Distinguishable Functional Modes in the Human Processing of New Information contained in Pattern-based Structures

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Abstract

Sequence Learning (SL) tasks have been used to investigate implicit and explicit aspects in human performance. In the present study the SL task approach has been adapted to investigate human performance under conditions of lacking information. In this case participants have to use their own model (participant model, PM) of a possible stimulus structure. Here we introduce the term Moment of Understanding (MoU) to identify a particular step during the SL task when the PM is adjusted to produce correct responses. It was found that distributions of the MoUs' allocations are non-random and similar under different conditions. It was possible to extract 2-component mixtures of normal distributions from these distributions. Thus, it seems that the adjustment of the PM includes at least two functional modes.

Introduction

Sequence Learning (SL) tasks have been used in a wide variety of experimental designs for investigating implicit and explicit aspects. During a typical SL task participants are asked to respond after the presentation of each element of a stimulus sequence (StS) (Cleeremans, Destrebecqz & Boyer, 1998). Thus, elements of stimuli were first presented to a participant and then the participant responded.

The SL task approach has been adapted for this study. In the adopted version, a participant first produced a response and then was presented with a corresponding StS element. Originally, the idea of such an adaptation was presented in Tarasenko, Inui and Abdikeev (2006).

The main difference between the presented approaches is the source of knowledge about stimuli. In a classical SL task, only the stimuli itself was the source of knowledge about stimulus structure. Participants had to repeat stimulus elements, thus they were driven by stimuli to learn their underlying rules. In the study mentioned above, participants had to estimate the allocation of the next StS element using their own model of the possible structure of stimuli. Such a model is called a participant model (PM). Thus, the task of the adapted SL is used to investigate how the PM is adjusted to produce correct outputs (participant responses).

Also in Tarasenko et al. (2006) the terms guessing and prediction were introduced. A prediction is treated as decision-making under conditions when complete information about a stimuli is available. In contrast, a guessing is characterized by decision-making when there is a lack of information. These terms were investigated from the point of view of availability of information about a stimulus structure during SL tasks. In this study these terms are discussed from the point of view of human performance.

Moment of understanding

Here we introduce the term Moment of Understanding (MoU). The MoU is defined as the first step during an SL task, starting from which a participant produces correct responses without any mistakes, thus the PM is adjusted to produce correct outputs. A series of responses during the period from the MoU until the end of an StS is called a Period of Understanding (PoU).

Experiment

The purpose of this study is to illustrate appearance of MoUs and investigate PM adjustment under conditions of new information contained in various pattern-based structures.

Method

A detailed description of the method is presented in Tarasenko et al. (2006).

Stimuli and procedure Six (2 rows by 3 columns) and eight (3 rows by 4 columns) Block Patterns (BPs) were used in the experiment. Each BP consisted of cells (states) and each state represents a choice. The entire set of 2-by-3 BPs is presented in Figure 1 a). Sample 3-by-4 BPs are presented in Figure 1 b).

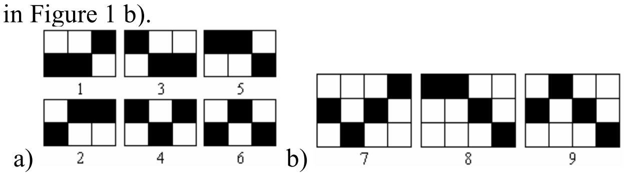

Figure 1: 2-by-3 and 3-by-4 BPs.

Each StS was generated using five repetitions of a BP. The Sts was presented column-by-column. Participants were instructed to estimate the appearance of the next StS element by choosing one of the states from a presented empty column during each step of an SL task. Each participant performed only one SL task. No practice was provided.

Participants In total 225 students participated in the experiment.

Results

In this study we require the PoU to be not less than a length of BP underlying an StS plus one. Therefore a series of correct responses starting later than 4 (2-by-3 condition) or 5 (3-by-4 condition) steps before the end of a stimuli is not considered to be a PoU. Consequently, the first correct response of such a series is not recognized as an MoU.

An analysis of the responses showed that 30% and 23% of responses contained no MoU for 2-by-3 and 3-by-4 conditions, respectively. The Binomial test revealed no significant difference between these two frequencies (p = 0.306). An analysis of MoU appearance in responses showed that distributions of the MoUs' allocations in responses are non-random for both 2-by-3 ($\chi^2(11, 79) = 30.82$, $p = 0.001$) and 3-by-4 (χ^2 $(15, 88) = 40.73$, $p = 0.000$) conditions. Correlation coefficients between the MoU and corresponding underlying BP numbers were found not to be significant for 2-by-3 ($r = -0.048$, $t(77, 0.05) = -0.42$) and 3-by-4 ($r = 0.073$, $t(86, 0.05) = 0.69$).

Further, the EM-algorithm was used to separate the mixture of normal distributions (normal mixture, NM) from the actual data. The 2-component NMs were extracted from data of both 2-by-3 and 3-by-4 conditions (Table 1).

Table 1: Mixtures of normal distributions

Condition	Mixture of normal distributions
2-by-3	0.75* N(5.36, 2.11) + 0.25*N(11.21, 0.71)
3-by-4	0.69* N(5.93, 2.16) + 0.31*N(13.22, 1.73)

The Kolmogorov-Smirnov test revealed no significant difference between actual MoU distributions and the corresponding NMs for both 2-by-3 (DN=0.21, K-S = 0.62, p = 0.82) and 3-by-4 (DN=0.21, K-S = 0.75, p = 0.63) conditions. Actual distributions of MoU with corresponding NMs are presented in Figures 2 and 3.

Discussion and Conclusion

The distributions of MoUs presented in Figures 2 and 3 illustrate that there are particular steps during which MoUs occurred most frequently. The steps of the most frequent occurrence in MoU distributions for 2-by-3 and 3-by-4 conditions are steps 5 and 6, respectively.

From the point of view of stimulus sequence structure these steps are the second steps after the information about the repetition was first presented. In Tarasenko et al. (2006) the guessing phase was defined as the period during which all underlying stimulus rules were first presented. Thus, the results of the present study confirm the acceptability of such a definition of a guessing phase from the point of view of information acquisition by participants.

An analysis of mixture separation shows that distributions of MoU have similar structures: they both could be represented as NMs. Thus, it seems that adjustment of the PM includes at least two distinguishable functional modes under conditions of new information contained in pattern-based structures.

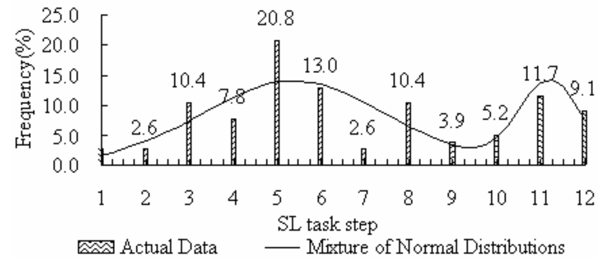

Figure 2: Actual distribution of MoUs and corresponding normal mixture for 2-by-3 BPs

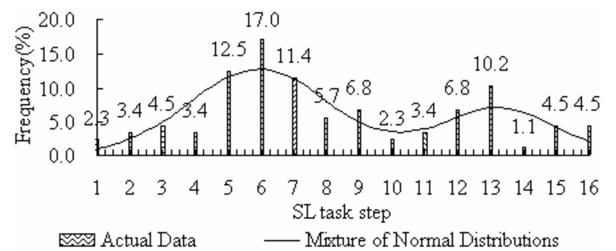

Figure 3: Actual distribution of MoUs and corresponding normal mixture for 3-by-4 BPs

From the point of view of human performance, during the first mode the participants try to guess a possible structure containing new information on the basis of their PMs or try to adjust their PMs to correct outputs as fast as possible (grasping), if the guessing fails. The second mode is characterized by a recurrent learning process which is similar to the one investigated in classical SL tasks.

Behavioral evidences for such modes obtained under different conditions were overviewed recently by Sanfey, Loewenstein, McClure and Cohen (2006).

We suppose that these modes represent consecutive stages of new information processing which are guessing and grasping on the one hand and recurrent learning on the other. However, precise mapping between mixture components and these modes as well as factors influencing mode switching require more detailed investigation.

References

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