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Full Length Article

# The influence of ball-swing on the timing and coordination of a natural interceptive task

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ABSTRACT

Successful interception relies on the use of perceptual information to accurately guide an efficient movement strategy that allows performers to be placed at the right place at the right time. Although previous studies have highlighted the differences in the timing and coordination of movement that underpin interceptive expertise, very little is known about how these movement patterns are adapted when intercepting targets that follow a curvilinear flight-path. The aim of this study was to examine how curvilinear ball-trajectories influence movement patterns when intercepting a fast-moving target. Movement timing and coordination was examined when four groups of cricket batters, who differed in their skill level and/or age, hit targets that followed straight or curvilinear flight-paths. The results revealed that when compared to hitting straight trials, (i) mixing straight with curvilinear trials altered movement coordination and when the ball was hit, (ii) curvilinear trajectories reduced interceptive performance and significantly delayed the timing of all kinematic moments, but there were (iii) larger decrease in performance when the ball swung *away from* (rather than in towards) the performer. Movement coordination differed between skill but not age groups, suggesting that skill-appropriate movement patterns that are apparent in adults may have fully emerged by late adolescence.

## 1. Introduction

Successful interception relies on a performer accurately positioning an end effector (e.g., the hands or a bat) so that it coincides with the arrival position of the target (Lee, 1998). Fast-ball sports (e.g., baseball, hockey and cricket) present an ideal task environment from which to explore the processes that support successful interception, because skilled performers thrive in conditions where the task demands approach the boundaries of human capability. Moreover, opponents often attempt to gain an advantage by manipulating the spatial and temporal constraints of the task. One possible strategy that opponents can use is to manipulate the flight-path of the target so that it follows a curvilinear (or *swinging*) trajectory during flight. This for example, can be seen by a baseball pitcher throwing a curveball, or a soccer free-kick being bent through the air. Recent studies examining the increased spatial

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and temporal demands imposed by swinging ball-flights suggest that the ability to accurately perceive the future arrival location of the target can markedly decrease when it follows a swinging flight-path, reducing interceptive proficiency (Craig, Bastin, & Montagne, 2011; Craig, Berton, Rao, Fernandez, & Bootsma, 2006; Craig et al., 2009). As a result, curving ball-trajectories represents an ideal model for a highly demanding interceptive task in which movement coordination can be examined to better understand how skilled performers develop expertise in interception (for a review, see Sarpeshkar & Mann, 2011).

The examination of motor actions performed during interceptive tasks (through kinematic analysis) offers an opportunity to better understand the strategies employed by skilled performers to deal with the spatio-temporal demands of the task at hand. Previous studies have helped to identify a range of kinematic parameters that distinguish skilled from lesser-skilled performers in fast-paced hitting tasks. As a case in point, Weissensteiner, Abernethy, and Farrow (2011) showed that a hallmark of skilled cricket batters was their ability to better synchronise the completion of their front-foot movement towards the ball with the initiation of their bat-downswing. By doing so, it was reasoned that skilled batters initiate their bat-downswing at the precise moment a stable foundation has been established by the feet to maximise the summation of forces from lower to upper body in the bat-swing (Abernethy, 1981). The identification of skill-based differences such as this helps to further our understanding of how experts learn to acquire skill in these fast interceptive actions (also see Abernethy & Russell, 1984; Bootsma & van Wieringen, 1990; Hubbard & Seng, 1954; Taliep, Galal, & Vaughan, 2007).

Skill-based differences in kinematic behaviour highlight the effective and efficient means by which skilled performers are able to coordinate their movement to be positioned at the right place at the right time. However, until now, these behaviours have generally been observed when intercepting targets that follow less-challenging *straight/linear* flight-paths, and it is not clear whether the same strategies promote successful interception when intercepting targets that follow a *curvilinear* flight-path. Curvilinear flight-paths arise as a result of pressure differentials around an object in flight that is either spinning (as is the case for a curving soccer ball), or has contrasting surface textures (such as the shiny and rough hemispheres of a cricket ball; for a comprehensive overview, see Mehta, 2009). This imbalance in pressure generates an additional force acting perpendicular to the object's flight-path, causing it to deviate in the direction of lower pressure (i.e., the Magnus effect; see Mehta, 1985, 2009; Walker, 1999). Although much is known about how a ball swings, surprisingly little is known about how performers might account for the continuous lateral deviation of the target in flight to facilitate successful interception (also see Casanova, Borg, & Bootsma, 2015). Craig et al. (2011) recently found that when attempting to stop balls in a virtual environment, recreational soccer goalkeepers were significantly worse at intercepting curving balls when compared to straight ones (15 vs. 57% of all targets). It was reasoned that the informational variables relied on when intercepting targets that follow straight trajectories (*viz.* changes in optical size and bearing of the target) may be less reliable when intercepting curving trajectories (Craig et al., 2009). Moreover, it has been hypothesised that fundamental limitations within the visual system may prevent performers from obtaining accurate perceptual information that specifies the target's future location, ultimately helping to explain the poorer performance seen when intercepting targets that follow a curvilinear flight-path (Craig et al., 2006; 2009).

It is possible that swinging trajectories could influence interceptive performance and movement kinematics in a number of different ways. First, the uncertainty generated by the *possibility* of ball-swing could in and of itself alter behaviour. That is, the possibility of a curving ball-trajectory could alter not only how an action is performed when the ball swings, but also when it *does not* swing. Second, the *presence* of ball-swing can increase the spatio-temporal precision required to successfully hit a ball because high spatial precision is required both laterally and in the forwards/backwards direction, and therefore it is likely to impact performance and how the action is performed. Third, there may be an interaction whereby the *direction* of ball-swing alters interceptive performance in a non-linear fashion. That is, any change in performance as a result of ball-swing may differ according to the direction of the swing (either in towards, or away from, the position of the performer).

### *1.1. Influence of the possibility of ball-swing*

While it seems reasonable to expect changes in behaviour when a target follows a curvilinear rather than a straight trajectory, the simple knowledge that the ball *could* swing may also alter behaviour. That is, the uncertainty generated when a curvilinear ball-trajectory is possible could alter not only movement coordination when the ball does swing, but also when it *does not* swing. It is well established that the context in which an action is performed can influence how that action unfolds (Todorović, 2010). For example, Tijtgat, Bennett, Savelsbergh, De Clercq, and Lenoir (2010) examined the timing and coordination of movement when catching balls that travelled at different speeds, and found that when the ball-speeds were blocked together, performers scaled the initiation of their hand movements to that individual ball-speed. However, when the ball-speeds were randomised, hand movements were initiated at a common time irrespective of the ball-speed. Similarly, Gray (2002) examined the influence of the prior sequence of pitches on the bat-swing of baseball batters of different skill levels. The results showed that the bat-swing of the lesser-skilled batters differed commensurate with the sequence of preceding pitches, significantly decreasing their interceptive performance. On the other hand, the skilled batters were able to combine the knowledge of the previous sequence of pitches with the perceptual information from ball-flight to adaptively modify their bat-swing parameters and successfully hit the ball. This suggests that the range of possible outcomes can influence the way that an action is performed; and in the case of ball-swing, it is reasonable to expect that the *possibility* of ball-swing might alter the kinematics when attempting to hit a ball that does not swing (also see Cañal-Bruland, Filius, & Oudejans, 2015). Moreover, based on the findings of Gray (2002), skilled performers should be better able to overcome these contextual effects and so should not be as influenced by the possibility of ball-swing when compared to lesser-skilled performers.