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IMPOSING DEMANDS ON PRECISION INFLUENCES THE HANDS DIFFERENTLY DURING ALTERNATED DISCRETE TOUCHING

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ABSTRACT
Purpose. How demands of precision influence the performance during alternated discrete touching is not well established in the literature. Hence, we compared both hands performance during alternated touching, manipulating the precision demand.
Methods. Overall, 23 right-handed adults participated in this study. The first task consisted of alternated touching with a pencil on both sides of a blank paper, performing as fast as possible, considering the first touch as reference for the next ones. Subsequently, touch dispersion and width were measured, and circular targets were drawn with those proportions. The second task consisted of performing as many hits as possible inside those targets. Apart from the delimitated target, increasing precision demand, the task parameters were equal.
Results. Movement time increased and the number of touches decreased from the first to the second task. However, the preferred hand displayed greater reductions in performance.
Conclusions. The perceptual constraint of adding a visual target affects motor control parameters in alternated touching, causing decrements in performance in both hands, but more evidently in the preferred right hand.
Key words: motor control, handedness, asymmetry, speed-accuracy trade-off

Introduction

The speed-accuracy trade-off paradigm has been tested in different contexts and tasks, and strong support has been found in its formulation (e.g., Elliott et al. [1] for a review) since Woodworth [2] and Fitts [3]. Higher movement speed leads to impaired accuracy, while higher accuracy leads to impaired speed. Previous studies have manipulated task parameters during alternated discrete touching, such as target distance and width, and investigated the characteristics of movement control in this task [4, 5]. However, perception may play an important role within this paradigm.

Perception has been defined as the interpretation and attribution of meaning to a given stimulus. It is a cognitive process involving various aspects of the central nervous system and higher-order thinking mediated by many cortical regions [6]. As such, some research has shown that visual perception affects motor responses [7, 8]. In the speed-accuracy paradigm, perception manipulations can involve visual layout changes and/or target illusions, in which both can alter performance or movement control parameters (such as precision and movement speed) during alternated discrete touching [8–10]. From the notion that motor behaviour emerges as a product of the interaction between the individual, the task, and the environment [11], the ecological dynamics approach could be applied to understand modifications in performance imposed by distinct perceptual manipulations. These modifications in task parameters can interfere in the movement system, leading to a change in the coordinative state of control [12], as the motor system fluctuates toward the most stable pattern of coordination given the novel task demands [13].

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Another way of manipulating perception within the speed-accuracy trade-off paradigm is the following: initially, participants are asked to perform alternated touches in a blank space; secondly, the touch dispersion is measured to create targets of the same diameter as those virtually produced in the first task. Applying this manipulation, previous investigation has already demonstrated that performance decreases regarding movement speed in the target condition, also affecting movement control by means of increasing the number of sub-movements [14]. This result suggests that, indeed, the affordances (i.e., a clue that the environment offers to the individual [12]) provided by the drawn target can interfere in motor performance. However, in Carlton's research [14], only 5 participants were tested with the preferred hand, leaving the question open as to whether this manipulation could influence (or not) the non-preferred hand.

Within this scenario, handedness is an essential factor that affects motor responses [15], as each hand can be considered as a different effector within the same individual, which interacts differently with the constraints imposed by a given motor task. For instance, Vaughan et al. [16] analysed the impact of handedness during alternated discrete touching with a stylus in 2 side-by-side targets, aiming to perform as many touches as possible while still being accurate. These authors verified that responses with the preferred right hand were faster and more accurate, occurring in shorter movement time for tasks of similar difficulty, just as Woodworth [2] had presented long ago. Performance asymmetries and differences in movement control between hemispheres, therefore, can be key-points to understand underlying mechanisms involving perception and handedness interactions.

The preferred hand has been associated with greater control of intersegmental dynamics in predictive environment, better accounting for interaction torques during multi-joint movements [17, 18]. The non-preferred hand, however, is associated with greater stabilizing capacity, especially during conditions of unpredicted perturbation [18, 19]. Hence, in alternated touching, the preferred hand has clear advantages given the dynamic constraints of the task, likely being able to better coordinate the movement parameters to perform an increased number of successful touches. In this context, the same constraint applied in a task could selectively influence the performance of each hand, given the specific interaction of task constraints and the effector [11] (i.e., right vs. left hand). These pieces of evidence suggest that hemispheric function specialization can lead to performance differences between hands in a variety of motor tasks. Considering that manipulating the demand of precision by the available visual information can affect movement parameters [8] and that each hand has specific neural asymmetries in motor control [18], our experimental approach is relevant to understand how changes in the visual stimulus of a target can impact on motor control in both the preferred and non-preferred hand.

In the present study, we aimed to analyse the effect of manipulating the demand of precision by adding the visual information of a target during the performance of alternated discrete touching with both hands. We hypothesized that: (H_1) manipulating the demand of precision, by drawing a target in the alternated touching task, would impair both hands performance; (H_2) there would be a more significant adverse effect on the performance of the preferred hand, since this hemisphere might greatly consider environmental clues (i.e., drawn target) to specify movement parameters. This research contributes to understanding how the demand of precision influences motor control during alternated discrete touching, also providing information on distinct motor control processes operating within the mediating contralateral dominant and non-dominant cerebral hemispheres.

Material and methods

Participants

A priori power analysis for the Wilcoxon signed-rank test was conducted in G*Power to determine a sufficient sample size by using an alpha of 0.05, a power of 0.80, a medium effect size ($dz = 0.55$), and one tail [20]. On the basis of the aforementioned assumptions, the desired sample size equalled 23.

A total of 23 right-handed participants, in accordance with the Global Lateral Preference Inventory [21], comprised a convenience sample for this study (M age = 28.9 years, $SD = 13$; 10 women, 13 men). Prior to data acquisition, the task parameters and conditions were explained, without providing details on the specific aims and manipulations to be performed.

Task and demand of precision manipulation

In the adapted Fitts task employed, the participants performed repeated discrete pencil (length: 16.5 cm, weight: 5.5 g) touches on each side of a paper (A-4 size). The paper was fixed in front of the participant, who sat in a height-adjustable chair. The task time (20 s) was controlled by a digital chronometer in all trials.

The participants performed the following experimental conditions: (a) no target right hand (NT-RH), (b) no target left hand (NT-LH), (c) visual target right hand (T-RH), and (d) visual target left hand (T-LH). Only the hand performing the initial trial was randomized between subjects, as no-target conditions were always performed first.

In the no-target condition, standardized instructions were to perform as many touches as possible on each side of the paper (separated by a midline). The participants were free to touch the paper with the pencil wherever they wished, with the only constraint that they should use their first touch as the reference for the next ones, during the 20-s trial. This procedure was selected for 2 reasons: (1) to assure that the performance of the alternated touching was as fast and as accurate as possible, and (2) because we intended to allow the participant to choose a preferred distance between the targets. Moreover, delimiting a specific distance would possibly create an internal constraint related to where the touches should be directed at, which could influence the demand of precision. The task was performed with both hands.

Subsequently, 2 measures were taken from the no-target condition to draw circular targets for the target condition: the smallest distance between a left and a right-side point, and the greatest distance between 2 points in the same side. These measures allowed experimenters to draw 2 circular targets that were the same distance apart from each other as the touches performed in the no-target condition, as well as targets with the same diameter as the touch dispersion performed in the no-target condition. This procedure was performed individually, producing unique target settings for each participant. With this measuring approach, the differences in performance between the no-target and the target conditions can be interpreted as solely caused by the effect of the perceived target – since the area available for touching was equal in size to the dispersion produced in the no-target condition. Then, the subjects performed the target conditions, with both hands, following the same instructions as in the previous condition (to perform hits as fast and as accurately as possible during the 20-s trial). Figure 1 illustrates the experimental procedures performed to set each target between conditions. When the participants finished the no-target condition, they were instructed to wait outside of the room while the target condition was being prepared. The subjects had a 2-minute rest between hands and conditions.

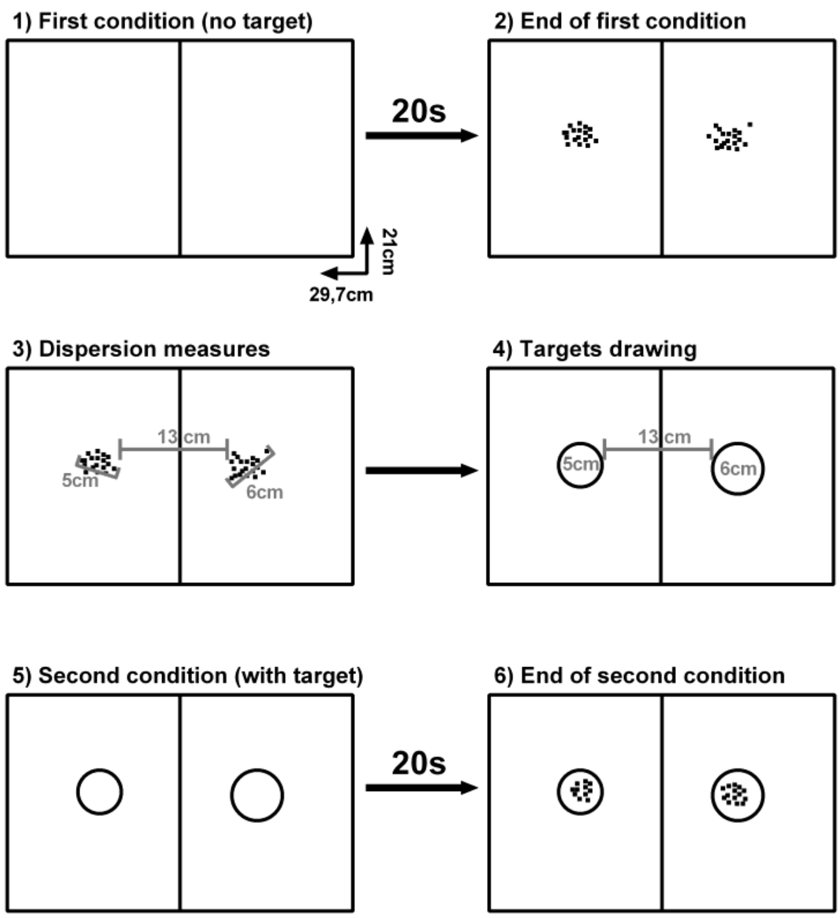


Figure 1. Experimental procedures

Hence, from one condition to the other, besides performing with both hands, the participants underwent a manipulation that increased the demand of precision, keeping all task parameters the same, except for the visual perception constraint created by the drawn target. The individuals had visual feedback on their performance throughout the entire protocol. In both conditions, instructions were given to ensure no focus on either speed or accuracy was prioritized.

Data acquisition and statistical analysis

To precisely compute the number of successful touches (ST), we recorded trials with an iPhone 6s at 60 Hz (Apple, Inc.). Two researchers viewed the videos at 1/4 the original speed, and each researcher counted the number of ST twice (all touches were considered successful in the no-target condition, while only the ones inside the target were considered successful in the target condition). No cases of divergent results in the counting happened. The participants performed the task sitting comfortably in a height-adjustable chair, in a quiet and well-illuminated room.

The distance measures presented in Figure 1 were acquired by using a rigid metric tape with a precision of 1 mm. Targets were further manually drawn with the assistance of a compass and checked by 2 researchers to assure measurement precision. We computed the following variables: the number of ST and total touches (TT), movement time (MT) $\left(\frac{20s}{TT}\right)$, target distance and width (Figure 1), and index of difficulty (ID), representing the rate of information processing in bits, in accordance with the Fitts equation: $\log_2\left(\frac{2d}{w}\right)$. Additionally, we calculated percentage performance differences $\left(\left(\frac{(Tperformance * 100)}{NT_{performance}}\right) - 100\right)$ for ST and MT between the no-target and target conditions in order to compare the effect of the increased demand of precision in each hand.

Normality and sphericity were not verified by the Shapiro-Wilk or Mauchly's tests, so we presented data as median and interquartile range. Comparisons between ST and MT in each condition were performed with Friedman's test, followed by the Wilcoxon signed-rank test when necessary. Significance correction was performed in the Wilcoxon test and set at $p < 0.025$. Considering that distance and target width were not the same between right and left hand, comparing ST and MT between hands would not be appropriate.

Aiming to understand in which hemisphere the demand of precision exerts greater influence in movement control parameters, we compared the percentage performance difference of each hand using the Wilcoxon test. IDs, target distance, and width were also compared between hands with the Wilcoxon test. Effect sizes for all the Wilcoxon tests were calculated by dividing the Z value by the square root of n (number of observations over both time points) [22] and interpreted in accordance with Cohen [23]. To check if males and females did not differ in their performance, the Mann-Whitney U test was conducted to compare their results. All data were processed in SPSS (v. 23, IBM Statistics) and, except when differently specified, the significance was set at $p < 0.05$.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional Ethics Committee.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

No performance differences were observed between males and females, for any of the variables analysed ($p > 0.153$; $Z < 1.42$). Table 1 presents comparisons between ST and MT in each experimental condition, as well as comparisons between IDs, target distance, and width between the right and left hand.

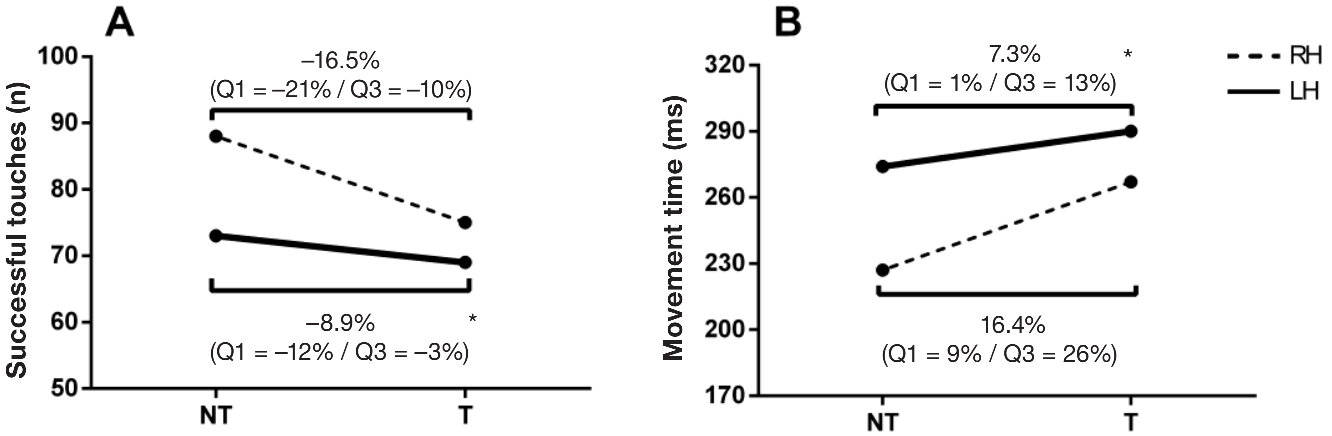
In the condition with targets, performance decreased for both hands. Effect sizes were considered large for the reductions in ST and MT of the right hand ($r = -0.60$) and moderate for the left hand ($r = -0.47$). A greater target size was verified with the non-preferred left hand, with a moderate effect size ($r = -0.46$), while the other variables did not differ significantly. The number of unsuccessful touches (out of the target area) was not significantly different between hands (right hand: 1, Q1 = 0, Q3 = 2; left hand: 1, Q1 = 0, Q3 = 2; $p = 0.55$; $Z = -0.60$). Figure 2 presents the amount of ST and average MT in both hands and conditions, as well as the performance percentage differences in ST and MT.

The percentage difference was significantly higher for the right hand in both variables, with large effect sizes ($r = -0.53$), which means that the preferred hand performance was proportionally more affected by the demand of precision compared with the non-preferred hand.

Table 1. Comparisons of successful touches, movement time, index of difficulty, distance, and target width in each experimental condition

	NT-RH	NT-LH	T-RH	T-LH	X^2	p
	Median (Q1–Q3)	Median (Q1–Q3)	Median (Q1–Q3)	Median (Q1–Q3)		
ST	88 (78–97)	73 (69–82)	75 (65–82)[a]	69 (59–75)[b]	52.3	< 0.01
MT (ms)	227 (206–255)	274 (244–290)	267 (231–303)[a]	290 (261–326)[b]	44.8	< 0.01
					Z	
		ID	2.20 (2.07–2.68)	2.16 (1.67–2.54)	–1.76	0.078
		Distance (cm)	6 (4.5–9.9)	7.5 (4.8–9.8)	–0.75	0.456
		Width (cm)	2.6 (2.1–3.4)	3.1 (2.4–4.1)	–3.13	0.002

NT – no target, T – with target, RH – right hand, LH – left hand, Q1 – first quartile, Q3 – third quartile, ST – successful touches, MT – movement time, ID – index of difficulty
[a] $p < 0.01$ vs. NT-RH ($Z = -4.10$), [b] $p < 0.01$ vs. NT-LH ($Z = -3.15$)
Significance in Wilcoxon comparisons was corrected to $p < 0.025$.



n – number of touches, NT – no target, T – with target, RH – right hand, LH – left hand, Q1 – first quartile, Q3 – third quartile
* $p < 0.05$ vs. RH ($Z = -3.62$)

Figure 2. Percentage difference in successful touches (A) and movement time (B) between hands in each condition

Discussion

The main result of this study was a reduction in ST and an increase in MT when a visual perception constraint was added to the task, which increased the demand of precision. The drawn target manipulation affected proportionally more the preferred hand performance. Thus, both initial hypotheses were confirmed. The findings imply that how the targets are built and perceived in alternated touching can provide different strategies to control accuracy and speed. Indeed, the trade-off between speed and accuracy is one of the most consistent paradigms in motor behaviour. Speed might be diminished at the cost of increased accuracy and vice-versa, depending on the task constraints. The following factors are known to influence performance during alternated discrete touching: time available for feedback information [2, 24], control of acceleration and deceleration movement phases [25], limited capacity of information processing in the central nervous system [3, 26], variability in the motor output [27], and parametrization of movement control [28]. In line with these previous investigations, our results advance with the speed-accuracy trade-off paradigm by verifying the influence of the demand of precision in alternated touching.

The performance losses in the target condition are consistent with previous research analysing perception effects on motor tasks [8–10]. Applying a very similar protocol, Carlton [14] revealed that MT was, on average, 22.7% slower in the condition with a delimited target, which is very similar to our observed 19.7% value (Figure 2, panel B, average value for RH). Both these results refer to the preferred hand performance, indicating a consistent finding regarding how much of movement speed can be compromised when a target is delimited with previous dots displacement. Similarly, Skewes et al. [9] manipulated perception in a discrete touching task, using same-size targets with a visual illusion that made them look different. These authors verified that bigger target perceptions led to higher amounts of ST, highlighting the impact of perception on motor control. The similarity to our experimental approach and results lies in the fact that our participants judged the target to be bigger in the first condition (without any target), leading to performance impairments when target perception suggested a smaller area to touch.

From a theoretical standpoint, the ecological dynamics approach poses that the perception-action cycle is influenced by a constant interaction between 3 factors: the individual, the environment, and the task constraints [11]. Within this perspective, performance differences between the experimental conditions were expected, as the addition of the target imposes an additional constraint on movement control. According to Carlton [14], the condition with a target requires the individual to divide their attention into both the spatial and the temporal monitoring of the task – leading to a less efficient use of visual feedback [29], which explains the performance loss. It is also worth noting that, in the current investigation, all participants used the entire virtual target area in the target condition, which provided trials with equivalent movement distance and spatial accuracy demands. Hence, it is safe to conjecture that the performance differences are primarily attributed to the increased precision demand perceived by the participant.

Regarding the preferred and non-preferred hand performances, our results also agree with prior research by Woodworth [2], Todor and Doane [30], and Vaughan et al. [16], by verifying greater precision and speed for the preferred hand on similar IDs. Although task parameters slightly varied between hands, hampering between-hand comparisons, there was a clear performance superiority with the preferred hand (more ST and faster MT). Previous research has suggested distinct control forms between the 2 hemispheres of the brain, noting linear trajectory advantages and better dynamic movement control for the preferred hand [19]. These control asymmetries relate to our findings because of the dynamic nature of the alternated touching task. Hence, the preferred right hand was expected to perform better given its increase capacity to coordinate movement parameters.

How each hand was differently impacted on by the precision manipulation performed in the present research also fits within the ecological dynamics framework. Considering that the effectors are different (right vs. left hand), the interaction with the task constraint is also modified within the perception-action cycle. As such, it seems that the drawn target can be considered as an affordance [12], with a stronger influence in the right hand, causing it to fluctuate towards a proportionally slower state of stability within the alternated touching coordinative movement pattern. Further supporting our findings, the dynamic dominance model, proposed by Sainburg [18], can also aid the interpretation of our results. According to the model, the left cerebral hemisphere is specialized in the dynamic aspects of motor control, such as intersegmental coordination and torque interactions during multi-joint movements. Hence, we speculate that the parameters specified by the increased demand of precision (drawn target) are mostly used to control movement dynamics and coordination, thus greatly affecting the preferred hemisphere performance. Contrarily, the right cerebral hemisphere, specialized in impedance control (stabilizing and positioning capacity), might not use perceptual visual clues as a major affordance related to the control pathway specifying movement parameters. Taken together, this theoretical background explains why the same manipulation could produce distinct results in each hand.

Some limitations, however, should be noted. While our behavioural data do not allow a confirmation of this explanation, this theoretical approach fits the current literature and explains the relatively higher performance loss, from one experimental condition to the other, in the preferred hand. Using a pen on a blank sheet of paper allows a condition without target only in the initial part of the task, as further dot placements create a supposed target reference. Applying this protocol in a digitalized manner, with additional kinematic measures in both right- and left-handed participants, would also provide further information on the topic.

Conclusions

Imposing demands of precision, by adding a circular target to the alternated touching task, reduces the number of ST and increases MT. Possibly, the perceptual constraint of a visual target affects motor control parameters, thus causing the decrements in performance. We also conclude that this manipulation has a superior influence on the right hand, likely owing to the left cerebral hemisphere specificity in dynamic control, which may be more prone to use environmental clues to set movement parameters. These results add to the literature of motor control, enhancing the comprehension of precision demands during alternated discrete touching.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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