

DOI: <https://doi.org/10.56712/latam.v5i1.1678>

Errors in memory recall, ToT, SoT, FoK and BoP. Operational classification

Errores en la recuperación de memoria, ToT, SoT, FoK y BoP. Clasificación operativa

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Artículo recibido: 25 de enero de 2024. Aceptado para publicación: 09 de febrero de 2024.
Conflictos de Interés: Ninguno que declarar.

Abstract


The evocation of memory is a critical cognitive process that involves the activation of engrams, which in turn evoke concepts. During memory recall, errors often occur, some of which are well-known, such as the tip-of-the-tongue (ToT) phenomenon or slip of the tongue (SoT). A related variable is verbal taxonomy closely associated with ToT and SoT, as well as the anxiety variable, which has been linked to the occurrence of these phenomena. The results of this research identify errors unrelated to verbs, leading to the operationalization of previously unidentified phenomena called Bias of Perception (BoP) and feeling of Knowing (FoK). This paper explores these errors and their systematic occurrence. In summary, this document seeks to increase understanding of errors that occur during memory recall, their causes, and their implications for cognitive processes.

Keywords: memory, evocation, recall, tip of the tongue, slip of the tongue

Resumen

Este artículo, se centra en el aprendizaje de conceptos, explorando la variabilidad de este proceso en relación con la taxonomía verbal y no verbal. Se examinan las teorías del concepto y memoria, especialmente el atomismo conceptual y la teoría de engramas, que proporcionan una base sólida para comprender los procesos de aprendizaje y formación de conceptos, elaborando una definición novedosa el “concepto dinámico” con base en dichas teorías. Con base en lo anterior, se diseñó un experimento para medir el aprendizaje, encontrando diferencias significativas entre el aprendizaje verbal y no verbal. En conclusión, el objetivo de la investigación es contribuir al conocimiento sobre la naturaleza de los conceptos y su relación con la formación de engramas en el cerebro. Al abordar las teorías existentes y realizar experimentos, se busca ofrecer nuevas perspectivas y avances en el campo de las neurociencias cognitivas.

Palabras clave: memoria, evocación, recordar, punta de la lengua, desliz de la lengua

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Cómo citar: Muñoz López, M. A., Hernández Pozo, M. del R., Almaráz Rodríguez, O. D., Mercado Piedra, J. A., & Ortega Muñoz, F. (2024). Errors in memory recall, ToT, SoT, FoK and BoP. Operational classification. *LATAM Revista Latinoamericana de Ciencias Sociales y Humanidades* 5 (1), 1365 – 1378. <https://doi.org/10.56712/latam.v5i1.1678>

INTRODUCTION

Memory is a brain function that can retain and reactivate internal representations obtained through intrinsic and extrinsic experiences (Dudai, cited in Josselyn & Frankland, 2018). These representations are encoded as enduring changes in the brain, referred to as engrams (Tonegawa et al, 2015), which are widely distributed within and across brain areas, relying on interactions among neural networks (Eichenbaum, 2016).

A crucial element in explaining this process is the formation and evocation of concepts. For this investigation, an approach is taken from the theory of engrams and conceptual atomism (Fodor, 1998), based on which, the dynamic concept definition was developed where the concept is described as:

a basic element of thought, crucial to intellectual processes; it lacks structure, becoming dynamic and relative on the experience of each individual. It consists of the evocation of recollections from memory, because of the reactivation of neural engrams and in response to stimulation elicited by properties of previously paired objects or external or internal phenomena by the quantitative or qualitative exposure between them and the individual. This activation caused lasting physical and/or chemical changes between specific neurons, forming engrams. (Muñoz-López, Hernández-Pozo & Almaraz, 2023, p.3)

When a set of neurons is reactivated in response to a stimulus, the resulting memory evocation can have certain errors. These errors are sometimes detected by the subject experiencing them when intentionally trying to access their memory. An example of these errors is the Tip of the Tongue (ToT), which occurs when an individual remembers the concept but can't express its signifier. Another known error is the Slip of the Tongue (SoT), characterized by using an erroneous signifier for the concept instead of the intended one. There's a substantial amount of research on the topic with differing conclusions.

James et al. (2018) suggested that the ToT error is related to anxiety-inducing evaluation situations. Sauer and Schade (2019) model the appearance of ToT states related to SoT, presenting a model proposing that these errors occur when something goes wrong during language production. They describe that in these instances, the target word and the error word match in syntactic category, and the target noun is replaced by another (Sauer & Schade, 2019). They also explain in their model the creation of the concept prior to lexical assignment. On the other hand, D'Angelo and Humphreys (2015) attribute the existence of ToT errors to inadequate learning through Hebbian reinforcement (Hebb, 1949), which, when corrected, decreases the occurrence of this error.

During the study of concept learning, formation, and recovery within its verbal and nonverbal axionomy (Muñoz-López, 2023; Muñoz-López, Hernández-Pozo & Almaraz, 2023), results showed errors in memory recall when attempting to link them with verbs. Additionally, due to the research design, errors not related to verbs were technically inferred. This led us to operationalize (Table 1) SoT and ToT errors, introducing two nonverbal errors into the study: Bias of Perception (BoP) and Feeling of Knowing (FoK), previously analyzed by various researchers, but now conceptualized in a nonverbal manner.

Table 1

Errors operationalization

Situation	Verbal	Non verbal
Omission error	Tip of the Tongue	Feeling of Knowing
Selection error	Slip of the Tongue	Bias of Perception

This operationalization (Table 1) stems from the nature of these errors, where a target word is omitted or expressed inaccurately. Another defining variable of these errors is whether the evocation aims to be verbalized or not. From this matrix, four types of errors emerge: the ToT, SoT, FoK, and BoP errors.

BoP and FoK Errors

These nonverbal errors are theorized in this study to encompass certain possibilities of error occurrence that were not previously recognized in the literature but are necessary to consider in the design of this research. Similar to ToT and SoT, both these errors are short-lived phenomena, as they imply that the subject, if familiar with the concept, simply cannot relate one property or more, to the rest that constitute the concept for a certain period.

The FoK error, or feeling of knowing, according to Kikyo, Ohki, and Miyashita (2002), is the sense of knowing something before being able to recall it (FoK), related to the ToT according to these researchers, it is the sense of knowing something before being able to verbalize it. However, in the context of this research, the term FoK will be used to describe events in which the subject experiences a stimulus but cannot evoke the necessary information from the previously paired concept to activate a response. In other words, when the subject is presented with a stimulus but cannot relate it to the paired concept. Example: when we feel like we want something sweet but don't know exactly what.

On the other hand, the BoP error is theoretically defined as the phenomenon in which an individual receives a stimulus and retrieves the necessary information that triggers a response; however, the response is not the one previously paired with the perceived stimulus.

METHODOLOGY

The subjects were high school students who can follow instructions and likely to have a high capacity for brain plasticity, which is important for experiments based on learning activities. Individuals with psychological disorders, blindness or visual impairments, and those unable to use the experimental materials were excluded as criteria.

The participants in this study were drawn from various regions in Mexico, with a particular focus on Durango, Sinaloa, Mexico City, and the State of Mexico. The sample comprised 268 individuals, with an average age of 17.33 years (standard deviation = 1.059). Of these, 158 (59%) were women, and 109 (40.7%) were men. Prior to their participation, participants were requested to provide informed consent, which included explanations regarding the confidentiality of their data, the voluntary nature of their participation, and a clear description of the research objectives. All procedures conducted in this study adhered to the ethical principles and were granted approval by the Universidad Pedagógica de Durango Ethical Board.

Design

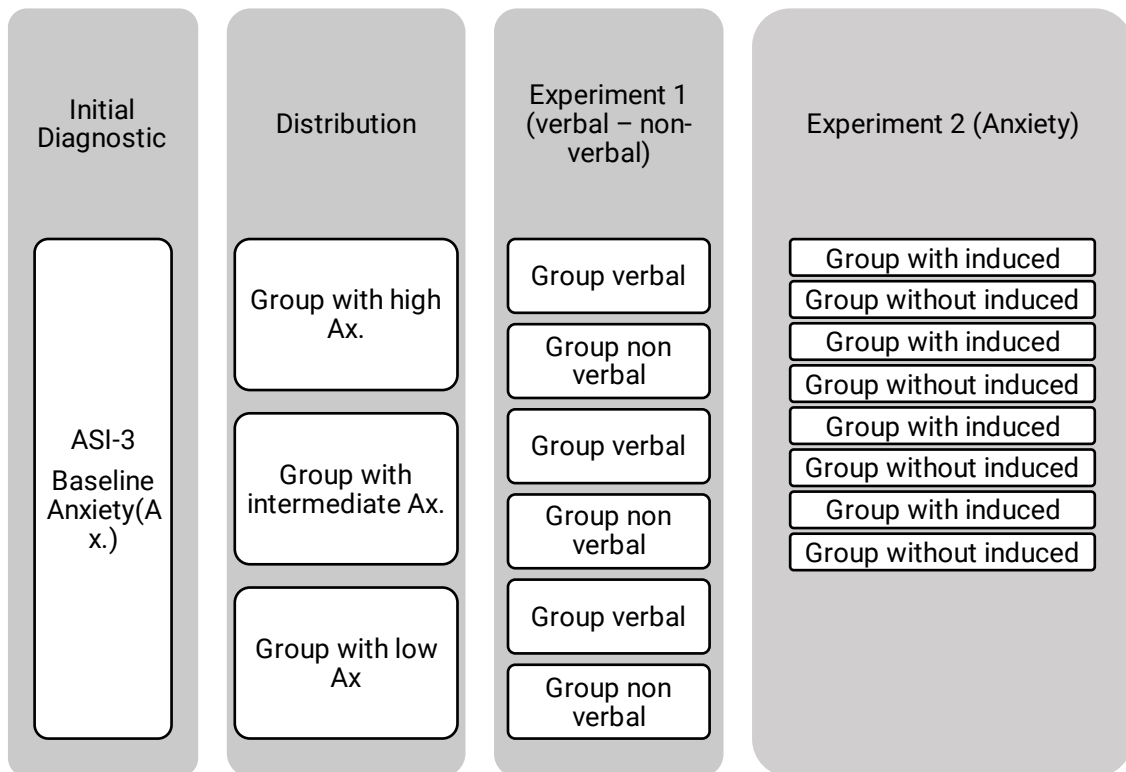
The participants were grouped based on their initial anxiety levels, which reflect the likelihood of an individual responding to life situations with anxiety. Baseline anxiety is a variable known to influence the learning process (Blumer & Benson, 1975). To minimize the impact of other variables, it was decided to categorize participants based on this criterion. Consequently, the matching process yielded three distinct groups: high anxiety, medium anxiety, and low anxiety.

Each resulting group was then randomly divided by the software into two subgroups: an experimental group and a control group (refer to Figure 2), with the independent variable being verbal or nonverbal information.

Following the completion of the first experiment, the two low-anxiety groups concluded their participation in the study. This decision was made in anticipation of the next experiment, which involves inducing anxiety through a stressor, where it is expected that any initial differences would become negligible. Thus, these two groups were considered to have completed their participation. The assessment is automatically conducted by the software as soon as the subject interacts with it.

Figure 2

Design



Data collection in this study was carried out using the software application employed in the experiment. To assess the subjects' anxiety levels, the ASI-3 questionnaire, which stands for the New Scale for the Assessment of Anxiety Sensitivity (Hernández-Pozo, Alvarado-Bravo, Espinosa-Luna, et al., 2021), was utilized. This questionnaire had previously undergone validation within the Mexican population and exhibited a high overall reliability score, with a Cronbach's alpha coefficient of 0.919.

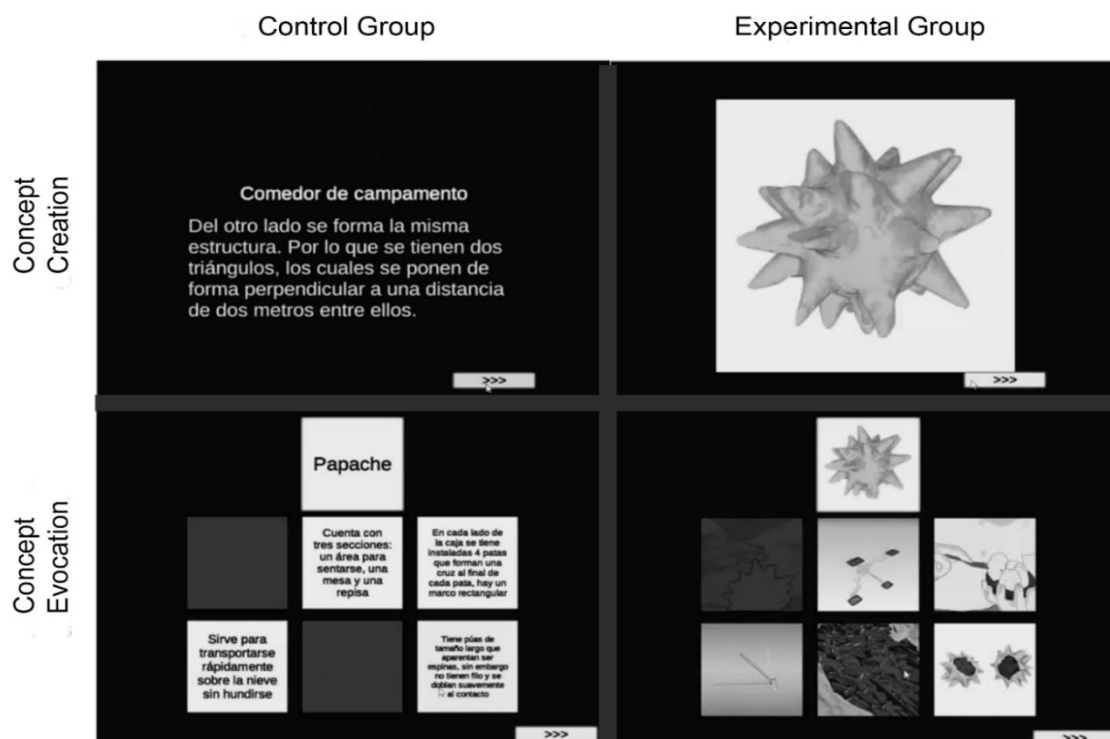
The data gathered by the experiment's software were automatically transmitted to a networked spreadsheet that aggregated data from all instances of the application's use. This method was implemented to minimize errors stemming from researcher bias during experiment evaluations or personal observations.

Experiment

An experimental design was employed, comprising two distinct phases. In the initial phase, participants were repetitively exposed to a set of interconnected stimuli, with the objective of constructing a conceptual framework, aligning with the proposals made by engram and informational atomism theories, particularly in reference to the phenomenon termed 'locking.' The stimuli's nature underwent alterations based on a taxonomy distinguishing between verbal and nonverbal categories (Figure 3), thereby defining the control and experimental groups. Subsequently, concept acquisition was assessed. During this phase, participants were presented with a stimulus and tasked with associating it with the properties they had previously linked to it. This procedural step aimed to replicate the theoretical frameworks underpinning this research.

Figure 3

Control and experimental groups



The experiments were double balanced in terms of learning and probing. In the training or learning phase, the training was balanced based on concepts. For each concept, seven exposures were conducted, resulting in a total of four concepts.

Table 2

Distribution example

Trial	Discriminative Stimuli	
	Concept 1	Concept 2
1	2	1
2	0	4
3	1	2
4	4	0
5	3	3

There were 5 probing trials per concept. Each trial consisted of a sample stimulus, six comparison stimuli, and discriminative stimuli presented with a balanced distribution of correct responses ranging from 0 to 4 for each concept (Table 2).

In the second stage, the subjects with medium and high basal anxiety randomly went to another stage, where they were exposed to anxiety stimuli before the evaluation, where they had to remember the concepts learned in the previous phase of the experiment. During the experiment, the control group was not exposed to anxiety-provoking stimuli.

Given the double-blind design employed in this study, the evaluation of the hypothesis was deferred until the conclusion of the experiment. This approach involved the random allocation of subjects to either the control or experimental group, with neither the participants nor the researcher being aware of the group assignments.

The experiments were meticulously balanced in terms of both learning and probing procedures. During the training or learning phase, the training regimen was equitably distributed across different concepts. Specifically, each concept received a consistent seven exposures, resulting in a total of four distinct concepts.

Table 3

Distribution table

Trial	Discriminative Stimuli	
	Concept 1	Concept 2
1	2	1
2	0	4
3	1	2
4	4	0
5	3	3

In experiment 1, each concept underwent 5 probing trials, with each trial encompassing a sample stimulus, six comparison stimuli, and discriminative stimuli. These stimuli were presented in a manner that ensured an even distribution of correct responses, varying from 0 to 4 for each concept, as indicated in Table 3. On the other hand, experiment 2 involved exercises focused on concept retrieval or information blocks. With a set of 10 probing trials, each offering 4 possible response options, with only one of them being the correct answer.

RESULTS

During the experiments, two types of errors were evaluated: 'omission errors' when the subject fails to select an option they should have, and 'selection errors' when they choose an item they shouldn't.

The errors operationalized in the design and theorized as BoP (Bias of Perception) and FoK (Feeling of Knowing) should manifest in the results. In this section, the occurrence of these phenomena is analyzed in order to study and verify if the theoretical concepts of BoP and FoK appeared in real situations during the study.

The significance of error occurrence was analyzed. In this case, the method was to compare with a modified Welch's T test, the mean of errors that appeared in the experiment with a mean without errors to which a 5% error was added, this represents results where errors would not exist, but could occur due to random or unrelated.

Table 4

Tests of Actual Error Occurrence vs. Random Occurrence

Error	Mean Exp1	Mean no error Exp1	P value Exp1	Mean Exp2	Mean no error Exp2	P value Exp2
Tip of the Tongue ToT	11.82	2.0	0.0	3.462	0.5	0.0
Slip of the Tongue SoT	9.12	4.0	0.0	2.8	0.5	0.0
Feeling of Knowing FoK	5.23	2.0	0.0	2.135	0.5	0.0
Bias of Perception BoP	10.34	4.0	0.0	1.81	0.5	0.0

Note: Experiment 1 is under normal conditions, while in Experiment 2, the subject experienced anxiety.

The ToT (Tip of the Tongue) error was operationalized as a verbal omission error. The number of possible errors during the first experiment was 40. Considering the 5% error, a mean of 2.0 was established for a situation with no error existence. As a result of the statistical test, the null hypothesis was rejected (Table 4), implying that the results obtained in the experiment suggest the statistically significant occurrence of the ToT error.

In anxiety situations, the results from the second experiment were reviewed, where the number of possible errors was 10. Taking into account the 5% error, a mean of 0.5 was established as the average occurrence of this error during the second experiment. According to the results of the statistical test (Table 3), it can be interpreted that the ToT error also appears in situations with state or induced anxiety. Considering that the percentage of error occurrence was 29.55% in normal situations and 34.62% in induced anxiety situations, it is believed that the error's occurrence increases in situations with anxiety.

Slip of the Tongue Error: The SoT error was operationalized as a verbal selection error. The number of possible errors during the first experiment was 80. Taking into account the 5% error, a mean of 4.0 was established for a situation with no error. The result of the statistical test (Table 3) suggests the statistically significant occurrence of the SoT error, compared to a random event or not existence. In anxiety situations, the results indicate that the SoT error also appears in state or induced anxiety situations (Table 3). Considering that the percentage of error occurrence was 11.4% in normal

situations and 28% in induced anxiety situations, it is believed that the error's occurrence increases in a ratio of more than 2:1 in situations with state anxiety.

Feeling of Knowing Error: The FoK error is methodologically a non-verbal omission error. The number of possible errors during the first experiment was 40. Considering the 5% error, a mean of 2.0 was established for a situation with no error. The results of the statistical test on the experiment suggest the statistically significant occurrence of the FoK error (Table 3). In anxiety situations, the result indicates the same conclusion (Table 3). Considering that the percentage of error occurrence was 12.5% in normal situations and 21.35% in induced anxiety situations, it is believed that the error's occurrence increases in situations with state anxiety.

Bias of Perception Error: Quantified as a non-verbal selection error, it had a possible occurrence of 80. Considering the 5% error, a mean of 4.0 was established for a situation with no error. The statistical test suggests the existence of a statistically significant occurrence of the BoP error in the experiment's results, and this was repeated in anxiety situations (Table 4). On the other hand, in normal situations, the percentage of error occurrence was 12.925%, and in induced anxiety situations, it was 18.1%. It is believed that the error's occurrence increases in situations where the subject is in a state of anxiety.

Comparison Between Verbal and Non-Verbal Errors

Behavior of Errors in Concept Retrieval: Secondly, upon recognizing the occurrence of errors, their performance was studied compared to other errors and in induced anxiety situations. When comparing groups with verbal and non-verbal information, no significant differences were found in the occurrence of selection errors between groups with verbal and non-verbal information. In other words, the SoT and BoP errors tended to appear to the same extent (Table 5).

Table 5

Comparison between verbal and non-verbal errors

Operationalization		Classification	N	Mean	p
Selection errors	Nonverbal	BoP	121	10.34	.366
	Verbal	SoT	154	9.12	
Omission errors	Nonverbal	FoK	121	5.23	.000
	Verbal	ToT	154	11.82	

However, concerning the appearance of omission errors or Tip of the Tongue (ToT) and Feeling of Knowing (FoK) errors, there was a statistically significant difference in their occurrence. These errors appeared more frequently when words were used more than twice the average. Among the four types of errors, the FoK error was the rarest in its occurrence, while conversely, the ToT error appeared the most (Table 5).

DISCUSSION

The results obtained from studying the occurrence of errors during concept retrieval helped address certain questions, such as whether the occurrence of these errors was significant enough to confirm their existence or if it was a casual or sporadic situation. It also provided insights into the situations in which they occurred.

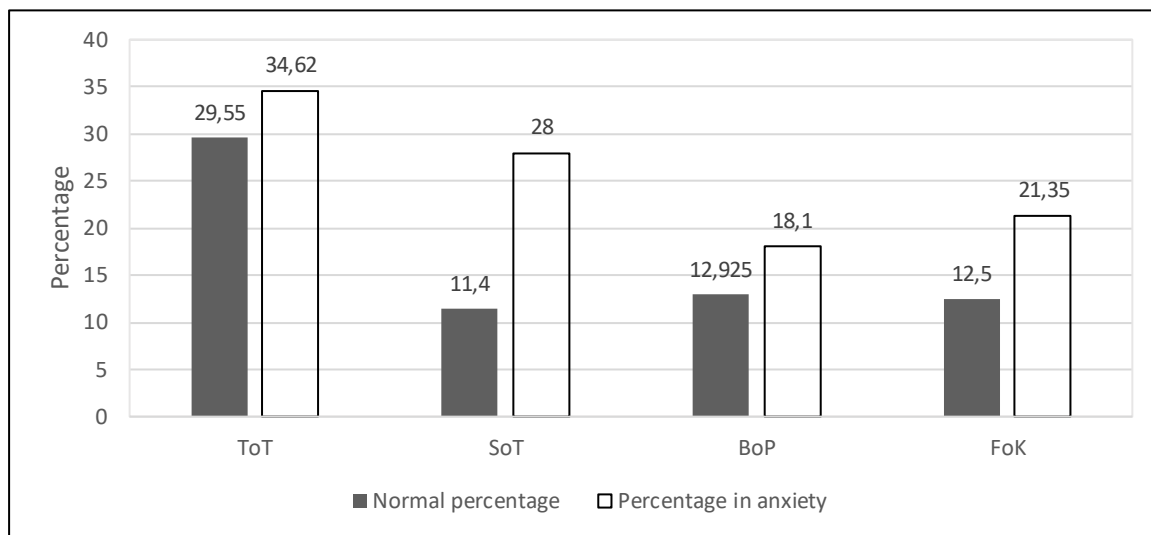
At first place the Tip of the Tongue (ToT) error was analyzed, to determine if its occurrence was consistent, it was compared to an average occurrence of zero (i.e., non-existence) plus a 5% error. The

result led to the rejection of the hypothesis of equality, favoring the appearance of the error in normal situations. This was similar in situations involving the variable of state anxiety in terms of its occurrence.

However, when comparing the percentages, the occurrence of ToT errors was higher in induced anxiety situations. These results align with what Blumer and Benson (1975) mentioned: that high levels of anxiety negatively impact cognition and behavior.

Figure 4

Percentage of occurrence of errors



Regarding the error known as a Slip of the Tongue (SoT), operationalized as a verbal selection error, its consistent occurrence was also studied, yielding data that imply its significant appearance. Additionally, in high anxiety situations, its occurrence increases at a ratio of 2:1 compared to stable situations (Figure 4).

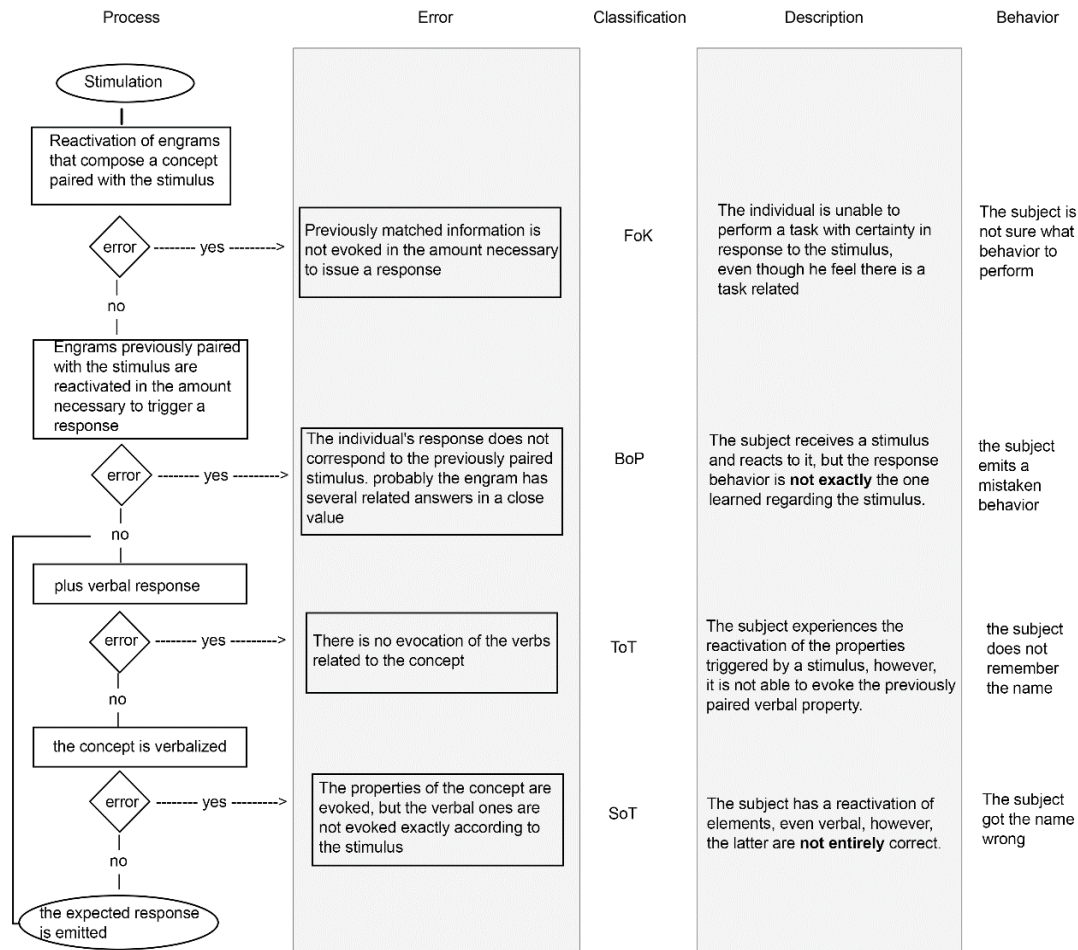
The non-verbal concept retrieval errors, the FoK error was operationally defined as a non-verbal omission error and showed consistent occurrence when compared to its non-occurrence. Similarly, the BoP error showed a significant increase in its occurrence during anxiety situations. Finally, it was found that the mean occurrence of the BoP error was significantly higher than its non-occurrence or random occurrence or sporadic plus the 5% error. Thus, it can be concluded that the errors examined in this study have an occurrence beyond chance.

According to the nature of the errors, they were divided into selection errors and omission errors. The errors of the first type were BoP and SoT errors, which involve mistakes in selecting a property of the concept. On the other hand, the omission errors, referred to as FoK and ToT errors, occur when, despite having activated properties, the object cannot be invoked verbally or non-verbally.

Based on this, a statistical analysis was conducted to determine if there were differences in occurrence between members of each group (BoP vs SoT) and (FoK vs ToT). While selection errors tended to occur without statistically significant differences, omission errors differed between them. This trend reiterated the study's finding that verbal concept retrieval posed greater difficulties, potentially related to the complexity of using words with various meanings in different contexts (Malt et al. 1999).

Figure 5

Properties of errors



Note: In SoT and BoP errors, although the response is wrong, this wrong behavior or verbalization and the reactivated engram has a high pairing with the stimulus. That is, the answer given is not random.

The error with the least occurrence was FoK, which defines the phenomenon where attention is given to a stimulus, but it's difficult to recall other properties with which it was associated to form a concept. In contrast, the ToT error had the highest occurrence. It involves three processes, as depicted in Figure 5, the activation of properties forming a concept, ensuring that the activated properties of the concept correspond to the stimulus, and that the activated concept is related to a correct verbal property and expressed. Expressing a concept correctly requires more complexity than simply recalling it initially. This could explain why the ToT error appeared most frequently during the experiments.

Therefore, as described by D'Angelo and Humphreys (2015), ToT errors occur when learning is implicit and hasn't been sufficiently linked to a word. This supports the notion that the error arises at the stage where the property of being verbal is added.

Anxiety's impact on concept retrieval, as shown in the results (Figure 3), was consistent with what happened. One possible reason for this is what Blumer and Benson (1975) discovered: when anxiety

reaches high levels, failures in cognition and behavior direction occur inadequately. This was evident in all scenarios presented, both in recalling verbal and non-verbal concepts. However, the reactivation of verbal concepts was significantly lower. The cognitive impairment induced by anxiety compounds the difficulty of working with verbal content due to its complexity (Malt et al. 1999).

Beck & Haigh (2014) discussed two types of information processing: automatic and reflexive. Automatic processing is unconscious but primary, while reflexive processing is secondary but conscious. Automatic processing swiftly handles stimuli, expending fewer resources, and activates in survival situations. For decision-making, it uses broad categories, leading to errors. Reflexive processing is slower and resource-intensive but tends to be consciously controlled. The meanings it uses are refined and contain fewer errors.

The above is of relevance as, when combined with the complexity of verbal concepts (Malt et al. 1999) and cognitive difficulties during anxiety situations (Blumer & Benson, 1975), it can be concluded that problems in recalling information, especially related to verbal concepts like ToT and SoT, may originate in part, from high anxiety or stress situations. This is reflected in the results where their occurrence significantly increased in induced anxiety situations. As Beck & Haigh (2014) describes, in survival situations, individuals tend to use automatic processing, which is quicker but less refined cognitively and prone to error.

These types of errors are common, especially in pressing situations, as described by Beck & Haigh (2014). In these cases, processing occurs in broad categories, leaving specific characteristics aside. In calm situations, reflective processing takes over, characterized by more refined cognitive activities.

In conclusion, this research reinforced understanding about errors in the retrieval of concepts and the nature of concepts in general. It highlighted how language, as a tool for retrieving information, is a cognitively complex process. This study naturally led to the operationalization of two new memory recall errors: BoP and FoK, which were subsequently recognized during the experiments.

Approaching the concept from an engrammatic perspective invites the development of a memory model that enables the simulation of complex behaviors, memory errors, and the behavior of concepts. This can be applied to both cognitive therapy and education.

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Declarations

This study was approved by the ethics committee of the Universidad Pedagógica de Durango, as part of the process of the doctoral thesis experiment, where this article is located.

Declaration of interests

The authors declare no competing interests.

Acknowledgments

No funding was received for this research.

Author contributions section:


Miguel Ángel Muñoz-López: Lead Researcher, writer, illustrator

María del Rocío Hernández Pozo: Thesis director, research, revision

Omar David Almaraz Rodríguez: Thesis director, methodology, revisión

Flavio Ortega Muñoz: Revision, writer.

Mercado Piedra, Juan Antonio: Revisión.

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