Video Article

The "Motor" in Implicit Motor Sequence Learning: A Foot-stepping Serial Reaction Time Task

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Abstract

This protocol describes a modified serial reaction time (SRT) task used to study implicit motor sequence learning. Unlike the classic SRT task that involves finger-pressing movements while sitting, the modified SRT task requires participants to step with both feet while maintaining a standing posture. This stepping task necessitates whole body actions that impose postural challenges. The foot-stepping task complements the classic SRT task in several ways. The foot-stepping SRT task is a better proxy for the daily activities that require ongoing postural control, and thus may help us better understand sequence learning in real-life situations. In addition, response time serves as an indicator of sequence learning in the classic SRT task, but it is unclear whether response time, reaction time (RT) representing mental process, or movement time (MT) reflecting the movement itself, is a key player in motor sequence learning. The foot-stepping SRT task allows researchers to disentangle response time into RT and MT, which may clarify how motor planning and movement execution are involved in sequence learning. Lastly, postural control and cognition are interactively related, but little is known about how postural control interacts with learning motor sequences. With a motion capture system, the movement of the whole body (*e.g.*, the center of mass (COM)) can be recorded. Such measures allow us to reveal the dynamic processes underlying discrete responses measured by RT and MT, and may aid in elucidating the relationship between postural control and the explicit and implicit processes involved in sequence learning. Details of the experimental set-up, procedure, and data processing are described. The representative data are adopted from one of our previous studies. Results are related to response time, RT, and MT, as well as the relationship between the anticipatory postural response and the explicit processes involved in implicit motor sequence learning.

Video Link

The video component of this article can be found at https://www.jove.com/video/56483/

Introduction

Implicit motor sequence learning, generally known as learning a sequence without knowing the sequence, is critical to our daily activities and has been well studied by a paradigmatic task named the serial reaction time (SRT) task designed by Nissen and Bullemer[1]. In this classic SRT task, participants press keys to respond quickly and accurately to visual stimuli. To examine sequence learning, the appearance of visual stimuli is manipulated to follow either a pre-structured or random sequence, which is unknown to participants. Learning is evidenced by the faster response time to the pre-structured sequence (*e.g.*, the training sequence) than that to the random or another pre-structured sequence[1,2]. While the classic SRT task typically requires bi-manual finger tapping, a vast majority of implicit motor sequence learning in everyday activities, such as dancing, playing musical instruments, or playing sports, involves whole body actions that present postural and inertial challenges not found in the classic SRT task. Thus, we proposed that sequence learning tasks need to be more multifaceted. In addition, the focus of the previous research has been almost exclusively on the cognitive component of the task (*e.g.*, decision making or action selection), ignoring the motor control issues involved in sequence learning (*e.g.*, movement execution). Thus, to further understand implicit motor sequence learning, it is essential to study sequence learning in a whole-body or gross motor task that better approximates our daily motor activities.

In our recent studies, we extended the classic SRT task to a modified SRT task where finger pressing was replaced by foot stepping to incorporate postural control into sequence learning[3,4,5]. This modified task presents its own advantages to complement the classic SRT task. First, the gross motor sequence learning task better mimics daily sequential activities where whole-body movement is involved. To date, our understanding of motor sequence learning typically comes from the classic SRT task, but little is known whether the knowledge of motor sequence learning from the classic SRT task remains to be true in learning sequential motor skills in daily activities. Thus, the modified SRT task allows us to examine whether the systematically reported characteristics (*e.g.*, age-independent implicit sequence learning between children and adults) in the finger-pressing SRT task remain when postural control is involved. Additionally, in populations with posture control and gross motor skill learning difficulties, such as children with developmental coordination disorder[6,7,8], understanding how posture control interacts with gross

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motor sequence learning is critical to help improve intervention strategies, and thus optimize the effectiveness of learning sequential motor skills in daily life.

Second, a common notion about implicit sequence learning is that motor planning, and not movement execution, plays an important role in learning a sequence in the classic SRT task[9]. This is because pressing keys does not involve moving to new locations in space, as the fingers are always on the response keys. However, many daily sequential behaviors involve large spatial movements. Little is known as to whether movement execution is a key player in motor sequence learning when large spatial movements are required. In the classic SRT task, response time, the summation of reaction time (RT) and movement time (MT), serves as an indicator of sequence learning. The foot-stepping SRT task, like other paradigms involving spatial movements[10], allows the researcher to disentangle response time in implicit sequence learning into RT, which reflects cognitive processing, and MT, which characterizes the movement itself.

Third, in addition to MT, the combination of the foot-stepping SRT task and motion capture techniques provides rich data on the continuous whole-body movement (*e.g.*, movement of the center of mass, or COM). Measuring the continuous change of movement has the advantage of revealing the dynamics of the cognitive processes underlying the discrete response measured by RT or MT[11,12]. In particular, learning sequences in the SRT task are typically explained as a mixture of explicit and implicit processes. That is, despite the common use of the SRT task as an implicit learning task, participants often show the capability to verbally recall the learned sequence after the SRT task, suggesting an explicit component involved in implicit sequence learning. Although the explicit component can be assessed by recall tests conducted after the SRT task[13,14], these post-task tests lack the ability to examine the temporal evolution of explicit knowledge during learning. We propose that with explicit sequence knowledge, an individual would know the location of the next stimulus, and thus produce anticipatory postural adjustment[15,16,17] in a feedforward manner to prepare for the stepping foot to move to the corresponding target. Therefore, examining the movement of the COM before the stimulus appearance (*i.e.*, anticipation) opens a window to studying the progressive development of explicit memory during implicit sequence learning.

The protocol demonstrates the experimental set-up and procedure of the foot-stepping SRT task. We provide representative results of response time, RT, and MT. In addition, we present results regarding the relationship between posture control and the explicit processes underlying implicit motor sequence learning.

Protocol

The protocol was performed in accordance with the guidelines approved by the Institutional Review Board at the University of Maryland, College Park.

1. Experimental Set-up

1. Set up a motion capture system as shown in **Figure 1a**. Place eight cameras in a circle with a radius of 4 m.
NOTE: The number and positions of cameras can be varied, provided all cameras are appropriately positioned to obtain a clear vision of all reflective markers attached to a participant's body.
2. Set up a stepping station in the center of the circle. Position a "home position" covered by dark blue felt mats in the center of the stepping station and place six stepping targets covered by light blue felt mats surrounding the home position as its front, back, and side (**Figure 1b**). Determine the distance between the targets and home position, according to an individual's stepping distance (see step 3 in the foot-stepping SRT task procedure).
3. To control the task pacing condition, place two electric rubber sensors, which generate analog signals when touched, under the home position to detect the time when the feet return.
4. Position a 23" monitor 2 m in front of the home position. The six visual stimuli are spatially matched with those six stepping targets on the floor.
5. Control the appearance order of the visual stimuli using a computer program installed in a laptop.
6. Synchronize the laptop and the motion capture system using a data output and acquisition device.
7. Turn on the motion capture cameras, and aim them so that each camera can view the volume surrounding the stepping station.
8. Identify whether there are unwanted reflective objects from the capture volume (*e.g.*, reflection from light, floor, or any reflective materials). Cover these identified reflective objects with fabric material, so that they are not mistakenly collected as data during experimental trials.
9. Using the instructions and equipment supplied with the motion capture system, calibrate the motion capture system to ensure accurate collection of 3-D data from reflective markers[18].
10. For dynamic calibration, wave the calibration wand supplied with the motion capture system through the space where all reflective markers would move when participants perform the SRT task. Collect 2,000 frames of imaging data for dynamic calibration.
11. For static calibration, place the calibration wand on the floor with a position and orientation which can be used as the origin of the coordination system of the motion capture system. Run the motion capture system to set the origin.
12. Design a marker set depending on the purpose of study.
NOTE: One example is shown in **Figure 1b** where a 38-marker set-up is used.
13. Follow the vendor-supplied instructions to create a labeling skeleton template that can be used for reconstruction and auto-labelling in later data acquisition and processing[18]. Specifically, ask a participant to stand on the home position of the stepping station with all markers attached. Instruct the participant to stand as still as possible and make sure all markers are visible through the motion capture system. Capture a trial (lasting about 10 s). In the motion capture system, assign each marker a name and create segments by connecting markers together. Link all segments to finalize the skeleton template (shown in **Figure 1c**).

2. Participant Preparation

1. Inform participants to wear appropriate attire (*e.g.*, shorts and a t-shirt) before visiting the lab.
2. Upon arrival, ask participants to carefully read and sign the consent form. Screen for study eligibility.

NOTE: The screening questionnaires could be different based on the purpose of each individual study. These questionnaires may include, but are not limited to, the hand dominance questionnaire[19], global physical activity level questionnaire[20], neurological health questionnaire, and the Movement Assessment Battery for Children[21].

3. Ask participants to take off their shoes and socks, then attach 38 spherical reflective markers, each 50 mm in diameter, to the skin at pre-determined significant bony landmarks using double sided, hypo-allergenic adhesive tape and pre-wrapping tape. This marker set-up is the same as the customized skeleton template shown in **Figure 1b**.
4. Clear all unwanted reflections other than those 38 markers from the participant's body (see step 1.8).
5. Instruct participants to stand quietly on the home position in a T-pose. Run the motion capture system to capture all markers for 10 s (*i.e*., the calibration trial).

3. The Foot-stepping SRT Task Procedure

1. Before each participant starts the task, set up the parameters, including, but not limited to: participant ID, group ID, number of learning block, the time length of stimulus presentation, and the time interval between stimuli (ISI) or response-stimulus interval (RSI) that controls the time interval between the completion of movement and the onset of the next stimulus (in this case, electric rubber sensors are needed under the home position; see protocol section 1 for details).
   NOTE: The ISI could be varied (*e.g*., 1,300 ms or 1,000 ms) according to the purpose of the study.
2. Instruct participants to stand on the home position and adjust the distance of the home position so that participants can comfortably step onto all six targets on the floor.
3. Instruct participants to quickly step on each target several times, and mark the distance from the home position to each target at the most comfortable stepping length for each participant.
4. Provide the task instructions to participants.
   1. Instruct participants that once a stimulus appears at one of six locations shown on the monitor, they need to step as quickly and accurately as possible to the corresponding target on the floor and then return to the home position.
   2. Ask participants to step with the right foot to the three targets located on the right side (*i.e*., targets 1, 2, and 6; **Figure 1a**), and the left foot to the other three targets (*i.e*., targets 3, 4, and 5; **Figure 1a**).
      NOTE: The numbers are invisible to participants during the entire task.
   3. Inform participants that there is a 3 min break after each run (*i.e*., learning block) of the task. Modify the length of the break based on experimental needs. Set a time alarm to remind participants of the end of the break.
   4. Instruct participants to keep their elbows by their side and bent at a ninety-degree angle when they perform the task so that the cameras can see the markers placed on the hip.

5. Run a practice block that consists of 36 steps (*i.e*., stimuli appear 36 times with a ISI of 1,300 ms; see the foot-stepping SRT task procedure for details) so that participants are familiar with the task. Instruct participants that stimuli will continuously appear at one of six locations and they need to respond to stimuli as fast and accurately as they can. Stimuli in this block appear in a random order.
   NOTE: The ISI could be replaced by an RSI (see the foot-stepping SRT task procedure for details). If a very short ISI is used, participants may not be able to respond to some stimuli. These steps are considered errors.
6. After the practice block, start the experimental blocks. In this protocol, there are six blocks and each experimental block is comprised of 100 steps/stimuli. Give participants a mandatory 3 min break after each block.
   NOTE: Under the 1,300 ms ISI condition, each block typically takes about 2.5 min. If a RSI is used, the length of each block may vary depending on how fast participants respond to stimuli.
   1. Instruct participants to complete six experimental blocks. Set the specific order of visual stimuli according to experimental purposes. Stimuli follow either a specified or random sequence. The presentation of stimulus order is unknown to participants.
      NOTE: The number of experimental blocks could vary. Here, a 6-block design is introduced where a specified sequence A is given in blocks 1 - 4 and 6 and a novel sequence B is presented in block 5. The specific and random sequence could also be varied. In this protocol, sequence A follows the order of 1423564215 (*i.e*., 1 - right side, 2 - right front, 3 - left front, 4 - left side, 5 - left back, and 6 - right back) and sequence B follows the order of 3615425214.
   2. Before each learning block, instruct participants to response to stimuli as quickly and accurately as they can.

7. Upon the completion of all learning blocks, ask participants to complete a posttest that consists of widely used recall and recognition tests described in the literature[13,14,22].

4. Data Processing and Statistical Analysis

1. For each participant, open collected data trials in the motion capture system software. Review each trial and fill in any gaps in the trial data according to the vendor-supplied instructions[18].
2. Export each data trial as an ASCII file that contains three coordinates for all 38 markers.
3. Derive variables (*i.e*., reaction time (RT), movement time (MT), response time, and trajectory of the COM) from the ASCII files following steps below:
   1. Input the ASCII data files into data analysis software. Use an eighth-order Butterworth filter with a cutoff frequency of 10 Hz to filter the data[3].
      NOTE: The way to derive the COM movement trajectory depends on the marker set-up. In the 38-marker set-up shown in **Figure 1b**, methods and anthropometric parameters described by De Leva[23] may be employed. One can also track the movement of the approximate COM measured by a marker set at the level of the fifth lumbar vertebra[24].
   2. Derive response time, RT, and MT following the descriptions below:
      1. Use the markers attached on the heels, big toes, and the 5th metatarsals to characterize the trajectories of foot movements in data analysis software.

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2. Plot the trajectory of these three markers along the vertical direction (perpendicular to the floor). Plot the trajectory of the toe marker within the horizontal plane (parallel to the floor) to identify whether each step is correctly performed to the right target. Steps to a wrong target are excluded for later statistical analyses.
3. Mark the baseline of each marker's height before and after each step.
4. Identify the movement onset of each marker as the first sample when the marker reaches 10% of the maximum height.
5. Since each subject may use different strategies to touch the target (using the toes or the 5th metatarsal), define the movement onset using the marker that reaches its peak the earliest.
6. Identifies the end-point of stepping as the time point when the used marker drops to the same height as the onset.
7. Continuously run the data analysis program until 100 steps are processed.
8. For all steps, calculate and output the response time as the temporal difference between the stimulus onset and the end of movement, RT as the temporal difference between the stimulus and movement onsets, and MT as the temporal difference between the movement onset and its end point. Save the output files in the .xls format.
9. Using these .xls files, calculate means of these variables for each block and across participants, data which will subsequently be used for statistical analyses.
10. Since there is typically a within-subject factor (*i.e.*, learning block) in the experimental design, use mixed-effect ANOVAs to analyze data (repeated measures ANOVA could be used with caution regarding the sphericity assumption). Determine the co-variance matrix used in the mixed-effect ANOVA by the Akaike's Information Criterion (AIC). Decompose the significant results from the ANOVA *using post hoc* tests with specific multiple comparison correction procedures (depending on the experimental design). Set the statistical significance level at $p = 0.05$.

Representative Results

The above paradigm is implemented by Du and colleagues in a series of studies[3,4,5]. We use a part of data adopted from one of these studies[4] to represent the usage of the foot-stepping SRT task. In this study, there are 6 learning blocks and a RSI of 700 ms is used. Visual stimuli followed sequence A (*i.e.*, 1423564215; **Figure 1a**) in blocks 1 to 4 and 6, and followed sequence B (*i.e.*, 3615425214) in block 5. The response-stimulus interval is set as 700 ms. **Figure 2a** illustrates 12 young adults' mean response times across six learning blocks. The response time here in the foot-stepping SRT task reveals the same pattern and comparable magnitudes to response time which were previously observed in the classic finger-pressing SRT task[2,25,26]. In particular, response time to a novel sequence is significantly slower in block 5 compared with the learned sequence in block 4 (difference = 83.4 ms ± 13.19, mean ± standard error; $p < 0.001$), indicating learning of the sequence[1,2]. Although sequence learning under finger-pressing and foot-stepping tasks has not been compared directly, the similar magnitude and pattern in response time suggest that implicit motor sequence learning may not be affected by the presence of postural control requirements in typically developed adults.

Figure 2b illustrates two components of response time: RT and MT. Mean RT exhibits the same pattern as response time. In particular, RT in block 5 is slower than that in block 4 (difference = 93.19 ms ± 12.69; $p < 0.001$). Unlike response time and RT, MT is comparable between blocks 4 and 5 (difference = -7.73 ms ± 3.88; $p = 0.072$). The same RT and MT results have been reported in our other studies[3,5]. These results together suggest that sequence learning is most likely to be reflected by RT, a proxy to cognitive processing, rather than MT, which characterizes the movement itself.

Figure 3 and **Figure 4** depict examples of the directions along which the COM moves 100 ms before the stimuli appears. The direction of the COM for each stimulus is very inconsistent at the beginning (*i.e.*, block 1), and these seemingly random movement directions do not change across blocks in one participant (**Figure 3**). For another participant (**Figure 4**), however, these random movement directions become more consistent as learning progressed across blocks. **Figure 5a** shows the significant changes in the movement direction variability across blocks ($F(5,55) = 3.07$, $p < 0.05$). Specifically, the variability increased from block 4 to 5 ($p < 0.05$), indicating that the COM movement direction would be an evident sign of motor sequence learning in the SRT task.

More importantly, the anticipatory center of mass movement is likely to reflect the explicit process operating in implicit motor sequence learning. The increased variability from block 4 to 5 was demonstrated only in participants (n = 6, $p < 0.05$) who acquired, at least partially, the explicit knowledge of the sequence, but not in participants (n = 6, $p = 0.98$) who did not show explicit knowledge; **Figure 5b** highlights this sequence knowledge. Moreover, the change in variability from block 4 to 5 is significantly correlated to the amount of explicit knowledge acquired by participants (**Figure 5c**).

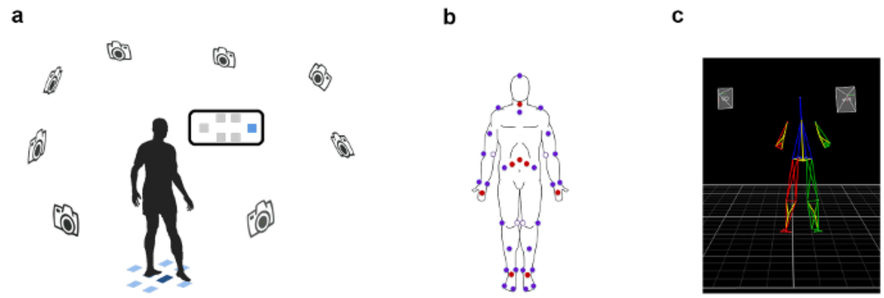

Figure 1: Experimental set-up. (a) Eight cameras are appropriately positioned so that clear data from all markers can be collected. Six stepping targets on the floor correspond to six visual stimuli shown on the monitor. **(b)** 38 spherical reflective markers of a 0.5 cm diameter each are attached on the skin at significant bony landmarks. These bony landmarks include the vertex, 7th cervical vertebra, sternal notch, acromions, elbows (lateral and medial), upper arms, wrists (radial and ulnar), 3rd knuckles, anterior superior iliac spines (ASIS), posterior superior iliac spines (PSIS), center between two PSISs, knees (lateral and medial), tibias, ankles (lateral and medial), calcaneus, big toes, and 5th metatarsals. Purple markers: markers visible from the front view; red markers: markers on the back; white markers: markers removed after the static trial. **(c)** A skeleton template based on the set-up of 38 markers. Please click here to view a larger version of this figure.

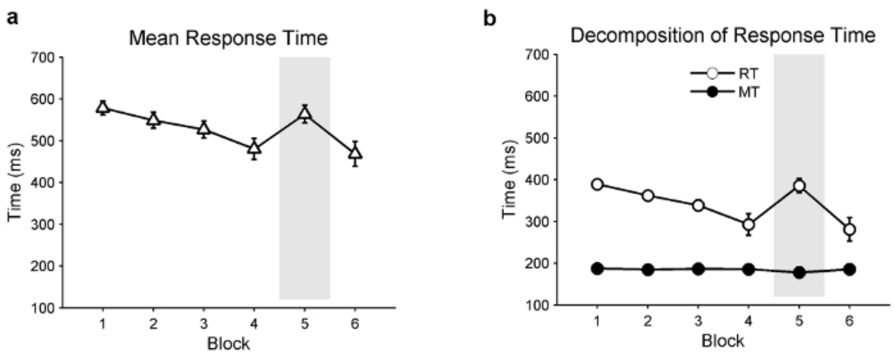

Figure 2: The decomposition of response time into RT and MT. (a) The mean response times across blocks. The gray area represents block 5 where the appearance of stimuli follows a novel sequence. Sequence learning occurs as revealed by a slower response time in block 5 than that in block 4. **(b)** RT, as a component of response time, exhibits the same pattern as response time, while MT does not change from block 4 to block 5. Error bar: Standard error of the mean. Please click here to view a larger version of this figure.

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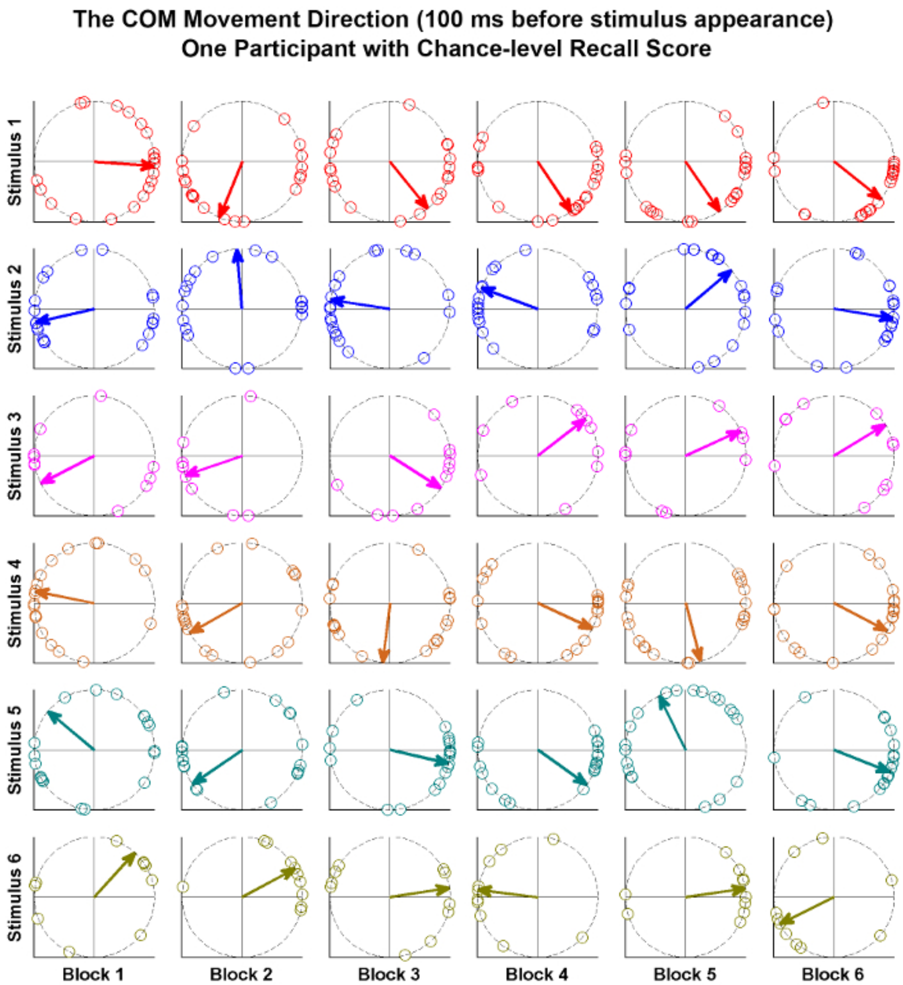

Figure 3: The COM movement direction from one participant with no explicit sequence knowledge. The COM movement direction is shown for each stimulus (stimuli 1- 6, see **Figure 1a**) across blocks. The COM could move from the origin to any position on the dashed circle, which represents all directions the COM could move. Empty circles represent the observed directions. The solid arrow represents the mean direction. Please click here to view a larger version of this figure.

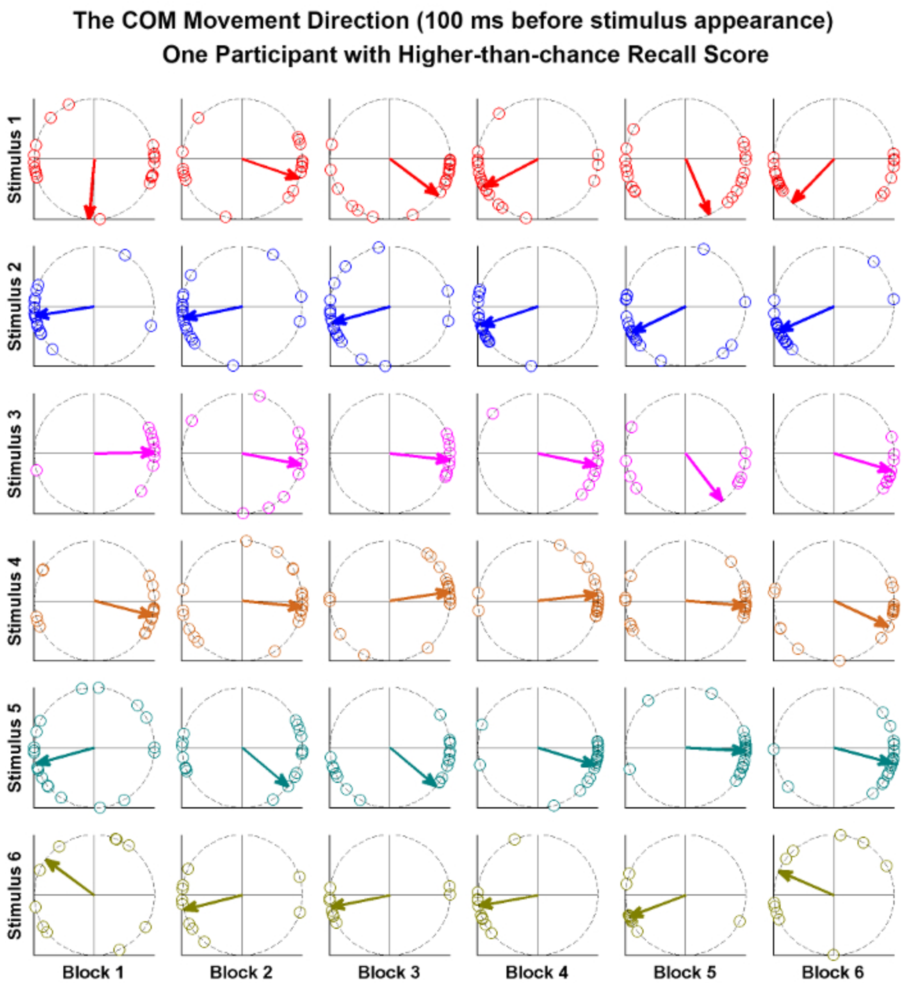

Figure 4: The COM movement direction from one participant with explicit sequence knowledge. The COM movement direction is shown for each stimulus (stimuli 1 - 6, see **Figure 1a**) across blocks. The COM could move from the origin to any position on the dashed circle that represents all directions the COM could move along. Empty circles represent the observed directions. The solid arrow represents the mean direction. Please click here to view a larger version of this figure.

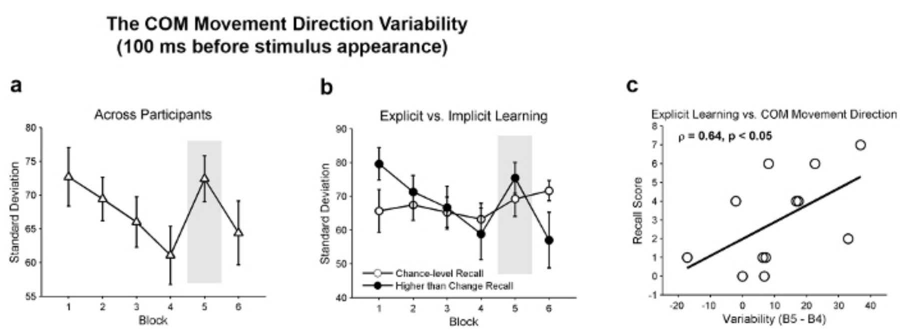

Figure 5: The variability in COM movement directions and its relationship with the explicit and implicit processes involved in sequence learning. The movement direction is quantified by the length of the arc between each empty circle and the point where the mean arrow points to in **Figure 3** and **Figure 4**. This is equivalent to the angle (in degrees) from the mean movement direction to the line connecting the origin and each empty circle. The variability is computed as the standard deviation across angles. **(a)** The mean variability across blocks: The gray area represents block 5, where the appearance of stimuli follows a novel sequence. The variability increased from block 4 to 5. **(b)** Such changes in the COM movement direction variability are shown only in the participants who acquire, at least partially, explicit knowledge of the sequence, but not in participants who do not show explicit knowledge of the sequence. **(c)** The change in variability from block 4 to 5 is significantly correlated to the amount of explicit knowledge acquired by participants. Error bar: Standard error of the mean. Please click here to view a larger version of this figure.

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Discussion

This protocol describes the experimental set-up and procedures for a modified SRT task. The modified SRT task shares its appealing simplicity with the classic SRT task, although the modified SRT task demands use of a motion capture technique. Like the classic SRT task, many parameters could be manipulated for specific research questions in the foot-stepping SRT task, including but not limited to: the length of interval-stimulus interval or response-stimulus interval[27], the type of sequence structure[28], and the awareness of sequence knowledge[29].

Compared to the classic SRT task, the foot-stepping task presents three advantages. First, the foot-stepping SRT task requires moving the legs while maintaining a standing posture of the whole body, rather than simply pressing four fingers while sitting as required in the classic SRT task. Thus, the foot-stepping task is a variant of the SRT task, which involves greater motor control complexity than finger pressing, and thus better approximates implicit motor sequence learning in daily sequenced activities. In addition, considering the interactive relationship between postural control and cognitive processes[30,31,32,33], this foot-stepping SRT task also permits us to understand how postural control interacts with gross motor sequence learning, especially in populations, such as children with Developmental Coordination Disorder[6,7,8], who have difficulties in integrating postural control and cognitive tasks. This line of research would serve as a foundation in the development of optimal interventions for children and adults with gross motor skill learning disabilities.

Second, performing a motor action typically involves multiple stages, including goal selection, motor planning, and movement execution. Since the classic SRT task requires only pressing keys, which does not involve moving to new locations in space as the fingers are always on the response keys, the task emphasizes goal selection, rather than movement execution[9], and the response time used to measure sequence learning is a mixture of goal selection and movement execution. The foot-stepping SRT task provides the opportunity to examine whether goal selection and/or movement execution significantly contribute to motor sequence learning. For example, one characteristic of movement execution, movement time (MT), could be examined in the foot-stepping SRT task. Although our representative results show no contribution of MT to implicit sequence learning, one fact worth emphasizing here is that both the classic SRT task and the representative protocol of the modified foot-stepping task do not require precise aim to response targets. For example, participants in the foot-stepping task are encouraged, but not strictly required, to accurately hit targets (but stepping toward the right direction is necessary), as they may shift their homing position slightly. Whereas, participants in the finger-pressing task always place their fingers on corresponding keys so that exact aim is not required. However, when precise aiming is necessary, movement execution may play a crucial role in sequence learning[10], suggesting the importance of dissecting multiple stages of motor performance (*i.e.*, goal selection, motor planning, and movement execution) to further understand the underlying mechanisms of motor sequence learning. Furthermore, the classic SRT task lacks its capability in elucidating the temporal evolution of cognitive processes operating in sequence learning. In contrast, the foot-stepping SRT task, like other SRT tasks involving spatial movements (*e.g.*, arm reaching and eye movement)[10,12], allows us to examine continuous movement trajectories. The measurement on temporal dynamics of movement could be used to reveal hidden cognitive processes in future sequence learning studies[11]. For example, using the COM movement before stimulus appearance, we may ascertain which target participants aim to before seeing the stimulus, as well as when consistent anticipations take place, which is not feasible in the finger-pressing SRT task.

Another prominent use of the SRT task is to pursue the progressive development of explicit sequence knowledge during implicit sequence learning. The SRT is commonly referred to as an implicit learning task[1,34]. However, sequence learning in the SRT task often involves an explicit process, as revealed by the ability to recall and/or recognize the sequence following the SRT task[22]. Since these recall and/or recognition tests are usually performed after the SRT task, it measures only the total amount of explicit knowledge acquired throughout the entire SRT task. It is hard to know when explicit memory of the sequence emerges and how it progressively develops through learning. Our representative results show that the foot-stepping SRT task presents its unique ability in examining the temporal evolution of explicit sequence knowledge across learning blocks. For example, **Figure 5a** shows that half of the participants started to acquire explicit sequence knowledge from blocks 1 and 2, and became more aware of the sequence in blocks 3 and 4.

In summary, this protocol introduces a modified SRT task that involves foot-stepping movement. This modified variant of the classic SRT task adds motor and postural demands that are indispensable in learning sequential skills in daily life. In addition, the foot-stepping SRT task allows the separation of goal selection and movement execution, two components that may differentially contribute to implicit motor sequence learning. The foot-stepping SRT task also provides a novel way to study the parallel operation of the explicit and implicit processes involved in motor sequence learning.

Disclosures

The authors have nothing to disclose.

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