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Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks

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ABSTRACT

The relationship between perception–action coupling and anticipatory skill in an interceptive task was examined using an in-situ temporal occlusion paradigm. Skilled and novice cricket batsmen were required to predict the direction of balls bowled towards them under four counterbalanced response conditions of increasing perception–action coupling: (i) verbal, (ii) lower-body movement only, (iii) full-body movement (no bat), and (iv) full-body movement with bat (i.e., the usual batting response). Skilled but not novice anticipation was found to improve as a function of coupling when responses were based on either no ball-flight, or early ball-flight information, with a response requiring even the lowest degree of body movement found to enhance anticipation when compared to a verbal prediction. Most importantly, a full-body movement using a bat elicited greater anticipation than an equivalent movement with no bat. This result highlights the important role that the requirement and/or opportunity to make bat–ball interception may play in eliciting skill differences for anticipation. Results verify the importance of using experimental conditions and task demands that closely reflect the natural performance environment in order to reveal the full nature of the expert advantage.

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1. Introduction

The examination of human motor expertise has historically involved experimental designs that fall short of accurately representing tasks as they occur in the natural environment. Research has commonly relied on verbal responses or simplified movements to provide insights to the perceptual processes underpinning skilled movement. This dissociation of perception and action has provided experimental convenience, yet been problematic in breaking the coupling between what are likely to be inextricably linked processes. Gibson (1979) highlighted the interdependency of perception and action in natural tasks, proposing that any protocol separating the two may fall short of understanding the true essence of skilled performance. Support for this position has been provided by Bootsma (1989; Bootsma and Wieringen, 1990), who demonstrated that visual-motor actions in coincidence timing are produced as a result of constant interactions between perceptual information and motor control. Oudejans, Michaels, van Dort and Frissen (1996) highlighted the importance of the link between perception and action in decision-making by examining the road crossing behaviour of pedestrians. In determining the size of gaps between cars allowing them to safely cross, more accurate choices were made by those participants who were walking while making these judgements when compared to those who were stationary. In this sense the addition of movement enhanced perceptual accuracy; conversely, the removal of action from a protocol may result in important elements of expertise being eliminated.

Clearly sufficient reason exists for motor control paradigms to accurately replicate natural conditions, yet this ideal has often been superseded by a desire for tight experimental control and administrative convenience (Abernethy, Thomas, & Thomas, 1993). The partitioning of perception and action has enabled rigorous regulation of experimental tasks but, as a consequence, has reduced the degree to which the tasks accurately reflect naturally occurring conditions. A *representative task design* (Brunswick, 1956) is a protocol which closely replicates the conditions occurring in the natural environment. More recently referred to within some realms of cognitive psychology as *ecological validity* (Neisser, 1976), this concept seeks to ensure that the critical sources of information relied on in the natural setting are available in the corresponding experimental representation. This necessitates not only an accurate depiction of the external and internal sources of information, but also of the performer's own response, ensuring that critical perception–action links remain intact.

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The dual-pathway theory of vision advocated by Milner and Goodale (Goodale, Milner, Jakobson, & Carey, 1991; Milner & Goodale, 1995) is often cited to be neuropsychological evidence for the need to preserve the perception–action relationship inherent in naturally-coupled movement tasks. Within this framework, visual input reaching the neural cortex is processed along two parallel pathways according to the intended use of that information. The ventral 'vision-for-perception' pathway is highly conscious and is used to produce a perceptual interpretation of our surrounds. In contrast, the dorsal 'vision-for-action' pathway, which is more primitive from an evolutionary perspective, appears to subconsciously produce online visually-controlled movements. As a result it is often referred to as the *visual-motor* pathway. Recently, van der Kamp, Rivas, van Doorn and Savelsbergh (2008) have argued that most existing studies of perceptual-motor expertise have inadvertently examined responses of the ventral visual pathway, not the dorsal pathway most likely to be relied on in the natural setting. They propose that the exclusion of realistic movement responses from many of the experimental paradigms used to examine the putative characteristics of expertise has rendered existing knowledge limited, and somewhat biased.

An important subset of research in motor expertise has involved the examination of performance in fast ball sports, providing insights to the skilled execution of interception in a highly time-stressed environment. This body of literature has consistently demonstrated that skilled performers are able to identify key information from the movement patterns of opponents, providing the performer with more time to produce the most appropriate response (Abernethy & Russell, 1987; Jones & Miles, 1978; Shim, Carlton, Chow, & Chae, 2005). This expert advantage in *anticipatory skill* is based on a capacity to more accurately interpret the kinematic information present in an opponent's movements prior to the availability of any ball-flight information (Abernethy, Gill, Parks, & Packer, 2001). A valid criticism of this work has been the dissociation of perception and action, with many paradigms relying on simple verbal or pen-and-paper responses. The expert advantage remains for studies incorporating simplified movements in their testing paradigms (e.g., Savelsbergh, Williams, van der Kamp, & Ward, 2002; Williams, Davids, & Burwitz, 1995), although these simplified or representative movements typically fail to provide an opportunity for actual interception. Minimal work has been performed to examine if, and to what degree, movement may enhance the expert advantage in anticipatory skill. Farrow and Abernethy (2003) studied the ability of expert and novice tennis players to predict the direction of tennis serves in-situ using a coupled and uncoupled response. Coupling proved advantageous with (but not prior to) ball-flight, leading the authors to propose the existence of a dedicated processor for interceptive movements that is reliant on ball-flight information.

Experimental paradigms designed to test the perceptual-motor skill of expert performers have more recently used the dual-pathway theory of vision as justification for participants to produce a movement-based response, reasoning that movement is required to elicit responses of the dorsal visual pathway (van der Kamp et al., 2008). Recent evidence suggests, however, that the incorporation of movement per se may not be sufficient unless the participant attempts to *intercept* an actual target. Króliczak, Heard, Goodale and Gregory (2006) used a hollow-face illusion to establish the degree of movement required to engage the dorsal visual pathway. It was demonstrated that the ventral system was responsible for movement control when participants used their hand to point at the location of a marker on the hollow-face — despite this being a movement clearly mediated by vision. An online visual-motor response with intention to intercept another object (in this case *flicking* the marker off the face) was required before the dorsal system was engaged for the control of movement. Further evidence using fMRI demonstrated that a real interceptive action and a mock (shadowed) one were mediated by different areas of neural processing (anterior intra-parietal area vs. right parietal cortex respectively; Króliczak, Cavina-Pratesi, Goodman, & Culham, 2007). This finding shows that a "fake" interceptive action will not necessary activate the same areas of the brain typically invoked by a real interceptive action. The implication from these studies for existing research into perceptual-motor skill is clear — simplified responses that are not interceptive may fall short of testing the dorsal visual pathway, and as a result they are likely to misrepresent (or at least underestimate) the true ability of skilled performers. An interceptive movement — or at least an intention to intercept – may be necessary to elicit responses of the dorsal visual pathway.

In the present study, a time-stressed interceptive skill was examined – cricket batting – where the detection of early information is essential for successful performance. In cricket batting the player attempts to intercept an oncoming ball bowled by an opposition player under conditions that typically impose considerable time constraints (for a description see Müller & Abernethy, 2006b). The temporal occlusion paradigm was used in-situ to test skilled and novice batters' ability to predict, at specific points in the event sequence, the direction of balls bowled towards them. Accurate occlusion was made possible using the event-related triggering of liquid crystal occlusion goggles, improving on the temporal precision achievable in earlier occlusion studies. Participants predicted the direction of the oncoming ball for a range of response conditions in which the degree of coupling between perception and action was systematically manipulated. The purpose of the study was to determine whether skilled participants, when observing an in-situ motor sequence, would demonstrate systematic improvements in their ability to predict the ball direction as the specificity of the action was enhanced. In particular it was expected that the opportunity to intercept the ball would improve skilled performance – and the expert advantage – above and beyond that for an identical representative movement where bat–ball interception was not possible.

2. Methods

2.1. Participants

A total of 12 skilled and 11 novice male participants voluntarily took part in the study. The skilled group consisted of male cricket batters (mean age 27.2 ± 6.4 years) with an average of 8.6 ± 3.8 years of senior and 7.0 ± 2.4 years of junior playing experience and who, at the time of the study, were competing in their respective first-grade regional/state competitions. None had experience at a national or international level. Members of the novice group (mean age 34.5 ± 7.8 years) were males with no senior cricket experience and an average of 0.7 ± 1.4 years junior experience. All participants gave written informed consent prior to taking part in the study.

2.2. Experimental task and presentation of test stimuli

A two-choice prediction task was designed in which participants were required to judge the direction of an approaching ball projected by an opposing actor (bowler). The task represented a cricket batter facing a bowler, in which situation the batter would typically try to hit the ball. The task therefore necessitated the batter making a judgment of ball direction relative to their usual stance position near the centre stump. In the sport of cricket a batter attempts to protect three stumps from being hit by a ball, with the batter standing to one side of the centre stump. Balls bowled or *delivered* by the bowler towards the batter's side of the centre stump are said to be directed towards the *leg* side, whilst balls towards the opposite side are towards the *off* side.

Three actors were employed to bowl in the study (one right-handed and two left-handed bowlers each with an approximate bowling speed of 90 kph). The actors followed a script of intended ball direction for all trials, with all except those trials where the ball was projected directly towards the centre stump being included in the final analysis. Actors correctly delivered 92% of trials as specified to the off or leg side of the centre stump, with post-hoc analysis of all deliveries demonstrating no difference in the number of deliveries presented to either side (off vs. leg side = 48.9 vs. 46.7%, $t\,(23) = 1.61$,

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