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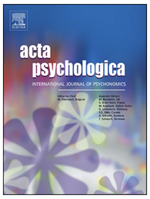

What's your number? The effects of trial order on the one-target advantage[☆]

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ABSTRACT

When moving our upper-limb towards a single target, movement times are typically shorter than when movement to a second target is required. This is known as the one-target advantage. Most studies that have demonstrated the one-target advantage have employed separate trial blocks for the one- and two-segment movements. To test if the presence of the one-target advantage depends on advance knowledge of the number of segments, the present study investigated whether the one-target advantage would emerge under different trial orders/sequences. One- and two-segment responses were organized in blocked (i.e., 1-1-1, 2-2-2), alternating (i.e., 1-2-1-2-1-2), and random (i.e., 1-1-2-1-2-2) trial sequences. Similar to previous studies, where only blocked schedules have typically been utilized, the one-target advantage emerged during the blocked and alternate conditions, but not in the random condition. This finding indicates that the one-target advantage is contingent on participants knowing the number of movement segments prior to stimulus onset.

1. Introduction

Everyday actions often contain several movement segments that are performed in series (e.g., picking up a glass of water and drinking it, turning on a light switch and opening a door, catching and then throwing a ball). When movements are comprised of a sequence of segments, reaction time (RT) is typically longer for multiple- compared to single-segment responses. This finding has been shown to be contingent on participants having advance knowledge of the number of segments (e.g., Klapp, 1995, 2003). Likewise, for movements involving multiple targets in a sequence, the time taken to reach the first target is typically longer than if the same first segment is executed in isolation (i.e., one-target advantage: Adam et al., 2000; Chamberlin & Magill, 1989; Fischman & Reeve, 1992). While the effect of response complexity on RT has been shown to depend on knowledge of the number of segments prior to stimulus presentation, there has been no systematic investigation of how the one-target advantage in movement time is influenced by the availability of advance information of the number of segments to be performed.

Since the work of Henry and Rogers (1960), several studies have shown that RT increases as the number of elements or the complexity of the task increases. However, this relationship between RT and response complexity has been shown to be contingent on participants having advance information on the number of elements in a sequence. Using morse code responses, Klapp (1995) showed that reaction time was greater for a four- compared to a single-element response under simple but not choice reaction time conditions. Klapp (2003) replicated these findings using speech articulation while also demonstrating that reaction time was influenced by the number of syllables when participants were informed of the number of syllables in advance but not other features of the response. The findings of Klapp (1995, 2003) have also been extended to sequential aiming movements. Khan and colleagues (Khan, Lawrence, Buckolz, & Franks, 2006; Khan, Mourton, Buckolz, & Franks, 2008) have shown that RT increased as a function of the number of targets in a sequence, only when the number of targets was specified in advance of the stimulus. RT was greater for two- compared to one-target responses when both the amplitude and the number of targets were specified before the stimulus and when only the number of targets was known in advance.

In addition to these effects on RT, movement time to the first target

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has been shown to be greater for multiple-segment sequences compared to single-segment movements (Adam et al., 2000). Theoretically, the one-target advantage has been explained by the movement integration hypothesis and the movement constraint hypothesis (Adam et al., 1995; Adam et al., 2000; Fischman & Reeve, 1992; Khan, Sarteep, Mottram, Lawrence, & Adam, 2011). The movement integration hypothesis states that movement segments are programmed and loaded into a "buffer" before the initiation of the response (Adam et al., 2000). For the transition between movement segments to be as smooth as possible, the implementation of the second segment is thought to be performed while the execution of the first segment is taking place (i.e., online). This overlap of processes is said to cause interference, resulting in longer movement times (MTs) to the first target (Adam et al., 2000). In contrast, the movement constraint hypothesis is based on the premise that variability at the proceeding targets increases as the movement progresses. Hence, to meet accuracy demands at the second target, the movement towards the first target must be constrained (Fischman & Reeve, 1992). Reducing variability at the first target is achieved at the expense of an increase in duration of the first movement segment (Fischman & Reeve, 1992).

According to both the movement integration and movement constraint hypotheses, movement segments are not controlled or prepared separately and instead share a functional dependence (Adam et al., 1995; Khan et al., 2011; Rand, Alberts, Stelmach, & Bloedel, 1997; Rand & Stelmach, 2000). For movements involving a reversal in direction at the first target, the nature of the integration between movement segments is more at the peripheral level whereby the antagonist muscles that decelerate the first movement also act as the agonist accelerating the second movement. In these cases, a two-target advantage may occur in which movement times to the first target are shorter for two- compared to single-segment responses (Adam et al., 2000).

In a series of experiments employing reversal movements, Khan et al. (2006) showed that the two-target advantage in movement time emerged for both simple and choice RT conditions. However, the difference in movement time to the first target between the single- and two-segment movements was less when participants knew the number of segments in advance (i.e. simple RT). Also, when participants knew in advance that a two-segment response was required, the presentation of a secondary probe RT task during movement execution resulted in a significant loss of accuracy at the first target. Khan et al. suggested that when participants knew the number of movement segments prior to the stimulus, there was a greater demand on the cognitive system during movement execution. This increased demand on the cognitive system was attributed to using visual feedback to implement the second segment during the first. This process was thought to explain increases in movement times to the first target in the reversal movements only when the number of segments was specified in advance (see also Khan, Mourton, et al., 2008). Because Khan et al. (2006) only employed reversal movements, the question remains as to whether the one-target advantage that has been observed for extension movements (i.e., when both movement segments in the same direction) materializes only if the number of movement segments is known in advance.

According to the movement integration hypothesis, the two movement segments are loaded into a buffer prior to response initiation. The implementation of the second segment during the execution of the first causes interference and hence the one-target advantage (e.g., Adam et al., 2000). Thus, the movement integration hypothesis would imply that advance knowledge of the number of segments is needed for the one-target advantage to emerge. However, because one-target advantage studies have typically employed blocked trial paradigms, it is unclear whether the number of targets must be known in advance of the imperative (i.e., "go") stimulus presentation (i.e., prior to the RT interval) for the one-target advantage to emerge. Similarly, along the lines of the movement constraint hypothesis, it is not clear whether processes prior to (i.e., programming) and/or during movement execution (i.e., online control) are responsible for constraining the movement at the first target. Therefore, an important consideration for the one-target advantage literature is the influence of trial ordering/sequencing effects on the planning and execution of the one- and two-segment movements, which may also be influenced by the repetition vs. non-repetition of a movement from one trial to another.

When performing a voluntary movement, the preparation and organization of the motor response may be facilitated if the movement is the same as on the preceding trial. Indeed, there may be a benefit in having to reproduce the same movement compared to preparing and organizing a different movement (e.g., Fischman & Lim, 1991; Rosenbaum & Jorgensen, 1992; Rosenbaum, Weber, Hazelett, & Hindorff, 1986). For instance, Rosenbaum and Jorgensen (1992) had participants touch one end of a dowel (i.e., black or white end) to a corresponding number located on the edge of a shelf on a 14-shelf bookcase. When the task was performed top-to-bottom or bottom-to-top of the bookcase, the participants' grasping orientation (i.e., thumb-up vs. thumb-down) was influenced by the previous trial. Rosenbaum and Jorgensen (1992) argued that it was more cost effective to perform the same grasp that was performed on the previous trial. Such an inter-trial influence could also be explained by a visual and/or proprioceptive reference arising from the previous trial (see also Cheng, Luis, & Tremblay, 2008; Cheng, Manson, Kennedy, & Tremblay, 2013; Whitwell, Lambert, & Goodale, 2008; Zelaznik, Hawkins, & Kisselburgh, 1983). Altogether, even when the number of movement segments is known, it is possible that the repetition vs. alternation of the number of segments can facilitate vs. impede the preparation of a movement, which in turn could have an impact on the emergence of the one-target advantage.

To investigate both the influence of the knowledge of the number of segments as well as the inter-trial influence on the one-target advantage, the current study employed blocked, alternate and random trial sequences with one- and two-segment extension movements. First, the blocked, alternate, and random sequences were employed to test if the presence of the one-target advantage, depends on knowledge of the number of segments in advance of the imperative stimulus. If the one-target advantage is contingent on prior knowledge of the number of segments (i.e., the predictability factor), then the one-target advantage should emerge during the blocked and alternate conditions but not the random condition. This finding would imply that the integration of segments during movement execution is dependent on planning processes prior to the RT interval, thus demonstrating interdependency between preplanning and online processes. In contrast, if the one-target advantage emerges across all sequencing conditions, such results would represent evidence that the implementation of the second segment during the first is not contingent on processes prior to the imperative stimulus. Second, the results of the blocked and alternate sequences were contrasted to investigate the inter-trial influence on how the planning and execution processes on a trial influence the same processes on the next trial. If the inter-trial influences (i.e., repetition) have a significant impact on the preparation and integration of multiple segments, evidence of the processes underlying the one-target advantage would emerge in the blocked compared to the alternate condition. These findings would have implications for both the movement integration and movement constraint hypotheses. Following from the assumptions underlying the movement integration hypothesis, the specific roles of advance information and repetition on the construction and execution of integrated movement sequences would be delineated.

2. Methods

2.1. Participants

Twenty-four students from the University of Windsor volunteered to participate in the study (male = 16; female = 8; M = 24 yrs, range = 20–28 yrs,). All participants were self-declared right-hand dominant and had normal to corrected-to-normal vision. Each participant signed a consent form before taking part and the study was approved by the Research Ethics Board at the University of Windsor.