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MATHEMATICAL MODELS OF HUMAN ATTENTION AND MEMORY PROCESSES

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Аннотация:Данная статья предоставляет общее представление о математических моделях, применяемых для изучения процессов внимания и памяти у человека. Процессы внимания анализируются с использованием теории обнаружения сигнала (ТОС) и моделей распределения ресурсов, а процессы памяти – с помощью марковских моделей и моделей экспоненциального забывания. В статье обсуждаются математические основы этих моделей, их значение в психологических исследованиях и практическое применение. Также рассматриваются возможности интеграции в области образования, клинической психологии и искусственного интеллекта. Статья подчёркивает взаимосвязь между науками психологии и математики.

Ключевые слова: внимание, память, математические модели, теория обнаружения сигнала, распределение ресурсов, марковские модели, кривая забывания, когнитивная психология.

Abstract: This article provides an overview of mathematical models used to study human attention and memory processes. Attention processes are analyzed through Signal Detection Theory (SDT) and resource allocation models, while memory processes are examined using Markov models and exponential forgetting curve models. The article discusses the mathematical foundations of these models, their importance in psychological research, and practical applications. It also explores integration opportunities in education, clinical psychology, and artificial intelligence. The article highlights the interdisciplinary connection between psychology and mathematics.

Keywords: attention, memory, mathematical models, signal detection theory, resource allocation, Markov models, forgetting curve, cognitive psychology.

Introduction

The integration of psychology and mathematics opens up new opportunities for understanding cognitive processes. Attention and memory are fundamental components of human mental activity, and mathematical models play a crucial role in analyzing them. These models make it possible to represent complex psychological phenomena in a precise and

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predictable form. This article discusses the main mathematical models used to study attention and memory processes, their types, and practical applications.

Attention is defined as the process of purposefully allocating resources during information processing. The following mathematical approaches are applied in modeling this process.

1. Signal Detection Theory (SDT)

Signal Detection Theory is widely used in analyzing attention processes. This model measures a person's ability to distinguish a signal from noise. SDT is based on two main parameters:

- **d' (sensitivity):** The ability to discriminate between signal and noise.
- **β (bias):** The tendency in decision-making.

For example, in a visual signal detection experiment, the participant's level of attention and error probability are calculated using SDT. Mathematically, **d'** is expressed as:

d′=μs−μnσd' = \frac{\mu_s - \mu_n}{\sigma}d′=σμs −μn

Here, μs\mu_sμs is the mean intensity of the signal, μn\mu_nμn is the intensity of the noise, and σ\sigmaσ is the standard deviation [1].

Reference:

[1] Green, D. M., & Swets, J. A. (1966). Signal Detection Theory and Psychophysics. New York: Wiley.

2. Resource Allocation Models

Attention is considered a limited resource, and its distribution across various tasks is analyzed using mathematical models. According to the model proposed by Kahneman (1973), attentional resources are allocated from a common "pool." This process is expressed as:

R=∑i=1nriR = \sum_{i=1}^n r_iR=∑i=1n ri

Where RRR represents the total attentional resources, and rir_iri is the amount of resource allocated to task iii. This model is useful for predicting attention distribution in multitasking environments [2].

Reference:

[2] Kahneman, D. (1973). Attention and Effort. Englewood Cliffs, NJ: Prentice-Hall.

Memory processes include storing, retrieving, and forgetting information. Mathematical models are important tools for analyzing these processes.

1. Markov Models

Markov models describe memory processes as sequences of states. For example, in the process of remembering words, the probability of recalling each word is considered to depend on the previous state. State transitions in memory processes are expressed as:

P(St+1 ∣ St)P(S_{t+1} \mid S_t)P(St+1 ∣ St)

Here, StS_tSt is the memory state at time ttt, and PPP is the transition probability. This model is widely used in word recall experiments [3].

Reference:

[3] Atkinson, R. C., & Shiffrin, R. M. (1968). Human Memory: A Proposed System and its Control Processes. In K. W. Spence & J. T. Spence (Eds.), The Psychology of Learning and Motivation (Vol. 2). New York: Academic Press.

2. Exponential Forgetting Curve

The process of forgetting information in memory is modeled as an exponential function. According to the forgetting curve model proposed by Ebbinghaus (1885), the retention of information decreases over time:

R=e−t/SR = e^{-t/S}R=e−t/S

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Here, RRR is the proportion of retained information, ttt is time, and SSS is memory strength. This model is useful for predicting retention duration in learning processes [4].

Reference:

[4] Ebbinghaus, H. (1885). Memory: A Contribution to Experimental Psychology. New York: Dover Publications.

Mathematical models of attention and memory processes are closely interrelated. For example, the level of attention affects the efficiency of memory encoding. While SDT and resource allocation models assist in analyzing attention processes,

Markov models and forgetting curve models play a key role in explaining memory processes.

Practical Applications

These models are applied in the following areas:

- **Education**: Memory models are used to optimize learning processes.
- **Clinical Psychology**: For diagnosing attention and memory disorders (e.g., ADHD or dementia).
- **Artificial Intelligence**: Mathematical models serve as a foundation for simulating cognitive processes.

Conclusion

Mathematical models of attention and memory processes play a significant role in psychological research. Signal Detection Theory, resource allocation models, Markov models, and forgetting curve models enable precise analysis of cognitive processes. These models are not only important in scientific research but also have great value in practical fields such as education, clinical psychology, and artificial intelligence.

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4. Ebbinghaus, H. (1885). Memory: A Contribution to Experimental Psychology. New York: Dover Publications.