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PERFORMANCE OF OLDER ADULTS AND COLLEGE STUDENTS IN A TASK OF REVERSAL LEARNING

DESEMPEÑO DE ADULTOS MAYORES Y UNIVERSITARIOS EN UNA TAREA DE REVERSIÓN DE APRENDIZAJE

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Resumen

El envejecimiento de la población se acompaña de varios desafíos que incluyen comprender los efectos del envejecimiento normal en las funciones cognitivas, incluida la flexibilidad cognitiva, la capacidad de cambiar el curso de una actividad para adaptarse a los cambios en la demanda de la tarea. Este estudio comparó el aprendizaje y la reversión de discriminaciones visuales simples en dos grupos de participantes sanos de diferentes edades. Doce estudiantes universitarios (18 a 24 años) y 13 adultos mayores sanos (60 a 77 años), todos con al menos 12 años de educación, aprendieron tres discriminaciones visuales

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simultáneas simples, seguidas de tres pruebas sucesivas de inversión de función de estímulos. Todos los participantes aprendieron las discriminaciones. Todos los jóvenes lograron el criterio en las reversiones, pero solo siete adultos mayores lograron el criterio en estas pruebas. Entre los adultos mayores que no alcanzaron el criterio, un patrón de errores no perseverativos fue el más común, con un rendimiento que disminuyó durante la exposición a las pruebas de reversión. Este patrón sugiere dificultades para establecer nuevas relaciones entre los estímulos y sus consecuencias en las reversiones. El envejecimiento normal parece afectar el desempeño de algunos adultos mayores en las tareas de reversión de discriminación.

Palabras clave: flexibilidad cognitiva; aprendizaje reversa; discriminación visual simples; control de estímulos; adultos mayores sanos.

Abstract

Population aging is accompanied by several challenges that include comprehending the effects of normal (healthy) aging on cognitive functions, including cognitive flexibility - the ability to change the course of an activity to adapt to the changes in the demand of the task. This study aimed to compare the learning and reversal of simple visual discriminations in two groups of healthy participants, matched in relation to education, however, differing in age. Twelve college students (aged 18 to 24 years) and 13 healthy older adults (aged 60 to 77 years), all with at least 12 years of education, learned three simple simultaneous visual discriminations, followed by three successive stimulus function reversal tests. All the participants learned the discriminations; however, only seven older adults achieved the criterion in the reversal tests. All the young participants achieved the criterion in the reversals. Among the older adults that did not achieve the criterion, a non-perseverative error pattern was the most common, with performance declining during the exposure to the reversal tests. This pattern suggests difficulties in establishing new relations between the visual stimuli and their consequences in the reversals. Normal aging seems to affect the performance of some older adults in discrimination reversal tasks.

Keywords: cognitive flexibility; reversal learning; simple visual discrimination; stimulus control; healthy older adults.

Cognitive flexibility has been defined as the ability to adapt the way of describing or responding to situations, changing, as a result, the course of an activity to adapt to changes in the task demand (Johnco, Wuthrich, & Rapee, 2014; Kortte, Horner, & Windham, 2002). It therefore consists of adapting behavior to changes in the environment: when, for example, a stimulus suddenly ceases to be associated with a particular reinforcer, the organism must adjust its behavior according to this change. If the organism is strongly influenced by the history of previous reinforcement, its adjustment to the new contingencies will be slow. If, on the other hand, it learns to benefit from changes in the reinforcing value of a stimulus, it will be able to adjust its performance to the new contingencies more rapidly, learning to ignore irrelevant cues or to quickly inhibit the behavior previously presented (Rayburn-Reeves, Molet, & Zentall, 2011).

Studies with healthy older adults have indicated that aging can negatively affect cognitive flexibility (Rhodes, 2004), with the most common way to assess this function being through neuropsychological tests. In general, these tests involve switching between categories. The tests most used for this are the Wisconsin Card Sorting Test, the Trail Making Test and its correlate, the Color Trail Test. Some studies have indicated, however, that the performance of individuals in these tests is correlated with the level of education of the subjects (e.g., Zimmermann, Cardoso, Trentini, Grassi-Oliveira, & Fonseca, 2015), since the nature of the tasks presented can favor individuals with higher education levels (Ardila, Ostrosky-Solis, Rosselli, & Gómez, 2000).

The task of learning and reversal discriminations has also been widely used as a model for studying cognitive flexibility (for a broad review of the discrimination reversal procedures employed and the neural and neurochemical mechanisms studied in performing the task, see Izquierdo, Brigman, Radke, Rudebeck, & Holmes, 2017). In its least complex version, a set of simple visual discriminations are taught to individuals and, without indicating, the reinforcement contingencies are reversed: responses that were initially correct start to result in errors and vice versa. In this task, the presentation of "flexible" behavior requires changing an initially learned pattern of responding, as well as discriminating any cues that indicate the change in ongoing contingencies and which require a change in the pattern of responding (D'Cruz, Mosconi, Ragozzino, Cook, & Sweeney, 2016).

According to Lionello-DeNolf, McIlvane, Canovas, de Souza and Barros (2008), the repeated reversal of these contingencies allows two points to be verified. The first is whether, over the course of the discriminations, individuals would become more efficient in adjusting to the new contingencies. The second is whether, without explicit and additional training, exposure to the differential consequences for correct responses and errors in relation to some members of the sets in the reversed contingencies would lead to a "spontaneous" reversal of the discriminative function for the other members of the sets. It is then possible to verify whether a variable applied to one of the stimuli in the set will have an effect on responses directed toward the other members of that set.

This procedure has been widely used in recent decades for the investigation of conceptual learning in several species of non-human animals, such as pigeons (e.g., Vaughan, 1988), sea lions (Kastak, Schusterman, & Kastak, 2001), rats (e.g., Dube, Callahan, & McIlvane, 1993; Nigrosh, Slotnick, & Nevin, 1975) and monkeys (e.g., Barros, Souza, & Costa, 2013), and also with humans. With the latter, reverse learning procedures have been widely used to characterize patterns, whether altered or not, of responding to the task in individuals with neuropsychiatric disorders, such as Parkinson's disease (Swainson et al., 2000), obsessive-compulsive disorder (Remijnse et al., 2006), schizophrenia (Leeson et al., 2009) and autism (Coldren & Halloran, 2003; D'Cruz et al., 2013; Lionello-Denolf et al., 2008). Some of the studies with children with autism investigated the brain circuits involved in the reverse learning performance. These studies suggest that activation patterns found (or not) in individuals with autism may indicate reduced sensitivity to reinforcement, which could lead to perseverative patterns of behavior (D'Cruz et al., 2016; Scott-Van Zeeland, Dapretto, Ghahremani, Poldrack, & Bookheimer, 2010), which would explain the apparent cognitive inflexibility in these individuals.

Despite the use of the reverse learning task for the study of individuals with different developmental profiles, the only study to our knowledge that used the task of learning and reversal discriminations similar to that proposed by the present research to investigate cognitive flexibility in healthy older adults was that of Mell et al. (2005). This study compared the performance of 20 young and 20 older (mean age of 67 years and about 14 years of education) adults in a probabilistic object reversal task. In this task, four out of six letters (e.g., C, F, H, N) were displayed on a computer screen. The participant chose one of these letters with a mouse and, for each letter, could receive 40, 20, 0, -20 or -40 points. Each letter was stochastically associated with a different probabilistic magnitude of points. For example, the selection of the letter N was followed by obtaining 40 points in 80% of the choices and 20 points in the remaining 20% of choices. The scoring scheme changed after the participant achieved a learning criterion (after receiving the maximum score in six to eight successive trials), in such a way that another letter was associated with the maximum score.

In the study by Mell et al. (2005) the older adult participants received significantly fewer points than the young adults and required a greater number of trials to achieve the learning criteria, as well as successfully completing fewer trial blocks and making more random errors (i.e., random, that could not be characterized as perseverative errors) compared to the young adults. The authors interpreted the results as failures to establish new relations between a stimulus and its consequence (stimulus-reward association): the older adults would have difficulties in relating new stimuli to the reinforcement consequences, which did not mean that they tended to persevere in the choices previously reinforced with the maximum number of points, therefore the errors were characterized as random. This study showed that healthy older adults had more difficulties in reversing established discrimination, however, the nature of the task prevented the analysis of the learning process or the deterioration of the participants' performance.

The present study, in addition to proposing the expansion of the investigation of the cognitive flexibility of healthy older adults through a reversal learning task, also proposed the analysis of the performance of the older adults throughout the process. Such an investigation is of interest since different patterns of "inflexibility" have been highlighted in the literature. The aim of this study was to compare the learning and reversal of simple simultaneous visual discriminations in two groups of healthy participants, matched in relation to education, however, differing in relation to age - college students and adults over 60 years of age.

Method

Participants

Participants were 25 adults, divided into two groups. The Older Adult Group (OG) was composed of 13 older adults (nine women) aged between 60 and 77 years (mean=65.4; SD=5.6). All had at least 12 years of education, however, the majority (11) had more than 16 years of formal education (mean of 16.5 years). These older adults were recruited from courses open to older adults at the university and from the researcher's contacts. The inclusion criteria in the sample were: being over 60 years of age, having at least 12 years of formal education, not presenting indications of neurocognitive disorders (Mini Mental State Exam score above the cutoff points for cognitive problems), not making use of antidepressant medication or medication that affected the waking state.

The College Student Group (UG) was made up of 12 college students (nine women), aged between 18 and 24 years (mean=19.2; SD=2.0), of the first year of Psychology (first semester of the course) and, therefore, with at least 12 years of formal education. The criteria for inclusion in the sample were: to be over 18 years of age, to be taking the first semester of the course (without contact with academic content that could interfere with the performance), not making use of antidepressant medication or any other medication that affected the waking state.

Each participant was individually informed about the study through a verbal explanation by the researcher regarding the aims and procedures to be adopted and signed a consent form. The study was analyzed and approved by the Ethics Committee for Research with Human Subjects of FFCLRP (CAAE 89585318.1.0000.5407).

Instruments

For the initial assessment of the OG participants, the Addenbrooke's Cognitive Examination - Revised (ACE-R) and the Color Trail Test instruments were applied. The UG participants only completed the Color Trail Test.

The ACE-R is a brief cognitive assessment battery, which assesses five cognitive domains: Attention and Orientation; Memory; Verbal Fluency; Language; and Visuospatial Skills. The ACE-R was developed by Mioshi et al. (2006) and adapted for the Brazilian population by Carvalho and Caramelli (2007), being referred to as a sensitive instrument to detect mild stages of dementia. The ACE-R provides the participant with a score between 0 and 100 points, with 78 being the cutoff point for the diagnosis of cognitive impairment. Each domain has a specific score, with its respective cutoff point: (a) Attention and Orientation - total score: 18; cutoff point: 17 points; (b) Memory - total score: 26; cutoff point: 15 points; (c) Verbal Fluency - total score: 14; cutoff point: 8 points; (d) Language - total score: 26; cutoff point: 22 points; and (e) Visuo-Spatial Skills - total score: 16; cutoff point: 13 points.

As the ACE-R does not allow adjustment of the cutoff for the patient's educational level, the score on the Mini Mental State Examination (MMSE - Folstein, Folstein, & McHugh, 1975) was taken into account. The MMSE is a cognitive screening test widely used to measure cognitive functions of orientation, memory, attention, calculation, language and visual construction. The maximum score of the test is 30 points. The cutoff point for cognitive impairment is 24 points for individuals with more than 4 years of education. The questions of the

MMSE are part of the ACE-R and the scores of the participants in this test were measured based on the application of the ACE-R.

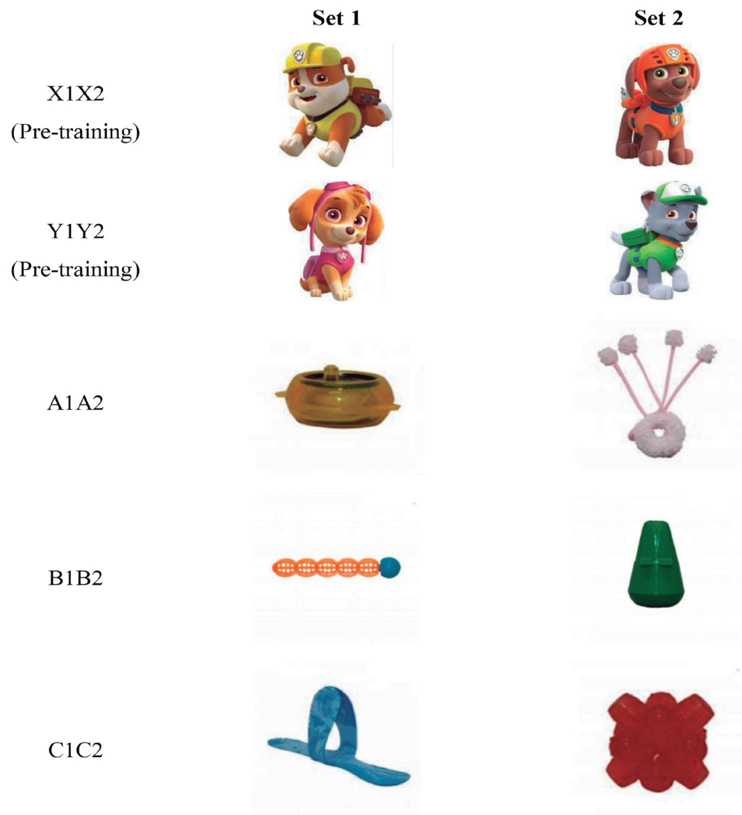
The Color Trails Test (D'Elia, Satz, Uchiyama, & White, 1996) aims to assess divided and sustained attention and was standardized for the Brazilian population by Rabelo et al. (2010). It is applied individually and consists of forms 1 and 2. In part 1, lines need to be drawn to connect circles containing numbers (from 1 to 25), always from the smallest to the largest. In part 2, the same should be done, but alternating the colors of the circles (e.g., 1-Yellow; 2-Pink; 3-Yellow; and so on). The score is determined by the time (seconds) that the participant takes to complete each form (1 and 2), taking into account the number of errors. The raw scores obtained are transformed into percentiles, depending on the age group (60 years or more, according to the standardization of the test), and classified into Lower, Middle Lower, Middle, Upper Middle and Upper. This test is also used as a measure of cognitive flexibility (e.g., Rasquin, Verhey, Lousberg, Winkens, & Lodder, 2002; Votruba, Persad, & Giordani, 2016).

Equipment and stimuli

The procedure was conducted on a notebook (Sony Vaio, with a 15" screen). In the procedure, the stimuli were displayed on the screen and the response choices were given using two buttons on the keyboard: the left arrow button indicated the choice of the stimulus shown on the left of the screen, and the right arrow button the selection of the stimulus presented on the right of the screen. The procedure was programmed in the open access PsychoPy 2 program, version 3.0.6 (Peirce et al., 2019). The program uses the Python programming language.

A total of 10 visual stimuli were used in the simple discrimination trials. Four figures were used for pre-training (figures from a cartoon, used in the initial trials to familiarize the participant with the task and the differential consequences of their choices) and six for the procedure itself (undefined colored forms, i.e., unrelated to any specific name assigned by the verbal community), divided into two sets (1 and 2) of three stimuli. The six undefined stimuli were taken from an open bank of figures, available online (Horst & Hout, 2016). Figure 1 present the stimuli used in the procedure.

Figure 1. Visual stimuli presented in simple simultaneous discrimination trials at different phases of the procedure.



Experimental setting

Data collection with all participants was carried out in a room in a university laboratory measuring 2m x 3m, which contained a table and chairs. The computer on which the procedure was conducted was placed on the table. During the procedure, the participant remained seated in the chair in front of the computer. Initially, the researcher sat next to the participant to give the initial instruction; once the procedure was started, the researcher sat on a chair in a corner of the room, out of the participant's visual field. At the beginning of the procedure, in front of the computer screen that presented two visual stimuli, side by side, the researcher read the following instructions: *"Two figures like these will be shown side by side at the same time on the screen. Only one is correct and you must learn which one is right. The computer will help you by showing a positive sign when you get it right or a negative sign when you get it wrong. To choose the figure on the right, you must press this key (pointing to the arrow key on the right); if you think the figure on the left is correct, press this key (pointing to the left arrow key). Being right or wrong is not related to any specific aspect of the figure - the color, shape or any characteristic of the figure, for example. So it is important that you pay attention to the computer signal after you choose one of these pictures. Do you have any doubts?"*. If the participant had no doubts, the researcher said *"Shall we practice a little?"*. If the participant asked a question, the part of the instruction related to that question was repeated, or the answer was given as briefly as possible, complemented by referring to the information in the initial instructions. For example, if the participant asked "*What is the criterion to be right or wrong?* ", the answer was "*You should pay attention to the positive or negative sign that the computer will show after your choice, because it is this sign that will tell you which is the right or the wrong figure*". After the doubts were resolved, the procedure was started.

Each trial consisted of the simultaneous presentation of two visual stimuli (e.g., A1 and A2) on the computer screen and the participant's response was to press the arrow key on the right or left, depending on the location of the stimulus selected. The figures were presented in the center of the screen, next to each other on a gray background, with a distance of 3cm between them. Correct responses (clicking on the stimulus defined as S^+), were followed by the presentation of a positive sign on a green background (thumb pointing upwards), which occupied almost the entire screen. Incorrect responses (clicking on the stimulus designated as S^-), were followed by the presentation of a negative sign on a red background (thumb pointing downwards), which occupied almost the entire screen. The intertrial interval was 1s. The location of the S^+ and S^- stimuli (right and left) was randomized so that the discrimination occurred in relation to the stimuli and not according to their position.

Procedures

The participants, individually, received an explanation about the study and, afterwards, the ACE-R instrument and the Color Trail Test (Forms 1 and 2) were applied. Then, the procedure was started, which was composed of four phases. At the end of each phase the experiment would end if the participant did not achieved a specified criterion.

Pre-training. The aim of this phase was to teach the participant the task (to inspect the figures on the screen, select and press the key corresponding to their choice and receive differential consequences for the choice - positive or negative sign). Two pairs of training figures were presented (characters from a cartoon); the first pair was presented in successive trials, until the participant achieved six consecutive correct responses (selected the stimulus considered correct). Then, the second pair was presented in successive trials, until the criterion of six consecutive correct responses was achieved. If the participant did not achieve the criterion established with one of the pairs within the limit of 18 trials, the procedure was terminated.

Simple simultaneous discrimination training. The aim of this phase was to teach the participant three simple simultaneous discriminations (A1A2, B1B2 and C1C2). In this phase, the stimuli of set 1 were designated as S^+ and those of set 2 as S^-. Initially, a pair of stimuli, A1 and A2, was presented for 10 consecutive trials, without performance criteria. In sequence, and without any indication, 10 trials with the pair B1B2 were presented, followed by another 10 trials with the pair C1C2 (the set of these 30 trials is called Block 10). Then, five consecutive trials from each pair (Block 5) were presented, then two consecutive trials with each pair, followed by a sequence of six trials alternating the stimulus pairs (Full Baseline). The criterion for ending the phase was that the participants presented 100% correct responses in the six Full Baseline trials. In case of an error, this block of six trials was presented again, with a limit of three presentations. If the participant did not achieve the proposed criterion, the procedure was terminated and the following message was displayed on the screen: *"We are finished! Thank you for participating!"* (closing message). If the learning criterion was achieved, the following message was displayed: *"Congratulations, you are doing great! Shall we continue? Please press the space key to continue"* (continuity message). In this case, the next phase was initiated. The minimum number of trials for this phase was 57.

Intermix. The purpose of this training was to teach participant to respond to the stimuli designated as S^+, regardless of the S^- presented in the trial. For this, 12 trials of pairs not directly trained were presented (e.g., A1B2; B1C2 - always with a stimulus trained as S^+ and another as S^-), with four interspersed trials of each S^+. The performance criterion established was 12 consecutive correct responses, up to the limit of 36 trials. If this criterion was not achieved, the closing message was displayed on the computer screen; if the criterion was achieved, the continuity message was displayed and the next phase started.

Repeated reversals. The aim of this phase was to verify whether the participants would reverse their choices when faced with the change in reinforcement contingencies (i.e., the stimuli considered correct in the previous phase became those considered incorrect and vice versa). The phase started with the presentation of trials in which the stimuli of set 2 (A2, B2 and C2) were considered S^+, while the stimuli of set 1 were considered S^-. The pairs presented were randomized (e.g., A1B2). After 12 consecutive correct responses and without any indication, a new reversal was initiated, that is, the stimuli of set 1 started to be considered as S^+ and those of set 2, S^-. Again, after the criterion of achieving 12 consecutive correct responses, a third reversal came into effect (set 1, S^- and set 2, S^+). In any of the reversals, the procedure was terminated if the participant did not achieve the criterion established in 37 trials (in the same reversal). In this case the closing message was displayed. If the criterion was achieved in the three reversals, the following message was displayed: *"We are finished! Thank you for participating!"*.

After the procedure was terminated (at any stage), the researcher thanked the participants and asked them what they had understood about the task performed. The researcher then answered questions and explained the procedure in general, up to the point that the participant had reached. The conversation always ended with a positive appreciation by the researcher regarding the participant's performance. After this brief conversation, the participants were allowed to leave.

Data analysis

The data related to the execution time of the Color Trails Test (Forms 1 and 2), the percentage of correct responses in the different learning blocks of simple discrimination, the frequency of errors and trials in the reversal tests and the number of breaks in the sequence of correct responses during the reversals were analyzed using a mixed model, applying the Analysis of Variance (ANOVA) for repeated measures, followed by Tukey's HSD follow-up test in the Statistica 7.0 program.

The error pattern of the participants in the reversals was also analyzed in a descriptive manner, by analyzing the distribution of correct and incorrect responses throughout the trials of the block and through cumulative frequency curves of the performance of the older adults that did not achieve the criterion in the reversal tests.

Results

Characterization of the sample

Table 1 presents the general characteristics of the OG participants and their performance in the standardized measures. Eight participants were retired at the time of the study; the rest continued to work regularly. All the participants scored between 28 and 30 in the MMSE (except O1, with a score of 26), therefore, above the cutoff point for cognitive impairment recommended for the test. In the ACE-R, the participants obtained total scores between 81 and 98 points, also above the cutoff point of the instrument for cognitive impairment. In the Color Trail Test, all participants presented an average or above performance: in Form 1, the mean execution time was 61.3s (*SD*=24.4) and in Form 2, 125.1s (*SD*=48.4).

Table 1. Characterization of the Participants of the Older Adult Group (OG)

Participant	*Gender*	*Age*	*Years Scho*	*Profession*	*Occupation*	*MMSE*	*ACE-R*	*CT1*	*CT2*
O1	M	60	17	Manager	Holistic therapist	26	86	30 (U)	124 (UM)
O2	F	60	17	Engineer	Business person	29	90	62 (UM)	110 (UM)
O3	F	68	17	Psychologist	Psychologist	29	98	64 (UM)	100 (U)
O4	F	61	17	Nurse	Retired	29	82	92 (LM)	134 (UM)
O5	F	61	17	English teacher	English teacher	30	90	70 (M)	111 (UM)
O6	F	77	12	Dressmaker	Retired	29	81	104 (LM)	246 (LM)
O7	M	75	20	Professor	Retired	28	95	85(M)	96(U)
O8	F	62	12	Technician	Retired	29	88	46(U)	148 (M)
O9	F	66	17	Professor	Retired	28	89	84(M)	199 (LM)
O10	F	63	20	Lawyer	Retired	29	91	46(U)	100 (U)
O11	M	68	17	Dentist	Retired	28	95	49(U)	75(U)
O12	F	68	17	Dentist	Retired	28	93	36(U)	84(U)
O13	M	61	17	Lawyer	Professor	28	95	30(U)	99(U)
Média		65,4	16,7			28,5	90,2	61,4	125,1

Note: M=male; F=female; Years Scho=years of schooling; MMSE= Mini Mental State Examination; ACE-R= Addenbrooke's Cognitive Examination - Revised (maximum 100); CT1=Color Trial Test, Form 1; CT2=Color Trial Test, Form 2; U=upper; UM=upper middle; M=middle; LM=lower middle.

The UG participants had between 12 and 15 years of education (mean 12.7 years). They only performed the Color Trial Test. The mean execution time for Form 1 was 32.6s (*SD*=5.4 - between 25 and 42 seconds) and for Form 2 the mean time was 60.1s (*SD*=10.2). All presented average or above performance in both forms.

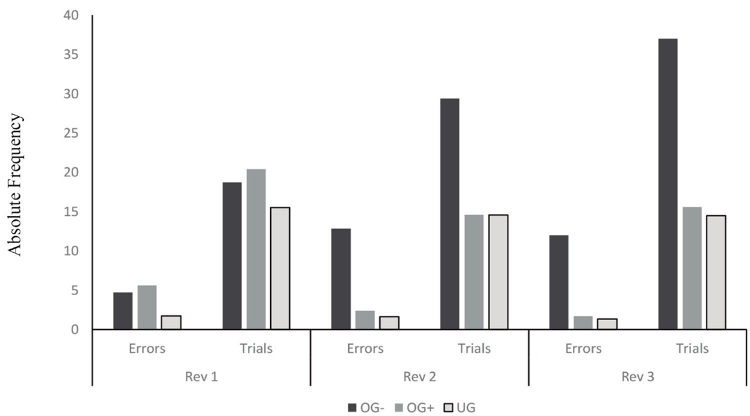
Although the groups did not present any differences when compared to the standardized evaluation patterns of the Color Trial Test, significant statistical differences ($F_{1, 23}$=9.70; *p*=.0048) were found in the comparison of the mean performance times of the groups. When comparing the performance between the forms, both among the college students and among the older adults, it was found that the time for execution was longer in Form 2 when compared to Form 1 (UG - *p*=.016; OG - *p*=.0002). The college students were faster than the older participants in Form 1 and Form 2. The performance of the OG in Form 1 was similar to the performance of the UG in Form 2.

Participants' performances in learning discriminations and reversals

There was no statistical difference between the performance of the OG and UG in learning the discriminations ($F_{3, 69}$=0.426; *p*=.99). All the participants, older adults and college students, learned the three simple discriminations with performances above 90% in all the learning blocks, including in the Intermix. The concentration of errors was significantly higher in Block 10 (beginning of the learning) than in the other blocks (*p*<.05).

In the reversal tests, all participants in the UG achieved the criterion established in the three reversals (12 consecutive correct responses in a maximum of 37 trials). However, only seven of the 13 participants in the OG presented this same performance. Among the participants that did not achieve the criterion in the three reversals, one (O9) did not achieve the criterion in the first reversal; three (O4, O6 and O8) did not achieve the criterion in the second reversal and two participants (O3 and O12) did not achieve this in the third reversal. The participants' performance was then analyzed according to their result in the reversals: Figure 2 shows the mean errors and the mean number of trials performed in each reversal, for the older adults that achieved the criterion (denominated OG+), for the older adults that did not achieve the criteria (denominated OG-) and for the college students (UG).

Figure 2. Mean frequency of errors and mean frequency of trials performed in each of the reversals (Rev), for the older adults group that did not achieve the criteria in any of the reversals (OG-), for the older adults that achieved the criterion in all reversals (OG+) and for the college students group (UG).



Among the OG+ and UG participants, the mean number of errors fell over the course of the reversals, as well as the mean number of trials required for the criterion of 12 consecutive correct responses to be achieved. Although in the first reversal the OG+ had a higher mean number of errors and trials than the UG, this difference practically disappeared in the following reversals. The OG- participants presented, on average, a performance very similar to that of the older adults in the OG+ in the first reversal (mean number of errors and mean number of trials). However, unlike the other groups, the participants of the OG- showed an increase in the mean number of errors and trials in the subsequent reversals, indicating that the difficulties of these older adults in the reversal task increased, rather than decreased, throughout the blocks.

There was a significant difference in the interaction between the reversals and the two groups of older adults ($F_{2,22}$=12.9; p=.0002). In Reversal 1 the performances of OG + and OG- were similar in terms of the number of errors (p>.05), but after Reversal 2, significant statistical differences can be seen, with a greater number of errors in the OG- (p<.05). When evaluating the mean number of trials, there was also a significant difference in the interaction between reversals and the two groups of older adults ($F_{2,22}$=11.65; p=.0004). In Reversal 1 the two groups were similar in the number of trials (p>.05), however, after Reversal 2, statistically significant differences were found, with a greater number of trials for the OG- (p<.05).

Table 2 presents the distribution of errors (in percentage) in each reversal for the UG, OG+, OG- participants.

Table 2. Distribution of the Errors of the Participants (in Percentage) Throughout Each Reversal: Up to the Third Trial (1-3); Between the Fourth and Twelfth Trial (4-12); and from the Thirteenth Trial Onwards (13-). The Participants Were Divided into the Groups: College Students (UG); Older Adults that Achieved the Criterion in the Three Reversals (OG+) and Older Adults that did not Achieve the Criterion in all the Reversal Tests (OG-)

	Reversal 1			*Reversal 2*			*Reversal 3*		
	1-3	4-12	13-	1-3	4-12	13-	1-3	4-12	13-
UG	81	14,2	4,7	90	5	5	76,4	17,6	5,8
OG+	43,5	43,5	12,8	82,3	17,6	0	66,6	0	33,3
OG-	60,7	32,1	7,1	18,7	29,6	51,5	12,5	33,3	58,3

Note: In the OG-, there is no data for O9 in Reversal 2, since this participant ended the procedure in the first reversal; in this same group, there are no data for O4, O6 and O8, since these participants ended the procedure in the second reversal.

Table 2 shows that, for the UG, the highest percentage of errors was always concentrated in the first three trials of each reversal. Some sparse errors occurred throughout the block, however, these errors were concentrated until the 12th trial. For the OG+, it was observed that, in the first reversal, the majority of the errors were concentrated until the 12th trial, with an equal distribution in the initial portion (until the 3rd trial) and middle of the block (until the 12th trial). In the subsequent reversals, the errors tended to be concentrated in the first three trials, indicating learning of the task. In the OG-, however, it was observed that the highest percentage of errors was gradually concentrated in the final part of the block (after the 13^{th} trial) throughout the reversals, indicating the deterioration of the participants' performance: while in the first reversal the highest percentage of errors was concentrated until the 3^{rd} trial (60%), in the third reversal the highest percentage of errors (58%) occurred after the 13^{th} trial.

An additional way to analyze the pattern of errors is to check the number of breaks in the correct sequences (sequences of at least two correct responses, followed by at least one error). A greater number of breaks indicates less perseveration of incorrect performance and more sparse distribution of errors. Table 3 presents these results.

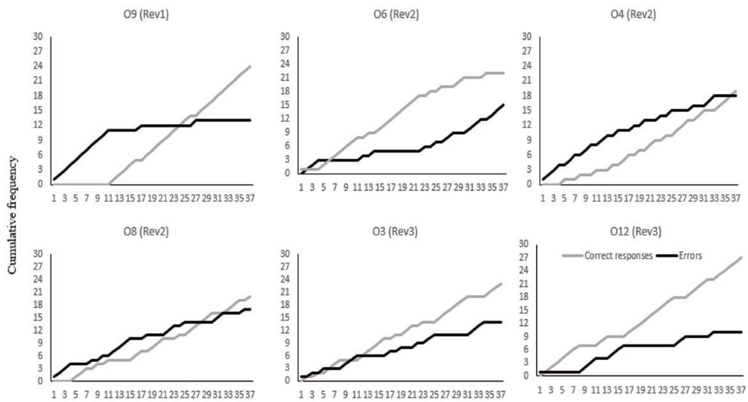
Table 3. Mean Number of Breaks in the Sequence of Correct Responses in the College Students (UG); Older Adults that Achieved the Criterion in the Three Reversals (OG+) and Older Adults that did not Achieve the Criterion in all the Reversal Tests (OG-)

	Reversal 1		*Reversal 2*		*Reversal 3*	
	M	*SD*	*M*	*SD*	*M*	*SD*
UG	0,33	0,49	0,17	0,39	0,33	0,49
OG+	0,71	0,95	0,00	0,00	0,14	0,38
OG-	0,33	0,82	2,67	1,75	3,67	1,03

Note: M=Average; SD=Standard Deviation

There was a significant difference in the interaction between the reversals and the three groups under analysis ($F_{4,44}=14.35$; $p<.0001$): in Reversal 1 the three groups were similar ($p>.05$), however, from Reversal 2, the UG and OG+ groups were statistically similar, with significantly lower values than the OG- ($p<.05$). Unlike the other two groups, the OG- showed a tendency to increase the mean number of breaks in sequence, which suggests an increase in the number of sparse errors for the OG- throughout the reversals. This pattern is clearer for the OG- when the individual performances of these participants were analyzed for the reversal test, in which each participant did not achieve the established criterion, as presented in Figure 3.

Figure 3. Cumulative frequency of errors and correct responses throughout the trials in the reversal test in which the older adult participants (OG-) did not achieve the performance criterion.



It is possible to see that none of the participants maintained a stable pattern of correct responses throughout the block, even when the correct response curve was clearly upward. Participant O9, for example, who did not achieve criterion in the first reversal, presented a sequence of incorrect responses at the beginning of the block. Then, the participant presented successive sequences of correct responses, interspersed with occasional incorrect responses, which did not allow the criterion of 12 successive correct responses to be achieved.

The participants that did not achieve the criterion in the second reversal (O4, O6 and O8) showed an even more unstable response pattern. It was observed that the correct response and error curves remained close throughout the trials, without indicating differentiation of the responding, which suggests that differential consequences programmed for correct responses and errors were not sufficient to reestablish the performance in the discriminations. Participant O6, who also ended the procedure in the second reversal, showed instability in performance at the beginning of the block, however, throughout the trials, presented a perseveration pattern in the incorrect responses, which remained until the end of the test, although with a pattern of negative acceleration from the 20th trial. For O6, the differential consequences programmed also seem to have had no effect on restoring the baseline.

Participants O3 and O12 did not achieve the performance criteria in the third reversal test. Although these participants went through the second reversal with a reduction in the number of errors (three and four, respectively) and trials (20 and 16, respectively), compatible with the pattern of the participants that achieved the criteria in all tests, the performance of both in the third reversal was very unstable. Several alternations of correct response sequences can be observed, followed by short sequences of incorrect responses, although, in general, the correct response curve of the two participants maintained constant acceleration.

Discussion

The result of greatest interest in this study refers to the differences found between the two groups of participants in the reversal tests, after learning the simple discrimination. Despite the two samples being comparable in relation to education and having shown similar performances in the discriminations learning, only seven of the 13 older adult participants reversed their choices from the change in the contingencies of reinforcement in the reversal tests. Although the number of errors in the older adult group as a whole was slightly higher than that of college students in the first reversal, in the following tests there was a clear division in the performance of the participants of the OG: the performance of the OG+ was similar to that of the UG, while the performance of the OG- showed a gradual deterioration in the subsequent reversals. What was found, therefore, was a variability in the performances of the older adult group, with some of them showing performance comparable to that of the young adults, and others significant differences compared to the students and the other older adults. The group of college students, in turn, presented a very homogeneous performance.

Studies on learning and reversal discriminations show improvements in the performance of participants over the exposure to repeated reversals, in studies with non-humans (Barros et al., 2013; Kastak et al., 2001, Vaughan, 1988) and studies with young adults (Rayburn-Reeves et al., 2011) and children (Canovas, de Souza, & Barros, 2013; Lionello-DeNolf et al., 2008; Minto de Sousa, Gil, & McIlvane, 2015; Postalli, Canovas, & de Souza, 2015), possibly due to the formation of a learning set (Harlow, 1949). This change in the performance pattern is easily verified from the number of errors made in the reversal blocks: this number decreases over the course of the reversals, reaching one or a few errors in the final blocks, concentrated in the initial part of the block (first trials). This result was verified in the present study with all the participants of the UG, and with the older adults of the OG+, although the number of errors in the first reversal was greater and the reduction in the number of errors during the reversals was slower for the group of older adults compared to the young adults. However, in the OG- there was a deterioration in performance during the reversals, with a progressive increase in the number of errors throughout the blocks and a distribution of errors that followed two distinct patterns: some older adults showed a perseverative pattern (O9 and O6), while others showed a random pattern of errors, with incorrect responses occurring in a sparse way, after sequences of correct responses.

Perseverative patterns of errors consist of sequences of errors, which occur mainly at the beginning of each reversal (see performance of O9 at the beginning of the first reversal and O6, at two moments of the second reversal). These performances are generally associated with difficulties in adjusting the performance to changes in reinforcement contingencies (set-shifting behavior) (Mell et al., 2005), in such a way that the individual has difficulty inhibiting a previously learned performance. This type of pattern has often been found in research with individuals with autism, in which persistent patterns of errors in discrimination reversal tasks (e.g., Coldren & Halloran, 2003; McEvoy, Rogers, & Pennington, 1993) and in card sorting tasks, such as those presented in the Wisconsin Card Sort Task, are identified (e.g., Reed, Watts, & Truzoli, 2011). In individuals with autism, persistent patterns of errors in experimental tasks have often been associated with inflexible and stereotyped behaviors that are characteristic of the condition (however, see Geurts, Corbett, & Solomon, 2009 for a review questioning these evidences).

In the present study, only two participants showed perseverative patterns of errors, which resulted in failures to fulfill the reversal discrimination criteria, and which could be associated with difficulties in adjusting to changes in the reinforcement contingencies proposed in the procedure. However, it is necessary to consider that O6 only presented this pattern in the second reversal, and not in the first, and that O9 stopped presenting this pattern at the end of the block. The majority of the other OG- participants presented a different pattern of errors.

Random errors (that is, spaced out across the block) are generally associated with decreased sensitivity to the consequences of responding, or, to put it another way, with difficulties in establishing a consistent relation between the S^+ and the reinforcing consequence (Mell et al., 2005) - difficulty in maintaining a new learned pattern. The change in the reinforcement contingencies that occurs in the reversal learning requires individuals to change their pattern of choice under control of both of an indication of an error produced by the response to previously reinforced stimuli, and of an indication of correct responses when choosing the stimulus with the previous S^- function (Izquierdo et al., 2017). This indicates that the consequences of responding to new reinforcement contingencies must exert strong control over the individual's performance. In addition, after changing their response pattern to stimulus sets, it is necessary for individuals to consistently maintain the new pattern of responding (Coldren & Halloran, 2003). For this reason, errors distributed throughout the reversal blocks, as well as repeated breaks in the sequences of correct responses, such as those found in the OG-, indicate that the ongoing contingences were exercising a weak control over the individuals' performance. These results seem to favor the idea that some healthy older adults, during the aging process, have reduced sensitivity to the ongoing reinforcement contingencies, which would cause impairments in tasks that require flexibility, such as reversal learning.

Accordingly, it can be said that some of the older adults that comprised the sample studied here had difficulties in what is usually called "cognitive flexibility" in the reversal of discriminations task, and that the evidence of this reduction in flexibility was: (a) the concentration of a large number of errors (greater than in the young adult group) at the beginning of the reversal blocks for some participants, when the reinforcement contingencies were changed; (b) the deterioration in performance over the course of reversals; (c) patterns of perseverative errors for some older adults, which indicated difficulties in adjusting to the new reinforcement contingencies; and (d) patterns of errors that indicated reduced control by the consequences of current responding, with random errors related to difficulties in maintaining the correct performance after a sequence of correct responses. In general, for the older adults that failed to achieve the criterion in the reversals, the difficulty can be attributed to a difficulty in "learning" an alternative response to that previously reinforced, which would support the hypothesis of difficulty in establishing the S^+ - reinforcement relation.

It is important to highlight that the deficits verified in the performance of the older adults in the OG- subgroup in the repeated reversals were not related to the performance of these older adults in the Color Trail Test (which is commonly used to assess attention and cognitive flexibility), to differences in education levels among the older adults in the group (the sample was matched in relation to this variable) or to eventual cognitive impairments, since no impairments were detected by the MMSE or in the ACE-R. Authors such as Votruba et al. (2016), state that potentially important behavioral deficits may be present in individuals with "normal" scores in the MMSE, however, with impaired performance in tasks that require cognitive flexibility, such as difficulties in decision-making and inability to respond appropriately to new situations.

It is possible that the failures to complete the successive reversal task can be attributed to specific characteristics of the older adults in the OG-, although it is not possible to determine exactly what those characteristics are. However, considering that several studies have registered the decline in executive functions as a whole during the normal aging process (e.g., Drag & Bieliauskas, 2010; Fisk & Sharp, 2004; Zelazo, Craik, & Booth, 2004), it seems important to more widely investigate whether the failures recorded here can (or cannot) be attributed to aging and which behavioral processes could be directly involved in the task. The performance variability found among the older adults in the OG- subgroup (e.g., phase in which performance deterioration occurred, type of error presented) suggests that different processes can contribute to the performance of the task in different ways. Identifying these processes and determining their role in performing the task is an objective for future research. In addition, the sample studied here, despite being homogeneous in relation to education, presented considerable variability in relation to other relevant variables, such as age or current occupation. Future studies should determine whether these variables are relevant to the performance of the reversal learning task, with the increase and stratification of the sample of older adults.

Population aging is a phenomenon of great social and economic importance. Despite the expressive number of studies dedicated to studying the effects of aging on the so-called cognitive domains, there are still a series of important questions with no clear answers. The results presented and discussed here indicate that the reversal discrimination task can provide relevant information about specific difficulties encountered by older adults during the aging process and that may be of interest for deepening the study on the way individuals deal with tasks that require performance reversibility.

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