernethy, 1988), where Abernethy did not find any comparable age progressions for the unskilled groups, indicating that the improvements evident for the skilled group are most likely experience-related and not simply due to biological maturation. Weissensteiner *et al.*, (2006) concluded that technical and visual perceptual skill components are not reliable discriminators of skill level at a relatively early stage of development (before the age of 15 years).

k) SUMMARY

To summarize, we have seen how cricketers require skill in a variety of complex, multi-joint, interceptive actions when batting, bowling, and fielding and that the spatiotemporal task constraints of cricket are very demanding. It has been shown how children have greater difficulty in coordinating actions when trying to displace moving objects in real-world tasks and that this greater difficulty is mainly due to an inability to correctly estimate arrival time of the moving object at the position where contact will occur. We have shown how sport performers must be able to identify the most information-rich areas of the display which is saturated with both relevant and irrelevant information, direct their attention appropriately, and extract meaning from these areas efficiently and effectively.

It has been shown that biological movement systems are characterized by dynamical systems and ecological psychology as complex, dynamical systems, and that they reveal how composite motor system degrees of freedom are coordinated and controlled during interactions with the environment. We have seen how the latest tendency is for movement models from sport and physical activity which emphasize a more functional view characterizing the intrinsic and inescapable link that exists between perception and control in natural environments and how this new perspective focuses on the higher-order perceptual variables at the level of the actor-environment system, thus increasing the different ways in which perceptual processes function during natural movements.

It has also been shown that experts are superior to non-experts not only in perception but also in stroke production and how they use enhanced perceptual-cognitive skills, such as attention allocation and cue utilization, which gives them the ability to know where and when to look for the information that is available. This is believed to be at the core of perceptual anticipation during time-constrained interceptive actions. We have reviewed how actors deal with rapid interceptive actions when they have very little time to make online adjustments and have shown how humans can make spatial adjustments during the very short time in which the movement is being executed, based on the visual information obtained from the moving object. This speed of response is limited however by the nature of the task with the largest expert/non-expert differences evident for interceptive sports.

Finally we have seen that children show the greatest differences in skill differences after 7 years of accrued experience and that the emergence of this skill and/or age difference appeared to be dependent upon the task used to measure anticipation. It was also found that improvements evident for skilled groups are mostly likely to be experienced based and not simply due to biological maturation. But it was stressed that technical and visual perceptual skill components are not a reliable discriminator of skill level at a relatively early stage of development.

2) INTRODUCTION

Recent research has begun to examine more closely how individuals in various interceptive sports including cricket are able to deal with extreme time and spatial constraints and yet make it all look so easy (Mann *et al.*, 2007). Research in a number of interception sports has shown some of the ways in which athletes anticipate an adversary's intention and thus arrive in time for a particular response even when the time available seems to be less than the amount of time needed to complete a particular action.

One of the most extreme of these interception sports is the game of cricket. (Regan, 1997) showed that top sports players maintain positional errors of less than 5cm and temporal errors of less than 2 or 3ms. Thus far, scientists have focused their studies on trying to understand what information is used by experts and by non-experts in two different ways. The first to be used was temporal occlusion using film or video, where the viewing of movement patterns is occluded at different time periods before, at or after ball release. Bowlers are filmed and then parts of their body are hidden from the batsmen's view, yet they have to try and anticipate the arrival of the virtual ball (Muller *et al.*, 2006). This method has been criticized because it supposedly changes the constraints imposed on the batsmen as they do not physically try to hit the virtual ball, or when they do try to hit the virtual ball with a bat, they cannot follow the ball after the virtual delivery as happens in the natural context (Stretch *et al.*, 2000). The second method uses liquid crystal occluding spectacles which retain the usual coupling between visual perception and action components thus removing some of the problems for which the first method has been criticized, (Muller & Abernethy, 2006). However, some problems still remain. For example, investigators have shied away from using fast bowlers because of the dangers inherent in high velocity cricket, using instead mostly spin bowlers. Using fast bowlers would mean more stringent time constraints which should make the known differences between expert and non-expert larger and produce other differences.

Using these two methods, differences between experts and non-experts in a variety of visual search mechanisms have been analysed. The accuracy or appropriateness of the movement response has been analysed by viewing the foot movements of the batsman and by measuring the nature of the bat-ball contact (Muller

& Abernethy, 2006). But until now most of the analysis has been done adults. Therefore very little is known about children and what visual search strategies they use and how they use them. Early results indicate that in adults, information for correct foot movements are obtained from early ball flight. For experts this information also comes from the bowler's body especially bowling arm and bowling hand when seen together. The bat-ball contact is dependent on pre-bounce and post-bounce information varying according to the length of the ball bowled. In cricket, contrary to other interception sports, the middle part of ball flight seems to be very important as it confirms the accuracy of the initial prediction of landing location based on pre-release and early flight information and is critical for successful batting (Land & McLeod, 2000). This advance information pick-up is dependent on the skill level of the batsman, the task constraints imposed by the type of bowler, the length of the ball and the type of ball bowled. Although it appears that only expert batsmen can use pre-release information, all levels of batsmen use ball flight information to a varying degree (Muller *et al.*, 2006).

Some of the studies that have been done resorted to using bowling machines to remove the irregularity from the balls bowled and in this way they are able to use faster deliveries without endangering the batsmen. However, these have been criticized because just like the temporal occlusion using film or video they change the constraints by removing pre-release information that is usually obtained from the bowler. This in turn leads to a reorganization of coordination and timing of the batting stroke which also appears to be inferior (Renshaw *et al.*, 2007). However, all of the studies have always used expert bowlers or bowling machines using similar speeds against expert, intermediate and non-expert batsmen. This leaves some doubt as to whether non-expert batsmen batting against non-expert bowlers (e.g. slower or producing less spin), for example, would be able to retrieve more or other ball information, including pre-release information.

As far as we are aware only one study, (Weissenteiner *et al.*, 2006), has been conducted using children cricket players but the bowlers they viewed were adults. Therefore, in the present study we propose to investigate what information young batsmen batting against young bowlers are able to retrieve from ball flight and whether they are able to obtain pre-release information from young bowlers of the same skill level. From the previous studies in fast ball sports on anticipation (Abernethy, 1988;

Tenenbaum *et al.*, 2000; Ward & Williams, 2003; Weissenteiner *et al.*, 2006) it has been shown that children can retrieve early ball flight information. However it is not yet known whether they can retrieve information from their adversaries' bodies. We also examined if there is any difference in using visual information by youngsters of different age groups (U-11 and U-15 years).

We will use occluding crystal spectacles to see what ball flight information is used by the young batsmen, when batting against bowlers of their own age group and skill level, by occluding the ball flight at different times (pre-release and post-bounce). Secondly, we have compared the results of the batsmen from different age groups to find out if there is a difference in the initiation of foot and bat movement and bat-ball contact.

In accordance with what has been shown in previous studies we expected to confirm that early ball flight information was utilized by the batsmen in both age groups. However, we did not expect to find that the U-11 batsmen used pre-release information. For the U-15 age group we hope to help resolve the discussion as to whether or not they can use pre-release information especially from bowlers from their own age group and skill level.

3) METHOD

a) PARTICIPANTS

Twenty male cricket players volunteered to participate in this study. They all played for the Amsterdam Cricket Club (VRA) in the Netherlands. They regularly practiced and were part of the following teams: the under-fifteen (U-15) team (N=6, average age 14.3 yrs.) and the under-eleven (U-11) team (N=14, average age 10.3 yrs). The parents of all the children provided informed consent before the experiment took place.

b) TASK AND APPARATUS

The experiment took place outside on a grass surfaced pitch with the normal dimensions (distance between wickets 18.29 meters for the U-11 and 20.12 meters for the U-15 batsman). To control the viewing period of the participants (batsman) they wore Plato occluding crystal spectacles (OCS). On the back of the cricket bat a 6-G (with a capacity to measure accelerations up to six times the gravitational acceleration), three dimensional accelerometer, was attached to measure movement initiation of the strike. Two digital video cameras with a sampling rate of twenty five Hertz were used.

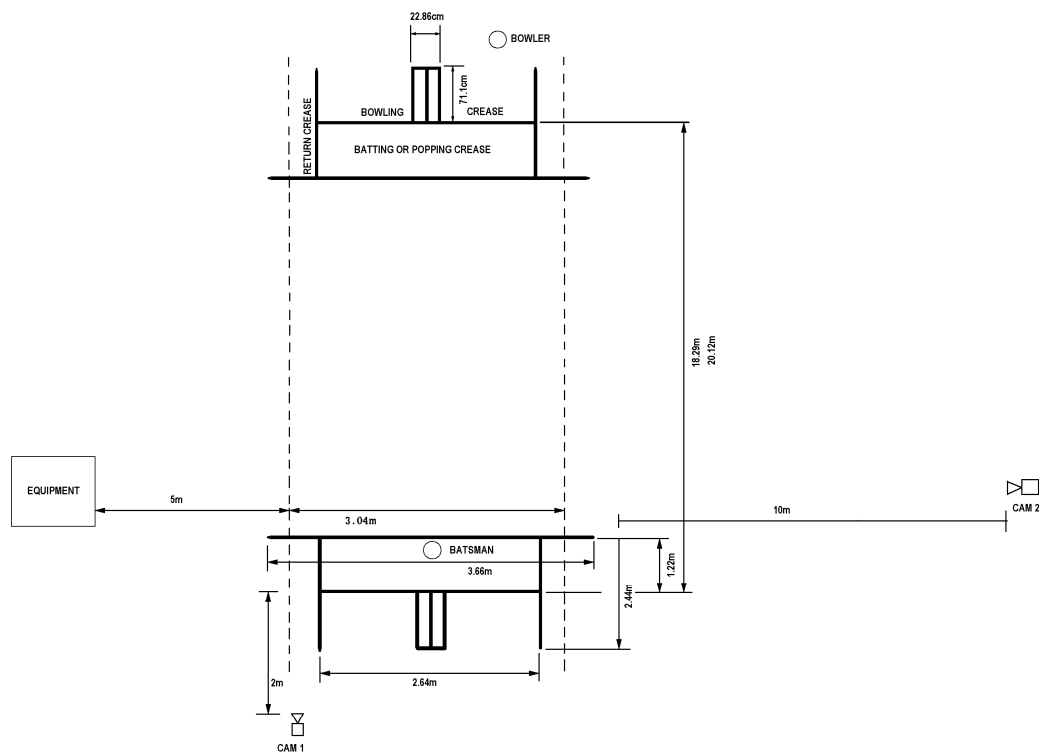


Figure 1: Schematic view of the cricket pitch and equipment that was used.

Camera one was placed two meters behind the batsman's wicket and slightly to the left of the batsman. Camera two was placed on the right hand side of the batsman and perpendicular to the wicket about ten meters away. In the front of each of the cameras a red light emitting diode was attached in such a way that it was visible on the recordings without obstructing the view of the wicket. When the OCS were closed, the light emitting diodes lit up. This signal also went, together with the signal from the accelerometer, to a signal capturing device so that the signals were synchronized. All the equipment was linked by coaxial cables. The synchronized signals were sent to a portable computer via a USB port where they were recorded.

c) PROCEDURE AND DESIGN

The study took place on three separate days within two weeks near to the end of the season. Before the experiment began, the batsmen-participants were allowed a few practice trials. The participants were instructed to try and strike the ball in any manner they chose (defensive or attacking), the only limitation being that they were not allowed

to strike the ball square to the off-side (left side for a right handed batsman), as the equipment and one of the investigators was in that position. The bowler was one of their peers, i.e., a team member of the same age group.

During the experiment each batsman had to bat against as many balls as was necessary to have at least five valid trials for each of the three viewing conditions: open, release¹ and bounce. Trials were classified as good if one of the following did not happen: the ball was bowled wide; the spectacles did not function properly due to low battery, the spectacles were opened or closed too early or too late for that particular condition and finally the ball was a full toss in the bounce condition. The OCS were controlled by a trained investigator who used his judgement to try and press the button that opened or closed the OCS at the correct moment. In the open condition (OC; the control condition) the batsman wore the occluding crystal spectacles but they remained clear all the time. In the release condition (RC) the spectacles remained closed until the moment the ball left the bowlers hand after which they were opened. Finally, in the bounce condition (BC), the spectacles remained open until the ball hit the ground in front of the batsman.

At the beginning of each condition the batsman was informed as to what the next condition would be. The three conditions were blocked, but ordered randomly across participants. After having obtained at least five good trials within a particular condition, the bowler and batsman were allowed to rest for a few minutes.

d) DEPENDENT VARIABLES AND DATA ANALYSIS

Initially we analyzed the complete videotaped recordings to determine badly bowled balls. We then analyzed the hits and misses for each batsman (i.e., whether or not the bat made contact with the ball). After this had been done the video was divided into individual trials and the bad trials i.e., those that did not satisfy any of the above conditions were removed. In Table1 we have a summary of the significance of some of the abbreviated words that will be used here.

¹ It has to be stated here that the reason why the RC was not done in the same way as was done by Muller *et al.*, (2006) is because children of this age have not yet developed a stable bowling pattern and often bowled balls that do not go where they want them to thus making it very dangerous to maintain the batsmen without vision from BR until BH to dangerous for this experiment.

Ball release (moment the ball leaves the bowlers hand towards the batsman)	BR
Bat movement (initial movement of the bat as a consequence of visual information received by the batsman)	BM
Foot movement (The moment the batsman moves his feet as a consequence of visual information received from the delivery of the ball)	FM
Ball hit (the moment the bat makes contact with the ball)	BH
Ball Bounce (The moment the ball makes contact with the ground in front of the batsman)	BB

Table 1: The abbreviations used in this section and their meaning

In addition to the percentage of hits and misses we also used the video recordings and data from the accelerometer to analyze BR and occlusion, reaction time and finally the speed at which the ball was bowled (i.e., distance between bowler and batsmen divided by the time taken for the ball to travel that distance). The following parameters BR-BM (i.e., bat movement onset in relation to the moment of ball release), BR-FM (i.e., foot movement onset in relation to the moment of ball release), BR-BB (i.e., moment of ball bounce in relation to the moment the ball was released), BR-BH (i.e., bat-ball contact in relation to the moment the ball was released), BM-FM (i.e., foot movement in relation to bat movement), BB-BH (i.e., bat-ball contact in relation to the moment of ball bounce), BM-BH (i.e., bat-ball contact in relation to bat movement onset) and FM-BH (i.e., bat-ball contact in relation to onset of foot movement) were also analyzed.

The different parameters were subjected to a 2(group: U-11 vs. U15) x3 (condition: OC vs. RC vs. BC) ANOVA with repeated measures on the last factor. In the case that the sphericity assumption was violated (i.e., $\epsilon < 1.0$), Huynh-Feldt adjustments of the p-values were reported. Finally, post-hoc comparisons were performed using t-test with Bonferroni correction.

4) RESULTS

One of the participants from the U-11 team was excluded from the analysis due to his very weak results in terms of the number of hits in all three conditions. Therefore, in the end, data from nineteen participants was analyzed.

a) BALL SPEED

Using the average of the ball flight time (1.369s and 1.103s for the U-11 and U-15 age groups, respectively) and taking an average distance of 16.5m between BR and BH, which takes into account that the batsmen had one foot in the bating crease and the other on the pitch for a distance between wickets of 20.12m for the U-15 group and 18.29m for the U-11 group (we can use the same estimate of 16.5m for the two groups because the U-11 group basically just stayed in their crease while the U-15 group took big strides forward), the ball speed was calculated.

The average speed that the ball was travelling towards the U-11 batsman was around 12m/s while for the U-15 it was 3m/s faster at around 15m/s. ANOVA reported a significant main effect between the two age groups (U-11 and U-15) for this difference in ball speed ($F(1,17)=6.588, p<0.02$), which indicates that the U-15 batsman had significantly less time to play their shots. This bowling speed is much slower than what top level senior batsmen have to face when batting against medium and fast bowlers who bowl at speeds greater than 25m/s, but not so far away from the speed at which spin bowler's are bowling at (about 18m/s) (Regan, 1997).

b) HITS AND MISSES

Figure 2 shows the percentage of hits and misses for each condition and for each of the two age groups.

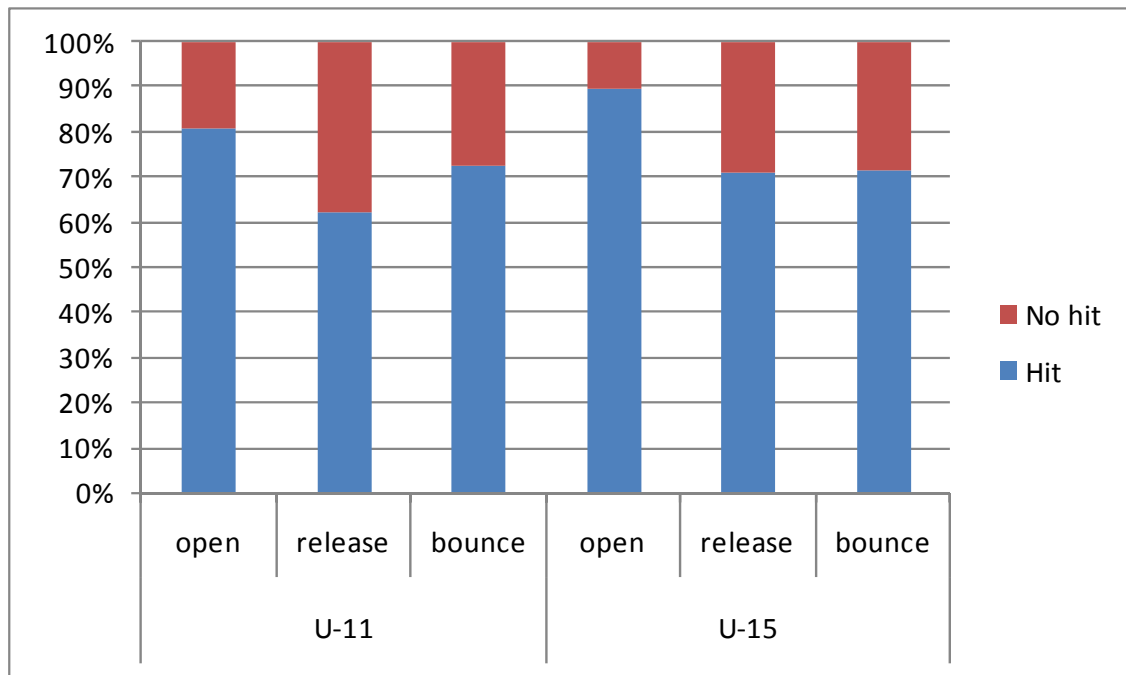


Figure 2: The percentage of hits/misses for the two age groups and the three viewing conditions.

When analysing the data, ANOVA revealed that there is a main effect in the percentage of hits in relation to the viewing condition, ($F(2,34)=3.445, p<0.05$). Post-hoc revealed that there is a difference in the percentage of hits between the OC and the RC. This seems to indicate that when there is a perturbation of the visual information available during the delivery and that it has an influence on the batsman's ability to hit the ball. No difference was found in the percentage of hits between the two age groups.

c) REACTION TIME

We calculated the reaction time for the two groups of batsman in the RC. This is the time between the opening of the OCS and the movement of the batsman. This gives us some indication of how effective each groups search patterns are when looking for visual information. The better search patterns should find the ball quicker in order to retrieve more reliable information earlier (e.g., speed and direction). The movement that was considered could come from either the foot or bat, depending on which the batter moved first in function of receiving visual information from the ball, although most of the time the batsmen moved the bat first. The mean value of the reaction time for the U-11 group was 0.358 sec ($SD=0.187$), while for the U-15 group it was 0.168 sec ($SD=0.047$) less than half that of the U-11. However, ANOVA did reveal a non significant but clear tendency for the factor group, when comparing the mean value for the two age groups ($F(1,16)=3.921, p<0.066$).

d) TEMPORAL CHARACTERISTICS OF THE BATTING ACTION: EFFECTS OF OCCLUSION

I. BALL RELEASE AND THE BATSMAN'S MOVEMENTS

Analyzing the relationship between the amount of time that elapsed from BR to BH for the different viewing conditions, we find that there exists a main effect, ($F(2,34)=3.619, p<0.05$). Figure 3 seems to suggest that this difference occurs between OC and RC. However, post-hoc did not reveal this difference to be significant.

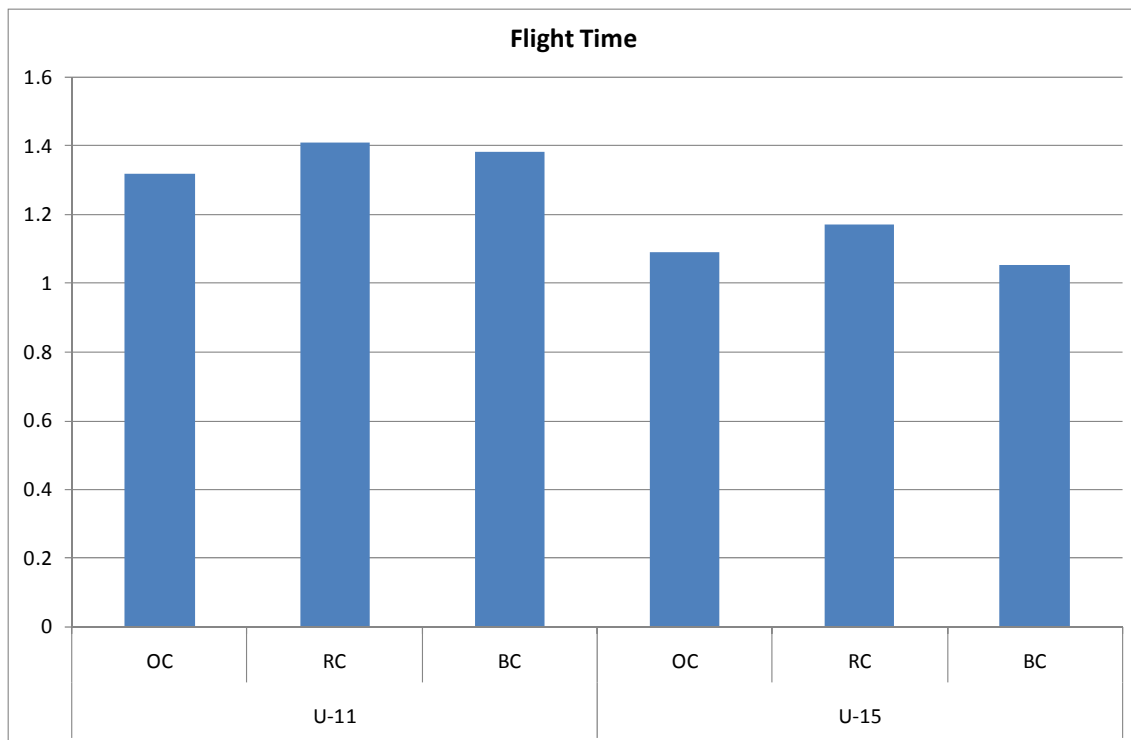


Figure 3: Ball flight time for the two age groups in the different viewing conditions

We also find a main effect when comparing the time difference between FM and BR, and BM and BR for the three viewing conditions ($F(2,34)=20.249, p<0.001$) and ($F(2,34)=18.346, p<0.001$), respectively. Post-hoc for FM-BR shows that the differences are between OC and RC and between RC and BC. For BM-BR post-hoc indicates a similar picture with differences between OC and RC, and RC and BC. This seems to show that the batsmen move their feet and bat later in the RC than in the other two viewing conditions. This can be explained by the fact that they receive information later in the RC.

A main effect between the two age groups was found when FM and BM were looked at in relation to BR, ($F(1,17)=6.588, p<0.02$) and ($F(1,17)=6.983, p<0.017$), respectively. This supports our earlier suggestion that the reaction times of the U-11 batsmen are slower than those of the U-15 batsmen and possibly that the U-15 can retrieve information from earlier on in balls flight or even the bowlers' movements.

II. BALL BOUNCE AND THE BATSMAN'S MOVEMENTS

ANOVA did not reveal any main effect for the time difference between BB and BH ($F(2,34)=0.332, p>0.05$), indicating that the viewing condition did not alter the time at which the batsmen hit the ball after it touched the ground in front of them. However, ANOVA does reveal a main effect for the time difference between BB and BM and also for BB and FM, ($F(1.713,29.126)=7.37, p<0.004$) and ($F(2,34)=15.688, P<0.001$), respectively. Here post-hoc shows that for BB-BM there is a difference between OC and RC and also between RC and BC. For BB-FM post-hoc also showed a difference between OC and RC, and between RC and BC. This means that the viewing condition alters the batsmen's initiation of movement but that they control this movement in such a way that the amount of time it takes to complete the stroke after BB is similar in the three conditions.

The main effect of group that we find when looking at BM, FM and BH in relation to BB ($F(1,17)=4.549, p<0.048$), ($F(1,17)=5.632, p<0.03$) and ($F(1,17)=6.529, p<0.02$), respectively, suggest that the two age groups have different strategies and capabilities in organizing their movements, due to different task and time constraints, in relation to where and when the ball bounces on the pitch in front of them. Ball speed probably has the biggest influence on these results but also the more refined bowling produced by the bowlers.

III. BAT-BALL CONTACT AND THE BATSMAN'S MOVEMENTS, I.E., MOVEMENT TIME

The time interval between BH and FM revealed a main effect for the three viewing conditions ($F(2,34)=6.686, p<0.004$). Post-hoc revealed that for this parameter there were differences between OC and RC and between RC and BC. This seems to indicate that there is a correlation between how early the batsmen receive ball flight information and their FM, as it occurred much closer to bat-ball contact in the RC. However, when analyzing the time difference between BH and BM we could find no

significant main effect ($F(2,34)=3.204, p<0.053$) but a clear tendency between the different viewing conditions was found. We found no main effects between the two age groups for these parameters.

e) OVERALL VIEW

In Figure 4 we can see a complete picture of the average time intervals that were recorded during this experiment for the two age groups and the different viewing conditions:

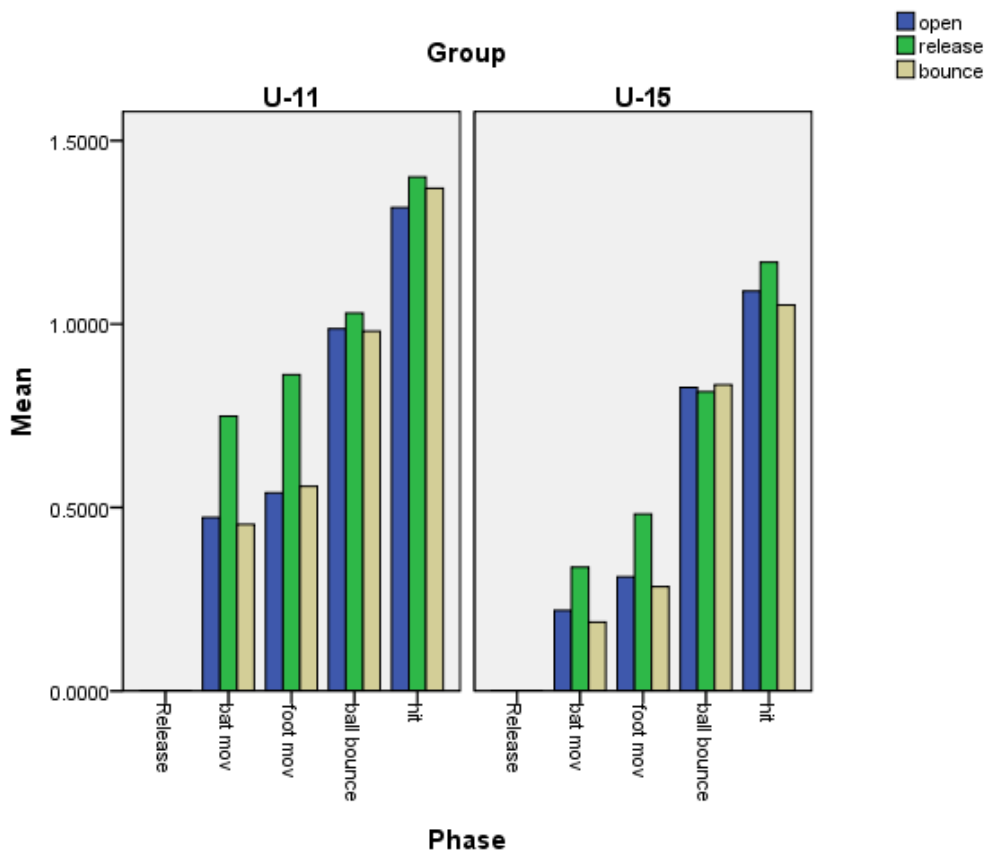


Figure 4: The time intervals that were recorded during the experiment for the two age groups and different viewing conditions.

In Figure 4 we can see that not only did the batsman in the two groups take longer to move their bats and feet in the release condition, but they also hit the ball later in that viewing condition as we have seen when analyzing BR-BM, BR-FM and BR-BH, respectively. We can also see that the U-11 group took much longer to react in the release condition than did the U-15 group (reaction time).

5) DISCUSSION

Although Bartlett (1947) established that anticipation was one of the important parameters of expert performance in time-constrained activities, very little is known today about how expert anticipation is developed through childhood to adulthood. Fast ball sports like cricket can have a very important role in resolving how and when the experts' anticipatory skill is developed and what developmental and practice experiences may contribute to this development.

Previous studies with adults in the sport of cricket have shown that top players use visual information from the bowler's bowling arm and hand before the ball has been released to anticipate where the ball will bounce on the pitch. Early ball flight reveals information which adult batsmen of all skill levels use to predict where the ball will bounce and also helps prepare the batsmen for what the ball will do while travelling through the air before and after the ball has bounced.

The objective of this work was to find the visual information used by children while intercepting a cricket ball with a bat in a natural setting. More specifically, we wanted to figure out whether children with ages between nine and fifteen years could retrieve information from the bowler before he released the ball, could use early and after ball bounce flight information. To this end, we investigated the capacity of the participants to intercept the ball with a cricket bat in different viewing conditions (different constraints) to try and determine whether like adults they use pre-flight ball information, early flight information, and/or post-bounce flight information

In the present study we found no difference between the two age groups in the BC where we occluded the final part of the balls trajectory. We therefore conclude that the occlusion of the balls flight trajectory after it bounced did not significantly affect the young batsmen's ability to hit it. This is contrary to the conclusions of Benguigui *et al.*, (2004) and others (e.g., Dorfman, 1977; Ripoll, 1994) who have stated that there is a large difference for occlusions of longer duration (>200ms) where extrapolation mechanisms are necessary between children and adults. This shows that the question of whether or not younger children differ from older ones (or more experienced) when the final part of the balls trajectory is occluded in interceptive actions in fast ball sport settings is still open for debate. One possible reason for this difference could be that our

experiment was carried out in an ecological setting and as a consequence is more familiar to the batsman.

It has been shown that reaction time decreases with age corroborating Olivier *et al.*, (1998) study which found that response time decreased from 8 to 22 years of age. We found a clear tendency to significance in the difference of reaction time between the batsmen from the two age groups. This is in accordance with Fairweather & Hutt (1978) who stated that an increase in reaction time is a function of the number of alternatives. They argued that the more experienced batsmen (U-15 in this case) can remove some of the irrelevant visual information available because of the experience they have acquired over the additional years of practice. We have seen that the ball flight time differed significantly in the three viewing conditions. This seems to be because the bowlers are influenced by the fact that they knew that the batsmen would only see the ball later in the RC and consequently bowled a slower delivery. Another possibility is that since in the RC the batsmen obtained information about the balls trajectory later and as a consequence all of their movements are slightly delayed including striking the ball. However, this last option is not supported by the fact that no significant difference is found between BB and BH in the three viewing conditions. In order to explore this issue further the difference in ball flight time for the three viewing conditions needs further analysis in future studies.

In general, we found that the U-15 batsmen move their bats and feet earlier than the U-11 batsmen. This coupled with the difference in reaction time seems to indicate that the older batsmen obtain ball flight information earlier. More specifically, in the RC the older children show clear indication that they as they initiate their movements much earlier than do the younger children. This can possibly be due to the faster deliveries which impose different time constraints for the two age groups. However, it could also be because the older, more experienced batsmen have a more refined search for useful information (where and when to look) and how to utilize it better than the younger, less experienced batsmen. That is, with experience and necessity attention gets educated to more useful information.

The differences between the two age groups in relation to BB is possibly because of the faster deliveries but it may also be due to the more correct foot

movement of the older batsmen who move their feet with conviction in the direction of the ball while the U-11 batsmen's foot movement were more unsure and irregular.

The movement time of the batsmen confirmed that they suffered the biggest perturbation in the RC. Here movement time was the shortest suggesting that the batsmen normally move in the direction of the ball as soon as they obtain information about ball flight and that this is an important component of expert performance in cricket batting confirming previous work on adults (Muller *et al.*, 2006).

The different variables that we were able to observe led us to the conclusion that for these age groups early ball flight information is more important than post-bounce ball information when coordinating the striking of the ball. We also believe that there is some indication that some of the players use the bowlers' pre-release movements to coordinate the initiation of their own movements although with this experiment we are not able to reach that conclusion unconditionally.

Although we did not find any significant difference in the percentage of hits between OC and BC, suggesting that viewing ball flight after BB is not important for children, it would be interesting to find out if they follow the balls trajectory after BB and if so for how long after BB. This could then be compared with the studies that have been done on adults and which estimate that they follow the ball for about 200ms after the bounce (Land & McLeod, 2000) to see whether children have already "discovered" that this capacity is important for successful cricket batting.

Our study was severely restricted by the fact that we did not have high speed cameras at our disposal. The 6-g accelerometer that we used also prohibited us from being able retrieve as much information about the bat movement after the forward stroke had begun because the acceleration that the children were able to produce was higher than this limit especially in the Z-direction (in the direction of gravity) but also in the X-direction (perpendicular to the stumps, parallel to the pitch). However it did permit us to get exact information between BM and BH. In future studies we could find out until how long before BH these batsmen can still produce small changes (corrections) to the initial BM. Also an accelerometer could be placed on either the batsman's feet or legs to get exact information on FM. A pressure glove on the bowler's hand can also reveal the exact moment that he releases the ball.

Although we did find some differences between the two age groups, it was much less than we were expecting based on previous studies on anticipation especially in adults where there were significant differences between batsmen of different skill level. We disagree with Weissensteiner *et al.*, (2006), when they stated that children below the age of 20 years do not provide evidence to indicate ability to pick-up advance information. This may be, as they have stated, because children are only able to pick-up advance information from bowlers from their own age group which we have used in our study.

We can therefore conclude that the occlusion of the balls flight trajectory after it bounced did not significantly affect their ability to hit it; that there is a clear tendency to significance in the difference of reaction time between the batsmen from the two age groups; and that the batsmen from both age groups had more difficulty in striking the ball when pre-release information from the bowler is occluded. However, most of these questions will continue open for discussion until we can see exactly what these batsmen are looking at during batting. At a practical level this study shows that children already pick up fundamental visual information when batting and that this can be explored to devise new training programs to stimulate them into searching for the essential information using better search patterns.

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7) APPENDIX

a) THE HISTORY OF CRICKET

The game of cricket has been around for a long time with some references to the game that goes back to the Platagenet period, although it is impossible to distinguish between what may be cricket and its brothers, cat and dog, stool-ball, rounders etc., and even at times its cousins, hockey and golf. The firmest but not secure, pictorial evidence is an illustration apparently of a man demonstrating a stroke with a stump to a boy holding a straight club and a ball in a decretal of Pope Gregory IX. In the 14th century there is a mention in the Wardrobe Accounts of the Royal Household of 100 shillings and 6 pounds being spent on “creag”. But it was only in the 17th century that the game took off, probably due to the enthusiasm of the English upper classes who gambled on the outcome of games. It is clear that it originated in the sheep-rearing country of the South-East, where the short grass of the downland pastures made it possible to bowl a ball of wool or rags at a target. The target was usually the wicket-gate of the sheep pasture, which was defended with a bat in the form of a shepherd’s crooked staff.

By the 17th century the game was quite popular as a rough rural pastime, but in the following century the leisure classes took up the sport. By the middle of the 18th century cricket was being played at every level of society. However, the game lacked a coherent set of rules. In 1835 the Marylebone Cricket Club gave its formal laws, which still stand largely intact today. Latter it was diffused to the English Colonies, where for various reasons in most of the Colonies, it has become a very popular sport. The rules of the game can be summarized by the humorous piece of text that follows:

The Rules of Cricket as explained to a foreign visitor

You have two sides, one out in the field and one in.

Each man that's in the side that's in, goes out, and when he's out, he comes in and the next man goes in until he's out.

When they are all out the side that's out comes in and the side that's been in goes out and tries to get those coming in out.

Sometimes you get men still in and not out.

When both sides have been in and out including the not-outs, that's the end of the game.

For more information on cricket terms, go to <http://nakedwhiz.com/crickgl.htm>