Research proposal

Cognitive control of series of actions: The importance of inhibition

hypotheses

Damien Lafont, PhD

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1. Introduction

It is known from a number of lines of work that people's performance at a given time is influenced by what they plan to do next. Such anticipatory effects have been treated as clues to the nature of human perceptual-motor planning (for reviews, see Rosenbaum, 1991, 2002). Thus, a vast amount of theoretical work on attention has been undertaken to better understand the mechanism of anticipation.

Land and Furneaux (1997) showed that our eyes do not just passively record the scene ahead, but actively seek information from it. Hence, in sport, reading, music reading, typing or driving there are benefits to think and see ahead.

In playing table tennis and other ball games the secret is to know what the ball is going to do as far ahead as possible, in order to allow time for the planning and execution of accurate responses. Players need to determine the future trajectory of the ball and the timing of contact with it (Land and McLeod, 2000). Ripoll et al. (1988) found that international table-tennis players anticipated the bounce and made a saccade to a point close to the bounce point. In cricket, where the ball also bounces before reaching the batsman, Land and McLeod (2000) found much the same thing as in table tennis.

Eye movements in reading are highly constrained to a linear progression of fixations to the right across the page, which allows the words to be read in an interpretable order (Rayner, 1998; Radach et al., 2004). Similarly, music reading shares with text reading the constraint that gaze must move progressively to the right (Land, 2006). Copy typing, like music playing, has a motor output, and typists of all skill levels attempt to keep the eyes about 1s ahead of the currently typed letter, which is the much same as in music reading.

Land and Lee (1994) found a clear relationship between direction of gaze and steering. In particular, drivers spent much of their time looking at the 'tangent point' on the up-coming bend.

Thus, many complex tasks require the integration of visual information mainly gained in the first part of the action. The benefit of early anticipation is therefore often taken for granted.

However, a recent study (Lafont, 2007) showed that top tennis players hold their head still when hitting the tennis ball, apparently inhibiting their desire to watch the ball after it leaves the racquet. By contrast, less accomplished tennis players do not hold their head still when hitting the tennis ball, apparently unable to inhibit their desire to watch the ball after it leaves the racquet.

In golf, Vickers (1992, 2004) found that almost all novices follow the ball with their eyes after they hit it whereas the good player maintains fixation on the same location at the point of impact through the swing, forward swing, contact, and for almost half a second after the ball is hit. It seems that experts in many tasks show similar fixation stage during the hitting phase as in soccer, baseball or rugby (Fig. 1). High-level athletes' performances suggest that there are certainly fundamental benefits in adopting this gaze behaviour jus after contact.

Holding the head still at the time of hitting the ball is likely to permit a more effective hit than allowing the head to turn, both from a biomechanical and cognitive perspective. Biomechanically, head stability is likely to allow for greater body stability altogether. Cognitively, holding the head still may heighten the player's focus on the place and time of contact.

Fig. 1. Gaze fixation on the contact point during hitting tasks in sports.

The early part of the ball trajectory (before contact) has been widely studied and is recognized as the most critical. However, there is much to learn about the way that eye should point in the transition of consecutive actions. In particular, the question of when anticipation should really be initiated has not yet been touched. This study will explore this question further.

Objective

In many activities, we are constantly counselled on the benefits of early preparation and the gift of anticipation. But can our efforts to prepare actually undermine our chances for success? Can our attempts to anticipate lead to our downfall?
Everyone knows that knowing what’s ahead helps performance. That it can sometimes hurt performance is the new here. The planned research is designed to investigate the hypotheses and, more generally, to explore the idea that anticipation can be detrimental to effective performance in some circumstances.

2. Hypotheses

Several hypotheses can be made about the importance and effects of full or partial visual feedback during the transition phase of series of actions, especially between time of contact and next ball release.

In general, it is largely admitted that the longer the ball is tracked, the more successful is performance. Since in many tasks, the experts must predict where the ball will be at a future time, they use advance visual cues to predict shot-type and direction. Usually, the eyes look at points that are particularly informative for the ongoing action. It has been pointed out that fixations on objects tend to precede actions. Then, information about both the target and the ball is used for planning next movement. Another important role of visual information before contact is in providing feedback information about the status of the ongoing movement. Hence, the before-contact period is important in providing information on the ball's trajectory and in planning the ensuing motor response. But what happens after contact? In fact, the transition phase has been rarely studied.

Because the initial impulse of the movement is not modified once begun, the presence or absence of the ball during this phase probably would not have an immediate influence on the movement, i.e. doesn't affect the guidance of movement. Thus, as a first step hypothesis, one could think that deprivation of visual feedback on the ball trajectory doesn't change the movement accuracy.

However, the surprising prediction that arises from recent observations (see section 1) is that people should do better when the ball disappears from view after it is hit than when the ball does not disappear from view after it is hit, at least if the disappearance time is not too long. According to that hypothesis, "gaze anchoring" would be crucial, and removing visual feedback of post-contact trajectory will have beneficial effects on subsequent movements. Some of these hypotheses are considered in the following paragraphs.

Interferences

In these recent observations, experts appear to follow a visual pattern named "dead-eye" gaze. The dead-eye gaze pattern generates visual and other spatial-analysis cues in a complementary, synergistic fashion that takes advantage of the underlying neuro-physiological processes more effectively than the "common" visual pattern. In particular, this visual pattern eliminates variable signaling during targeting occasioned by the brain having to account for shifting eye positions (Bach-y-Rita et al., 1971; Senders et al., 1978; Wurtz and Goldberg, 1989). In brief, it would prevent the inflow of visual inputs that could interfere with the aiming commands set earlier, i.e. the numerous fixations as the ball traverses along its path (continuous refocusing).

By fixating a single location longer, the players give themselves a great deal more time without interference from other sources. The post-contact fixation may prevent the intake of interfering information from the moving ball in the visual field. It can be seen as visual strategy which eliminates the continuous refocusing on the ball and would avoid the brain to constantly receive inaccurate visual information about the true location of the ball which in turn leads to inaccurate motor output. Rather than use multiple information about the speed, position, velocity, expert players simply limit the number of variables to be controlled.

Outcomes

Another idea tends to suggest that suppression of visual feedback does more than simplifying the visual input. Indeed, we have a natural impulse to anticipate the response of our actions, to evaluate the possible outcomes. Thus, when the ball's movement remains visible from start to stop, we tend to adopt a feed-forward behaviour. This implies a period when vision is mainly concerned with checking consequences. Sometimes, in hitting tasks, such behaviour could cause subjects to begin moving their eyes even before contact.
What is much less natural and more difficult to achieve is being comfortable with not knowing. However, we have certainly much more time to prepare the next action than we usually think.
To properly see and react, we must abandon our plans and preparations, our intents and expectations, and see what actually occurs in the moment. We must have the ability to abandon outcome expectations.
In this context, one can put forward another hypothesis concerning the positive effects on performance during the occluded conditions. Indeed, because subjects could not see the ball in the invisible-ball conditions, they received no concurrent visual feedback about the progress of the movement. Thus, the immediate result of their movement is not available. The attention of the participant is therefore not directed to the effect of the action but to the action itself. It would allow the players to place less value on the outcome of their shots, to abandon expectations and intention, therefore allowing staying on the process and providing better movement accuracy. In addition, being detached from the urge to anticipate and simply seeing the moment, we can suppose the concentration is more narrowly focused on the task at hand.

Alternative eye-movement theory

We can replace the above hypotheses in the broader perspective of the work of Abrams et al. (1990) who studied various aspects of visual-feedback processing related to the production of aimed movements, especially the roles played by different sources of visual feedback (e.g., vision of the effector and the target for a movement). They proposed three eye-movement hypotheses that describe the coordination of the gaze when aiming at near targets. In the position-only hypothesis, the eyes locate the target and remain fixated through completion of the movement. In this hypothesis, information derived directly through fixation on the target is necessary to complete the movement accurately. In the movement-only hypothesis, the eyes move in a coupled fashion with the aiming limb. In this case, information arising from the oculomotor commands or proprioceptive inflow from the eye muscles is needed to ensure the accurate completion of the movement. The third hypothesis, movement-plus-position, is a hybrid of the first two.
Here, an alternative hypothesis emerges: A switch from the eye "time-locked" with the ball movement to a stable gaze anchored on the contact point would improve performance. Such visual referential switch – despite less natural – would be more efficient as compared to when they let their gaze move during the hitting process. In particular, gaze anchoring would guarantee a superior motor skill execution. Thus, the differences between expert and less skilled performers could lie in part both on the organization of the information chain and on the simplification of visual input.

Motor control

Moreover, this study should help to add understanding of several key issues in the field of human motor control, especially how we control the serial order of our behaviors (see

Rosenbaum et al., 2007). When we engage in behaviors that have distinct elements, the elements of the behaviors must be ordered correctly. Otherwise the behavioural outcomes would be maladaptive (Rosenbaum, 1991). Here, we clearly pose the problem of hierarchical treatment of information. Establishing a constraint hierarchy – a set of prioritized requirements defining the task to be performed - is one of the most important aspects of motion planning (Jax et al., 2003). Our study could provide evidence for the hypothesis of the hierarchical organization for behavioral plans.

Anticipation

In particular, one element governing constraint hierarchy is the optimization of the anticipation processes. Land and Furneaux (1997) underlined that in playing table tennis and other ball games the secret is to know what the ball is going to do as far ahead as possible, in order to allow time for the planning and execution of accurate responses. Indeed, planning, preparation, and anticipation put the player into an optimal position from which to see and react. It is why we have a natural impulse to anticipate for the impending actions so that we can prepare. Thus, preparation, the first part of the reaction process has been largely studied. In particular, it has been showed that the most relevant information on the ball is gathered during the first part of the trajectory. Most of studies highlight the potential benefits of early anticipation.

However, there is a fine line between anticipating a future action and over-anticipating, i.e. to initiate a new action too early. It is well illustrated in sport, where we must learn to observe our opponent's shots and not be caught "over anticipating."

Recent observations in sport contexts suggest the capture of subsequent cues and evaluation of the upcoming event is not immediately useful after contact. In specific situations, visual search initiated too early after contact would be even maladaptive for the movement. More specifically, at this time, it can be hypothesized that the period of time after contact when the gaze is stable serves as inhibitory process of too early anticipation process for the next action. In other word, there would be a time window where the initiation of anticipation could be postponed until additional information becomes available. This means the player could give themselves more time before initiate the next shot, i.e. initiate visual search for the next ball later.

To date, despite the great amount of research that has been done regarding the anticipation, it is unclear when anticipation should be initiated relative to the movement that should be performed next. Our research will help address this issue.

Inhibition

Finally, as stated in the introduction, thinking ahead may be just one *should not do* when hitting a tennis ball or, perhaps, when hitting a baseball. It is known that inhibitory control is an important part of performance, and it may well be that observations indicating that top tennis champions keep their heads steady when hitting the ball (Lafont, 2007) reflect a greater capacity for inhibition (or future eye positions) among top players than among lesser players. This finding, from the study of expert performers, may illustrate a much wider point about the importance of inhibition in the control of movement sequences. Since there is little direct evidence on this question, addressing it will be an important priority for the future work.

3. Perspectives

In this study we hope to gain a more precise picture of the role of visual feedbacks underlying the decision processes and obtain a more precise idea of what the player is required to do, in terms of actions and cognitive processes. More specially, by studying how the control of visual feedbacks affects performance, we will be able to understand more fully the contribution of the transition phase between consecutives actions.

An interesting perspective is therefore using the results of this study as training purposes. Indeed, in sport, skilled athletes may not be aware of the important visual cues they are attending to. They play the game properly but have little insight into the role of their eyes and employ a traditional input pattern as their default visual strategy which could be not always the most efficient.

As evoked earlier, the strategy which consists of focusing on the contact point could be an efficient way to use the eyes in fast-moving ball sports. We can hope that it would allow the player not only to simplify the input information but also to exercise skilful decision making. Hence, gaze control training could be probably used to optimize repetitive hitting tasks.

4. References

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