Statistical Knowledge Transfer Across Stimulus-Response Associations

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Abstract

Probabilistic information appears in various forms in our environment. Research on transfer in changing conditions generally shows success, but it is unclear whether people acquire the rule itself or the underlying structure. Our study explored this by testing participants in a two-session statistical learning task with different stimulus-response associations. The rule transfer group learned the same sequence in both sessions, while the structure transfer group learned different sequences with the same structure. The control group learned only in the second session. Neither rule nor structure knowledge improved learning in the second session, but both experimental groups showed greater acceleration than the control group, indicating a dissociation between statistical learning and visuomotor performance. Thus, relearning occurs rather than transfer, but visuomotor performance generalizes. Our findings suggest that transfer is evident in visuomotor learning but remains limited in statistical learning.

Keywords: transfer; statistical learning; motor learning; rule learning; structure learning

Introduction

Regularities are present in our everyday surroundings in various forms. Therefore, learning the hidden rules and structures beyond the stimulus-response associations makes the behavior more flexible and adaptive. The capacity of extract of these probabilities called statistical learning (Conway, 2020), which operates across modalities and domains This raises the question: is it possible to transfer the statistical knowledge acquired, i.e. in this case, to apply the regularities learned in one task to another task and, if so, what is it learned from the rich information set?

Based on previous research, the transfer of acquired statistical knowledge can be diverse (Feng et al., 2023; Haider et al., 2020; Rosenthal et al., 2013; Turk-Browne & Scholl, 2009), but its exact nature is not yet fully understood, i.e., the characteristics that individuals extract from the environment. Theories are divided on whether statistical learning is specific or generalizable (Frost et al., 2015). Although this study does not aim to resolve that debate, it contributes to understanding what aspects of statistical information are generalized—whether it's the specific rule or the underlying structure that generates it.

The goal of the present study is to examine how individuals extract and apply statistical regularities across different contexts. Participants were divided into three groups: one involving the same hidden rule (rule transfer), another with a different underlying structure (structure transfer), and a control condition without a rule. In this task, participants learn to respond faster and more accurately to high-probability triplets. The rule defines which triplets are more predictable, while the structure refers to the broader sequence pattern that generates these probabilities (see Figure 1).

To be able to assess transfer we used two versions of the same statistical learning task, which differed in stimulus presentation: the spatial ASRT relied on spatio-temporal patterns, while the direction-based version included identity-based cues (see Figure 1). However, the position of stimuli of the two types can be matched. We hypothesized that participants in the rule transfer group would be able to recall previously acquired knowledge despite changes in the surface parameters of the task. In the case of structure transfer, the acquisition of the new regularity will be faster and greater than for the control group.

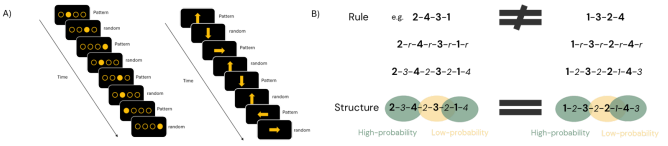

Figure 1: A) The two types of the Alternating Serial Reaction Time task. B) The rule and structure in the task. The task involves creating rules (sequences) using four positions, with random stimuli inserted between sequence elements. The key unit is the triplet. As the task alternates between sequential and random stimuli, some triplets occur more frequently and become predictable, leading to faster and more accurate responses. Changing the sequence alters specific triplets, but the underlying structure—two triplet types based on occurrence probability—remains constant.

Results

Data from seventy-two participants were included in the analyses. The Alternating Serial Reaction Time Task (ASRT, Howard & Howard, 1997) was used to measure statistical learning. During the ASRT task, participants learn a probability-based sequence with a second-order non-adjacent regularity. Due to the structure of the task, some triplets of stimuli occur with a higher probability than others. During trials, individuals learn these probabilities and therefore their reaction time is reduced to more predictable stimuli, which is called statistical learning. The experiment consisted of two sessions, 24 hours apart. On both occasions, participants performed one type of ASRT task (spatial or direction-based, i.e., with different stimulus-response associations) with or without a hidden sequence (i.e., random stimulus presentation) for 20 blocks. The following parameters were randomized among participants: task type (spatial or direction-based), sequence type (sequence or random), and sequence identity (same sequence across the two sessions; AA or different sequence; AB). For hypothesis testing, we run linear mixed models.[1]

Did experimental groups transfer the learned rule or structure to the second session? There was a significant statistical learning as shown by the significant main effect of Triplet [$F(1, 87385.450) = 184.5878$; $p < .001$], Block [$F(1, 87446.719) = 34.8906$; $p < .001$] and Triplet and Block interaction [$F(1, 87385.565) = 24.4577$; $p < .001$].

Significant Group and Block interaction [$F(2, 87445.391) = 27.619$; $p < .001$] indicates that both the rule-, and structure groups were faster than the control group. The Group and Triplet interaction was not significant, the rule and structure transfer group showed similar rates of statistical learning as the control group (who had not previously learned), so the transfer was not successful (see Figure 2).

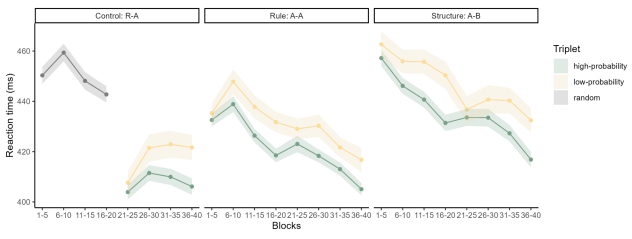

Figure 2: The x-axis shows progress in the task across both sessions. To enhance clarity, we averaged reaction times over five blocks per participant. The y-axis represents group-averaged reaction times. Green indicates high-probability triplets, yellow indicates low-probability triplets, grey indicates random trials, and error bars show 95% confidence intervals. Each facet represents a group, left to right in the following order: control, rule transfer and structure transfer.

Discussion

Based on the results, all three groups showed successful statistical learning. Both rule, and structure knowledge resulted in greater speed-up on the modified task compared to the control. However, contrary to our expectations, this was not associated with significantly greater learning compared to the group that had not previously encountered statistical information.

This suggests that the rule may be relearned rather than transferred when task parameters change. Alternatively, rewriting stimulus-response associations might counteract transfer, canceling its effects. Although statistical learning did not transfer, both transfer groups showed greater improvement in the second session than controls, indicating that visuomotor – but not statistical – learning is generalizable, highlighting a dissociation between the two.

The present study contradicts previous findings by showing no evidence of rule or structure transfer since past research has demonstrated successful transfer across modalities, responses, and structures (Feng et al., 2023; Haider et al., 2020; Rosenthal et al., 2013; Turk-Browne & Scholl, 2009) and Garner et al. (2016) found rule-based (instead of one-to-one mapping) stimulus-response mappings support transfer. There was no stimulus-response one-to-one correspondence, yet we could not detect successful knowledge transfer. This may suggest that the acquired representations were not abstract enough to generalize across task types.

The unexpected result of the research is that, in contrast to statistical learning, visuomotor learning is facilitated by knowledge of rule and structure. From this, we can tentatively conclude that in the case of visuomotor learning, it is not the stimulus-response associations themselves that are stored, but the “reflexive” ability to respond to a flashing stimulus as quickly and accurately as possible.

[1]https://github.com/cintianagy/transfer_otdk

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