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The StartReact effect in tasks requiring end-point accuracy

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HIGHLIGHTS

- A startling auditory stimulus (SAS) speeds up the initial part of movement execution in tasks requiring accuracy, as it happens with open-loop ballistic tasks.
- If SAS is applied once the programme has been launched, it does not interfere with its execution.
- The StartReact effect is restricted to movement onset, while the slow phase adjustment (*homing*) depends on sensory feedback.

ABSTRACT

Objective: Fast and accurate movements are often performed in response to a sensory signal. In reaction time tasks, execution of open loop movements is speeded up when a startling auditory stimulus (SAS) is applied together with the imperative signal (IS). In this study, we examined the effects of a SAS on the performance of a task that demands accuracy.
Methods: Nine subjects were asked to move a monitored pen to a target point located in a table at a fixed angular distance of 30 degrees from a start point. The target was a spot of three possible diameters: 5, 10, and 20 mm. Finger force for pen holding, pen tip pressure against the table and kinematic variables of the forearm movement were measured for three conditions: control, SAS delivered at IS (SAS-IS trials) and SAS delivered during movement execution (SAS-MOV trials).
Results: Two movement phases could be identified in the movement trajectory and force profile. The first phase, ballistic, was significantly shortened in SAS-MOV trials, with earlier and larger peak velocity and peak force with respect to control trials. The second phase, slow approach to target, was longer in SAS-IS trials but not in SAS-MOV trials. Accuracy was maintained throughout all conditions and stimulation modes.
Conclusions: A SAS speeds up only the first (ballistic) part of the movement in an accuracy task. Slower target approach compensates for the accelerated initial movement. No changes in the last part of the movement are seen when a SAS is delivered after movement onset.
Significance: The StartReact effect is restricted to the onset of a complex movement, when muscles are activated in a ballistic mode, without feedback.

1. Introduction

Some complex voluntary movements require a high level of dexterity and accuracy. For instance, object displacement is usually performed fast, with an adequate grip force to maintain the object steady and timely. When performing a skilled limb displacement, it is considered that the grip force is related to limb acceleration (Nowak and Hermsdörfer, 2004; Hermsdörfer et al., 2011; Nowak et al., 2013). This suggests that specific motor actions are part of a preconceived motor plan. However, timely execution of some corrective actions indicates also that the motor system responds to sensory inputs acting as imperative signals (ISs) along

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movement execution. For proficient execution of simple tasks on demand, subjects may use pre-programmed movements that should be ready for execution at perception of the IS (Henderson and Dittrich, 1998). The ability to perform rapid and accurate actions would be an advantage in these cases but, according to Fitt's law, there should be a trade-off between accuracy and speed that would prevent execution of perfectly accurate tasks in speeded up movements (Plamondon and Alimi, 1997).

It is known that voluntary reactions can be speeded up by a startling auditory stimulus (SAS) delivered at the same time as the IS, a phenomenon termed StartReact (Valls-Solé et al., 1999; Carlsen et al., 2004). The same phenomenon has been described in relatively complex movements, where tasks, mainly open-loop, are temporally advanced in such a way that there is also shortening of their termination (Reynolds and Day, 2007; Queralt et al., 2010; Castellote et al., 2012). However, the phenomenon has not been studied so far in tasks in which the main requirement is accuracy and any change during task execution may have an unwanted effect.

With these premises in mind, we considered the hypothesis that a SAS may disrupt the execution of a task requiring accuracy when presented (a) together with the IS, or (b) close to end-point reaching. By presenting the SAS together with the IS, we aimed at knowing whether the necessary commands for reaching end-point accuracy are packed together with the initial ballistic movement, or they are modified on-line interfering with accuracy during execution. By presenting the SAS near to end-point reaching, we aimed at knowing if the required end-point adjustments are permeable or not to external interferences.

2. Methods

2.1. Subjects

Nine healthy subjects (four females and five males, aged 28–55 years) took part in the experiment. All were self-reported right handers with normal or corrected-to-normal vision, and were free from any neurological deficit that could affect the execution of the task. Subjects gave their informed consent for the experiment, which was approved by the local Ethics Committee.

2.2. Set up

Subjects were comfortably sitting on a chair in front of a drawing table, whose surface was inclined 30°. The table had two marks: the starting point and the target. The starting point was centred at subject's midline, 20 cm from the body and the target adjusted for each subject at 30 angular degrees to the right for a straight elbow extension movement. Both, the starting point and the target were visible to the subject at all times. Subjects were requested to hold with their right hand a home-made pen that monitored, through two strain gauge systems, the pinch grip force of the subject's fingers during the hold, and also the force at the pen-tip during table contact (Biontec, Barcelona). The subject's task was to move the pen from the starting point to the target. The departure point was a fixed 5 mm diameter spot. The end-point spot had three possible diameters: 5, 10 and 20 mm (Fig. 1A). An electrogoniometer (Model X 65; Biometrics; Gwent, UK) was fixed at the elbow to record forearm angular displacement reflecting pen motion, which allowed for off-line calculation of time-dependent kinematic variables. Adequate switches, one on pen tip, one on the departure spot and one on the target spot gave accurate information about departure and arrival times of the pen tip during task performance.

2.3. Procedure

Subjects were told to move the pen as quickly as possible between the two targets while ensuring they landed within the second target following a somatosensory IS (a weak electrical stimulus on their left index finger). The IS was delivered after a verbal forewarning (the word 'ready') by pressing a computer key hidden to the subject's vision. The time interval between forewarning and IS was variable between 1 and 3 s. Subjects

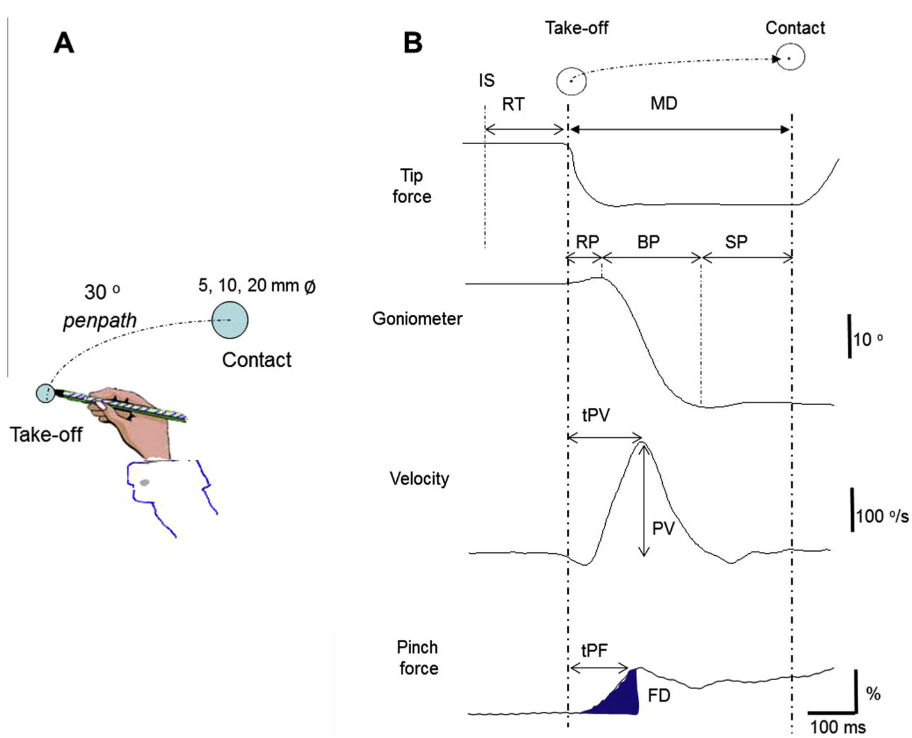

Fig. 1. Schematic representation of the set-up (A) and recordings from a representative subject (B). IS: imperative signal; RT = reaction time; MD = movement duration; RP = raising phase; BP = ballistic phase; SP = slow phase; PV = peak velocity; tPV = time to peak velocity; FD = pinch force developed; tPF = time to peak force. Tip force was used as the marker for take-off and end of the movement, while the goniometer and velocity profiles were used for determining movement phases.