Acta Psychologica 185 (2018) 33–40

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Examining the effect of state anxiety on compensatory and strategic adjustments in the planning of goal-directed aiming

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A R T I C L E I N F O

Keywords:
Anxiety
Self-focus theories
Distraction theories
Planning
Online control

A B S T R A C T

The anxiety-perceptual-motor performance relationship may be enriched by investigations involving discrete manual responses due to the definitive demarcation of planning and control processes, which comprise the early and late portions of movement, respectively. To further examine the explanatory power of self-focus and distraction theories, we explored the potential of anxiety causing changes to movement planning that accommodate for anticipated negative effects in online control. As a result, we posed two hypotheses where anxiety causes performers to initially undershoot the target and enable more time to use visual feedback ("play-it-safe"), or fire a ballistic reach to cover a greater distance without later undertaking online control ("go-for-it"). Participants were tasked with an upper-limb movement to a single target under counter-balanced instructions to execute fast and accurate responses (low/normal anxiety) with non-contingent negative performance feedback (high anxiety). The results indicated that the previously identified negative impact of anxiety in online control was replicated. While anxiety caused a longer displacement to reach peak velocity and greater tendency to overshoot the target, there appeared to be no shift in the attempts to utilise online visual feedback. Thus, the tendency to initially overshoot may manifest from an inefficient auxiliary procedure that manages to uphold overall movement time and response accuracy.

PsychINFO classification

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1. Introduction

The effect that state anxiety (i.e., anxiety pertaining to a perceived threat within a particular situation) has on the performance of perceptual-motor tasks has attracted considerable research interest (see Eysenck & Wilson, 2016; Nieuwenhuys & Oudejans, 2012 for recent reviews). This interest is not surprising when we consider the large number of domains where individuals have to perform accurate movements under high-stress situations (e.g., medicine, aviation, military and sport). To date, the research findings have predominantly substantiated two select groups of anxiety theories: self-focus and distraction.

Self-focus theories (conscious processing hypothesis (CPH); Masters, 1992, explicit monitoring; Beilock & Carr, 2001) state that anxiety leads to attention being directed toward the performers' own movements, which may revert performance to an early-declarative stage of development (see Fitts & Posner, 1967) and/or elicit an internal focus-set that can heavily attenuate performance (see Wulf, McNevin, & Shea, 2001). Alternatively, distraction theories (processing efficiency theory (PET); Eysenck & Calvo, 1992, attentional control theory (ACT); Eysenck, Derakshan, Santos, & Calvo, 2007) suggest anxiety can re-direct attention to irrelevant sources of worry, which may then compromise the availability of resources needed for processing task-relevant information. In this regard, performance effectiveness may be upheld by utilising auxiliary resources (e.g., mental effort), but at the expense of performance efficiency.

Recently, researchers have tried to understand more about anxiety and its related processes by exploring the specific effects it has on the planning and subsequent control of action (e.g., Allsop, Lawrence, Gray, & Khan, 2016; Causer, Holmes, Smith, & Williams, 2011; Coombes, Higgins, Gamble, Cauraugh, & Janelle, 2009; Lawrence, Khan, & Hardy, 2013; Vine, Lee, Moore, & Wilson, 2013). Most notably, Lawrence et al. (2013) posited an experimental design that directly examined distraction and self-focus theories by formulating opposing hypothetical outcomes within a single goal-directed movement. Adapted from the

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https://doi.org/10.1016/j.actpsy.2018.01.008
Received 8 June 2017; Received in revised form 16 December 2017; Accepted 19 January 2018
Available online 06 February 2018

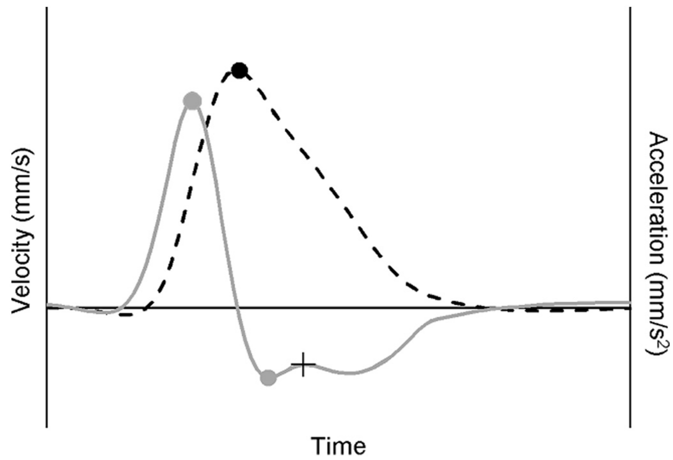

Fig. 1. Representative velocity-acceleration profile of a discrete goal-directed aim. The primary (left) and secondary (right) vertical axes indicate the magnitude of velocity and acceleration, respectively. The *black dotted line* and *gray solid line* indicate the velocity and acceleration respectively across time (horizontal axis). The *solid circles* represent key kinematic landmarks: peak acceleration, peak velocity and peak deceleration in ascending order of time. The *cross-hair* represents the end of a primary submovement and beginning of a secondary submovement (marked by discontinuities in acceleration for this particular example).

notion that manual goal-directed movements comprise two components – planning and control (Woodworth, 1899; see also Elliott, Helsen, & Chua, 2001); it was reasoned that distraction theories would allude to differences between high and low anxiety conditions during the planning phase of the movement, while self-focus theories would argue differences during the control phase of the movement. These competing sets of hypotheses assume that planning needs attention toward task-relevant information (e.g., target context), while control unfolds automatically with limited cognitive involvement. To infer planning and control processes, the researchers adopted a measure of spatial variability – dispersion of displacement at select kinematic landmarks (peak acceleration, peak velocity, peak deceleration, movement end) throughout the entire trajectory (see Fig. 1). This measure is adapted from the notion that high-velocity long-amplitude movements naturally subtend greater amounts of variability compared to low-velocity short-amplitude movements (Schmidt, Zelaznik, Hawkins, Frank, & Quinn, 1979; see also Meyer, Abrams, Kornblum, Wright, & Smith, 1988). Therefore, in an instance of a sudden decline in variability before the end of the movement, we can infer that an intervening control process was implemented and involved the use of online sensory feedback (Khan et al., 2003a; see also Khan et al., 2006). At the same time, any differences in variability between conditions that are captured during the early portions of the trajectory would reflect planning-related alterations, presumably with the aid of terminal feedback obtained from the previous trial (Khan et al., 2003b). The results showed that there was greater spatial variability at the end of the movement for the high compared to low anxiety condition with no differences in the early portions of the movement. Thus, the findings offered strong support for the tenets of self-focus theories.

However, a follow-up study (Allsop et al., 2016) showed that while there was a similarly negative impact of high state anxiety in online control, there was also an impact observed within the early planning phase of the movement. Namely, there was lower spatial variability at peak acceleration, peak velocity and peak deceleration in the high compared to low anxiety condition. In addition, there was greater mental effort expended following the high anxiety condition. Hence, these findings seemed to reconcile the view of distraction theorists (e.g. Eysenck & Calvo, 1992), as there were changes made in the planning of the movement, while performance efficiency was compromised. As a result, the authors proposed that self-evoked auxiliary resources might have enabled some accommodation within pre-movement planning because of an anticipated deleterious effect of anxiety during late online control.

This conjecture is heavily adapted from recent developments to the two-component model of manual goal-directed movements (Elliott et al., 2010; Elliott et al., 2017). That is, while there are two dichotomous components, the anticipation of online sensory feedback can greatly inform the planning process so much so that online control is contingent upon the pre-planned use of sensory information. To elucidate, prior knowledge of visual feedback for goal-directed movements typically elicits a larger magnitude force and shorter proportional time at peak velocity (i.e., positive skew in the time-course of movement velocity) (Hansen, Glazebrook, Anson, Weeks, & Elliott, 2006; Khan, Elliott, Coull, Chua, & Lyons, 2002; see Causer, Hayes, Hooper, & Bennett, 2017 for an example of oculomotor control in golf-putting). What's more, a suspected decline in the ability to control can cause an increasingly shorter proportion of time to peak velocity (Mottet, van Dokkum, Froger, Gouïach, & Laffont, 2017; Timmis & Pardhan, 2012; Welsh, Higgins, & Elliott, 2007). That is, a further and faster reach within the early portions of the trajectory is presumably prepared to accommodate the late online control phase. In this regard, the forces and timing of goal-directed movements are parameterized with a view to utilising online sensory feedback. This view contends that performers must initially comprehend the sources of sensory information that they will receive late on in the movement.

Of interest, the planning of goal-directed movements is also contingent upon the potential outcome of movements (i.e., errors) and their implications for overall energy-expenditure (Elliott, Hansen, Mendoza, & Tremblay, 2004). As a result, the limb will typically fall short of the target prior to undertaking late online control because it avoids an overshoot error that requires more time and energy to amend (Lyons, Hansen, Hurding, & Elliott, 2006; Roberts, Burkitt, Elliott, & Lyons, 2016; cf. Roberts et al., 2016). Corrections to an initial overshoot require performers to reverse the limb, which contend with the more demanding situation of overcoming inertia and alternating agonist and antagonistic muscle functions. Hence, it is in the performers' best interest to "play-it-safe" and initially undershoot the target if indeed they are to potentially miss and assume a late correction. Because of this particular feature in planning, it stands to reason that in situations of greater uncertainty there will be a more conservative means to avoid an undesirable movement outcome – the more uncertain the outcome, the greater the undershoot. Indeed, it has been shown that unintended spatial variability negatively co-varies with the extent of the primary movement amplitude (Worringham, 1991; see also Harris & Wolpert, 1998).

However, a feasible alternative may be offered by Allsop et al. (2016) who indicated that performers may contest the negative effects in online control by inversely limiting the need to amend the limb following an initial restriction to the spatial variability. In a similar vein, Cassell and colleagues (Cassell, Beattie, & Lawrence, 2017) found that the prolonged movement times from practice with anxiety to transfer with no anxiety (control) failed to unfold in the reverse context (i.e., no anxiety-practice to anxiety-transfer). Indeed, the absence of a negative specificity effect when transferring to a situation of anxiety was suggested to result from performers opting for an open-loop approach where extending the time for visually-regulated online control served no added benefit. Taken together, it may be conceived that the performer seeks to "go-for-it" by way of a pre-planned arrangement to limit the variability and increase the chances of landing inside the target without the guidance of online visual feedback. Therefore, a high-stress situation may be likened to an approach typically adopted in open-loop/no vision conditions – trajectory modifications being isolated to the early movement phases without concern or accommodation for visually-regulated online corrections. While this approach may seem counter-intuitive due to a failure to take advantage of the visual feedback that is available, it is still very much a possibility if the performer assumes online control serves no further advantage to an already