ARTÍCULO ORIGINAL

Evaluación Neuropsicológica del Control Inhibitorio y el Control de la Interferencia: Validación de Tareas Experimentales en el Contexto Ecuatoriano.

Neuropsychological Evaluation Of Inhibitory Control And Interference Control: Validation Of Experimental Tasks In The Ecuadorian Context.

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Resumen

En este artículo se reporta un estudio en el cual se adaptó y validó tres tareas experimentales (SIMON, Go/No-Go y Stroop Victoria) para valorar el control inhibitorio y control de la interferencia en una muestra de estudiantes ecuatorianos. La muestra estuvo conformada por 100 estudiantes entre 6 y 15 años de edad (M=10,13 años, DE= 2,48) pertenecientes al sistema educativo público de Ecuador. El proceso que se siguió en la adaptación y validación fue mediante la traducción lingüística de los experimentos, posteriormente se siguió un juicio de expertos y un estudio piloto. En los resultados se encontró que no existen diferencias estadísticamente significativas en las medidas que valoran el control inhibitorio y de la interferencia considerando como factores de comparación las variables sociodemográficas de los participantes. En el análisis correlacional se encontró una asociación estadísticamente significativa entre las mediciones de los experimentos. Se concluye analizando las asociaciones encontradas y subrayando la necesidad de continuar aportando evidencia en la línea de investigación de adaptación y validación de reactivos de uso en la evaluación neuropsicológica.

Palabras clave: Evaluación neuropsicológica, SIMON, STROOP, GO/NO-GO, control inhibitorio.

Summary

This article reports a study in which three experimental tasks (SIMON, Go / No-Go and Stroop Victoria) were adapted and validated to evaluate the inhibitory control and interference control in a sample of Ecuadorian students. The sample consisted of 100 students between 6 and 15 years old (M = 10.13 years, SD = 2.48) belonging to the public education system of Ecuador. The process followed in the adaptation and validation was through the linguistic translation of the experiments, followed by an expert judgment and a pilot study. In the results it was found that there are no statistically significant differences in the measures that assess the inhibitory control and the interference considering the sociodemographic variables of the participants as comparison factors. In the correlation analysis we found a statistically significant association between the measurements of the experiments. We conclude by analyzing the associations found and underlining the need to continue providing evidence in the research line of adaptation and validation of test for using in neuropsychological evaluation.

Keywords: Neuropsychological evaluation, SIMON, STROOP, GO / NO-GO, inhibitory control.

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Introduction

Inhibitory control is an executive function that allows human beings to control automatic impulses, permitting a conscious self-regulation of their behavior, thoughts and emotions, in addition to having self-control on actions with a strong predisposition to be triggered by an internal or external influence from the individual.[1]

This executive action is one of the most important for an individual to be able to successfully adjust to social norms. Once the inhibitory control dominates the tendency of an individual to act automatically, it opens the door to a cognitive process of high complexity, where the information is kept online to be used at the exact moment of a problem resolution, while an appropriate action moni-

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toring is being executed until the individual reaches an adjustable and creative solution for what they are doing.[2]

Interference control has to do with the role of automatic impulse control that handle selective attention and cognitive inhibition. Interference control allows humans to pay attention to a particular environment stimulus, by inhibiting the tendency to get distracted by the presence of irrelevant stimulus (a highlighted stimulus, something colorful, a loud noise, etc.) while performing a task, allowing this way to voluntarily select or ignore particular stimuli that do not contribute to achieve the proposed objective.[1,3]

According to Barkley[2,4,5] inhibitory control will include the capacity to control interference and two high complexity executive competencies. Inhibitory control then deals with (a) the capacity of the individual to stop an automatic action, for example when a student has the impulse to get out of his classroom without permission and stops before executing the action and adjusts his automatic impulse by asking for permission; (b) the ability to stop an impulsive or automatic response during its process, for example when a student is already about to leave the class without permission and by an automatic action tendency he stops and comes back, and (c) the resistance to interference, which has to do with the control of elements that could become a distraction, for example when a student is performing a task and must inhibit the tendency to perform other leisure activities instead.[6]

As far as the neurobiological substratum of the capability to control automatic responses, it has been linked to the most developed structure of human ontogeny of the nervous system: the prefrontal cortex,[7] brain area where three major functions are performed based on a complex configuration brain system, which in general terms handles (a) planning/programing, (b) monitoring/supervising/regulating, and (c) verifying/proving mental activity and conscious behavior.[8]

One of the major evidences that have permitted to link the performance of the inhibitory control and the interference control, in addition to the rest of executive functions to the role of the prefrontal cortex, is the clinical evidence existing in human beings when they have an injury in that area of the brain,[9,10] which is characterized by manifesting a behavior without conscious regulation from impulses, where the individual behaves without planning his actions, a monitoring system that allows him to determine if his behavior is correct or not, if he is respecting social norms or not, without realizing if his actions go according to his objectives; to sum up, an unmeasured behavior for situations where human beings must regulate themselves and resolve an issue in a monitored and creative way.[11,12,13]

Another aspect that has been highlighted in subjects presenting frontal brain damage is the lack somatic markers when facing a particular situation or stimulus where inhibitory or interference controls should be activated. This means that when humans are facing a stimulus or situation where a usual behavior needs to be prevented as a response and a somatic marker, which is a physiological signal issued by the nervous system to stop an individual from doing something, is not activated, then the lack of this signal causes individuals to act in an automatic manner.[14,15]

ADHD (attention-deficit disorder with hyperactivity/impulsivity) children are one of the clinical populations where a hypothesis has been drafted regarding frontal lobe dysfunction symptomology. It has been determined that these children when facing tasks where their impulses must be controlled have a greater difficulty achieving it than children without ADHD. Moreover, when faced with stimuli called No-Go (before which they must inhibit their response) they will lack an appropriate somatic marker, which at a physiological level issues a signal to stop before the No-Go stimulus.[13]

This could explain why individuals with higher levels of impulsivity or hyperactivity present difficulties in their daily lives, in their work, family and social environments; since the physiological signal to stop before a No-Go situation is not properly activated, they have automatic reactions so when facing real live situations they act without proper behavior planning, monitoring or verification. For example, when they need to stop before a red light they don't; when someone offends them they can´t stop their aggressive response; they get distracted with any irrelevant element, among other characteristics of individuals with inhibitory or interference control alterations.[16,17]

With respect to the evaluation of inhibitory and interference control, diverse methodologies can be used in the clinical practice of neuropsychology. On one side, we have the contribution of behavioral valuation scales that allow us to evaluate the functionality of these mental capabilities in daily life activities and in real conditions for the subject. On the other, we count with experimental tasks that allow us to issue a criterion thru a controlled situation, in which inhibitory and interference control can be evaluated purely and specifically, decreasing as much as possible the presence of exogenous variables that could influence the results.[18,19]

According to Bonilla, Ángel, Galvis-Jaramillo, Pachón and Rubiano[20] the response process before a stimulus in which the inhibitory control should be executed, corresponds to a more complex process with a bigger delay at a cerebral level, since more brain structures are involved compared to the brain structures involved in an automatic response. For example, when an individual faces a No-Go stimulus, the cingulate anterior cortex is added to the response brain system, which is responsible

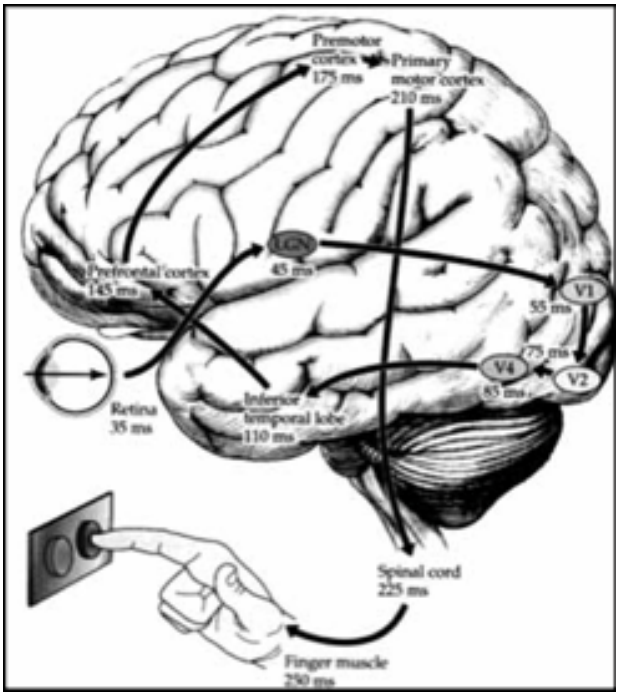

Figure 1. Path of brain process responding to a visual stimulus.

for solving the problem before issuing the response. This will not happen with a Go stimulus where the individual has automatic behaviors. Figure 1 describes graphically the neuropsychological system that human beings will follow for motor responses.

Within the described context, the need of developing a research that seeks to validate experimental tasks to evaluate inhibitory control and interference control for the Ecuadorian population becomes eminent. It is imperative to have within our context reactants adjusted to neuropsychological evaluation. In this sense, we report as follows the process performed to adjust three experimental tasks helpful to evaluate this neuropsychological value: SIMON, Go/No-Go and STROOP VICTORIA.

Material and Methods

Participants

The sample was formed by 100 participants aged between 6 and 15 years old who attend Ecuadorian Public Schools. In terms of gender distribution, 57% of participants where male and 43% female. The average age of the sample was 10.13 (DE 2,48).

Experimental Tasks

Go/No-Go Task

This experimental task was developed to evaluate inhibition of motor response. When presented with specific stimuli, the subject must issue or inhibit a response.[21] The stimuli used in this experiment are called Go and No-Go.

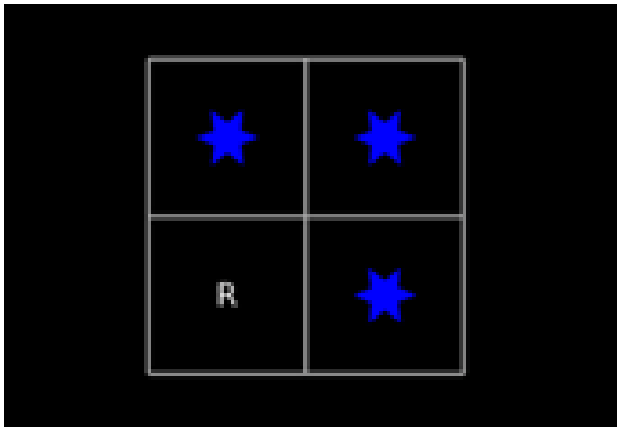

Figure 2. Presentation of the Go/No-Go Experimental Task

For the first ones, the subject must respond by pressing a button every time he is exposed to one. On the other side, for No-Go stimuli, the participant must inhibit a response (he doesn't answer) when exposed to them. The ratio of appearance of each type of stimuli is 80% Go and 20% No-Go stimuli, presented randomly.

The Go/No-Go experiment selected for the study was the one proposed by the Psychology Experiment Building Language (PEBL, Figure2),[22,23] which has two positive qualities worth highlighting. Firstly, it is of free usage, which makes it accessible in the Ecuadorian clinical context and especially for the development of thesis or research studies in the context of mental health sciences. Secondly, it is an open code, which permits to configure the experiment based on the needs of the scientific in charge of it.

SIMON Task

It is an experimental task that allows to value the tendency of an individual to behave automatically.[24] For this test, a stimulus is presented in a determined visual hemifield and with a color answer: if it is blue the answer must be done with the right hand and if red with the left hand. In this experiment, the subject must activate the inhibition of an automatic response since if the red stimulus is presented in the right hemifield; there is a tendency of responding with the right hand. However, this tendency must be inhibit and the participant must respond with his left hand.[5]

As with the prior task, the SIMON experiment (Figure 3) used was from the PEBL system,[22,23] which includes 140 trials, which are presented randomly during the experiment and which take around 6 minutes to perform. The stimuli presented are two blue and red circles that appear on the left, central and right side of the screen of the participant. The response must be done in terms of the color of the circle and not its location on the screen.

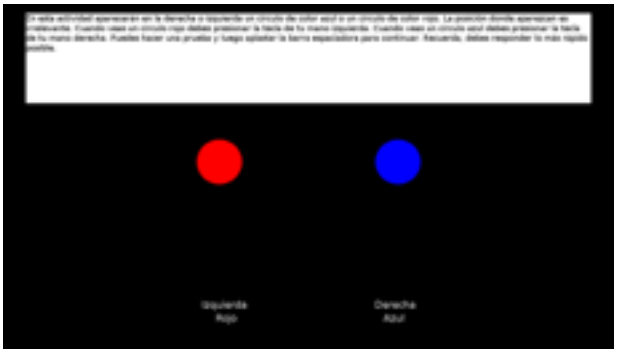

Figure 3. Presentationof the SIMON Experimental Task

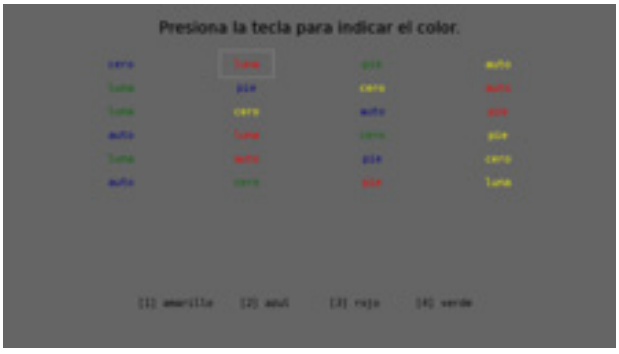

Figure 4. Presentation of the Stroop Victoria Experimental Task

Stroop Victoria Task

This experiment consists of three phases; each one has 24 stimuli (Figure 4). In the first phase the participant must answer with the color of each of the presented circles (yellow, blue, red and green). For the second one, they respond with the ink color of the four written words (zero, moon, car and foot). The third phase includes an interference stimulus. Here the participant must indicate the color of the ink of the written word. Opposed to the prior two stages, here the subject must inhibit the tendency of automatic response that arises when reading each word since he can find the word yellow written in red ink. He then needs to inhibit his automatic reading tendency and respond with the color of the ink.[25]

Adaptation Process

The first step followed to start with each experimental task was to translate into Spanish each of the instructions since the only available versions of the experiments in the PEBL system were in English. As mentioned before, the PEBL system advantage is its open code, so all changes were introduced in this configuration. Figure 5 shows an example of modified code.

Once the experiments had the appropriate linguistic conditions, an expert review followed in order to perfect the presentation of instructions, stimuli and other information included in each experiment. Then a pilot study was made with 20 subjects, which did not participate in the study, with who we were able to perfect each task. Finally, we proceeded with the application of the tasks to the sample population of our research.

Research Design

The current study is a transversal quantitative research with correlational,[26] which purpose was to adapt and validate three experimental tasks essential for the neuropsychological evaluation of inhibitory and interference control.

Data Analysis

Descriptive statistics techniques were applied based on central tendency and dispersion measurements. Furthermore, inference techniques of correlation and measurement comparisons were used, considering sociodemographic variables of participants as comparison factors.[27]

Procedure

Once the experimental tasks passed the expert review and the pilot study, they were applied individually to the participants in a distraction free environment and under the direction of the research team of this study. It is important to mention that during the entire time of the study, all Helsinki ethics standards for research with human beings were respected. Each participant signed an informed consent form; their collaboration was voluntary and they had the freedom to withdraw from the study at all times. Their physical and psychic integrity was always respected and the information obtained was

Figura 5. Source Code for PEBL system

Table 1. Descriptive Statistics.

	ENG	TRGN	EIST	TMST	TES	TRS
Media	39,41	729,84	2,51	84,32	16,55	851,58
Standard Deviation	22,61	1561,42	2,83	16,81	12,85	231,47
Minimum	6	388,02	0	43	2	457,87
Maximum	153	14584,59	12	176	72	1769,76
Percentiles 25	23,00	493,57	,00	76,00	9,00	699,57
50	35,00	549,78	1,50	79,00	13,50	809,66
75	50,75	613,28	4,00	87,00	21,25	970,70

Key: TRS (reaction time in milliseconds for SIMON experiment), TES (total errors for SIMON experiment), EIST (errors facing interfering stimuli for STROOP experiment), TMST (total movements made in the STROOP experiment), ENG (errors made with No-Go stimuli during the Go/No-Go experiment) and TRGN (reaction time in milliseconds for Go/No-Go experiment).

handled with absolute confidentiality.[28] Furthermore, we need to point out that this study to adapt three experimental tasks belongs to a broader research that analyzed the inhibitory control of children with attention-deficit disorder with hyperactivity.

Results

Table 1 shows the general descriptive statistics results obtained for each of the experiments and table 2 exposes the statistics obtained according to the participants' gender.

Figure 6 shows the obtained scores in the errors committed with the interference stimuli of the SIMON experiment, with the intrusion stimuli of the STROOP VICTORIA experiment and the total errors found in the Go/No-Go experiment, according to the age group of the participants.

Once the descriptive statistics analysis was made, a correlation process was applied between all the measures obtained in the experiments. Table 3 shows all correlation coefficients with their respective significance, obtained by crossing the different variables.

Discussion and Conclusions

The current study reports the customization made for three experiments essential for the neuropsychological evaluation process of executive functions, specifically those related to inhibitory control and interference control in a sample of Ecuadorian students.[29]

Table 2. Descriptive Statistics using gender as a comparison factor.

Indicator	Media	Standard Deviation	Average Comparison
ENG Men	42,96	21,57	t=1,66 p=0,10
ENG Women	35,50	23,22	
TRGN Men	534,35	76,95	t=-2,53 p=0,01
TRGN Women	583,51	97,39	
TES Men	15,85	8,30	t=1,59 p=0,12
TES Women	13,00	7,45	
TRS Men	806,73	179,56	t=0,09 p=0,92
TRS Women	810,68	176,23	
TMST Men	83,94	17,22	t=-0,23 p=0,81
TMST Women	84,83	16,48	
EIST Men	2,02	2,28	t=-1,84 p=0,07
EIST Women	3,17	3,35	

Key: TRS (reaction time in milliseconds for SIMON experiment), TES (total errors for SIMON experiment), EIST (errors facing interfering stimuli for STROOP experiment), TMST (total movements made in the STROOP experiment), ENG (errors made with No-Go stimuli during the Go/No-Go experiment) and TRGN (reaction time in milliseconds for Go/No-Go experiment).

The contribution of this study for the neuropsychology research line in Ecuador lies in the possibility to rely with reactants free of use to be applied in further research in the Ecuadorian context. All three experiments analyzed in this study can be use free of charge and can be modified according to the purpose of the research.

With respect to the obtained results, we need to point out that there were not significant statistical differences for most measured variables of the experiments when they were compared according to the gender of the participants. The result is in agreement with prior research where such comparison was also made.[30]

When measuring the errors made when exposed to stimuli where the response had to be inhibit, it was found that all results tend to improve as they are in a later stage of their childhood stage.[31] Nevertheless, scores decrease again when teenage stage begins where the number of mistakes before stimuli where automatic responses had to

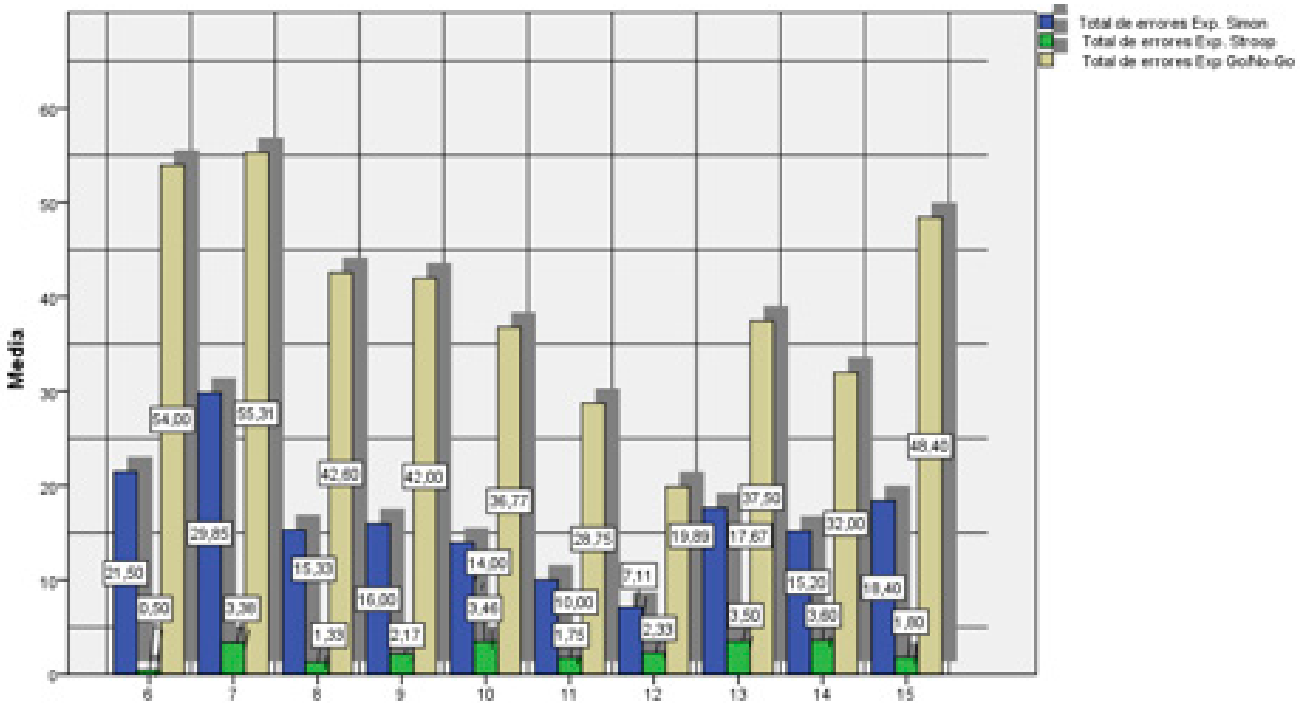

Figure 6. Descriptive values considering the age group of participants. Blue: total errors for SIMON experiment. Brown: errors made with No-Go stimuli during the Go/No-Go experiment. Green: errors facing interfering stimuli for STROOP experiment.

Tabla 3.

		TRS	TES	EIST	TMST	ENG	TRGN
TRS	Correlation	1					
TES	Correlation	,278	1				
	Sig. (bilateral)	,011					
EIST	Correlation	,064	,108	1			
	Sig. (bilateral)	,567	,335				
TMST	Correlation	,259	,269	,556	1		
	Sig. (bilateral)	,019	,015	,000			
ENG	Correlation	,445	,471	,086	,137	1	
	Sig. (bilateral)	,000	,000	,442	,220		
TRGN	Correlation	,304	,277	,175	,417	-,080	1
	Sig. (bilateral)	,006	,012	,119	,000	,476	

Key: TRS (reaction time in milliseconds for SIMON experiment), TES (total errors for SIMON experiment), EIST (errors facing interfering stimuli for STROOP experiment), TMST (total movements made in the STROOP experiment), ENG (errors made with No-Go stimuli during the Go/No-Go experiment) and TRGN (reaction time in milliseconds for Go/No-Go experiment).

be inhibited increased. This is characteristic of the teenage years where the level of impulsivity tends to increase.[32]

In terms of the association of measurements, we found that, for the great majority there is a statistically significant correlation, which means that the valued variables between the different experiments measure a similar aspect of the inhibitory and interference control. Only the errors of intrusion obtained in the last phase of the Stroop experiment did not correlate with the rest of the scores. This has a statistical explanation since the rest of the measurements had a greater variability, opposed to what was found with Stroop. Moreover, other research has justified this lack of association because the Stroop experiment acts in a different level of inhibitory and interference controlled when compared to the Go/No-Go and Simon experiments.[13]

Finally, it is important to set the path that needs to be followed in neuropsychological research field in Ecuador which is in its early steps. There is still a lot to contribute in the validation of measurement reactants, so further research that is consequent from this study lies in the analysis of more experimental tasks and traditional pencil and paper tests in addition to the development of neuropsychological evaluation scales designed by dominating behavioral reporting.

If any researcher is interested in using the experiments described in this paper, they can be downloaded free of charge in the following links:

- SIMON Experimental Task: https://www.dropbox.com/sh/gseb4p4i99e6iwd/AABBPCGg4zsm0jIPbTd6L2OIa?dl=0
- STROOPVICTORIAExperimentalTask:https://www.dropbox.com/sh/n9yg7m2ms5s70lb/AAByjvxC8J4U7vs3h5TbPhp_a?dl=0
- GO/No-GO Experimental Task: https://www.dropbox.com/sh/k3awgvz7u2e3hjg/AABDrcqQ0tibYf2b1NsfZ0Eka?dl=0

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