AGE EFFECTS ON CONTEXTUAL IMPLICIT LEARNING

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BUCARAMANGA

OCTOBER, 2017

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Abstract

New studies suggest that cognitive control interferes in automatic and implicit processes, including creativity, problem solving, and statistical learning. Furthermore, studies have proven that cognitive control decreases as people age; therefore, automatic and implicit processes are favored. This research seeks to determine the effect of decreased cognitive control on implicit contextual learning task-related performance by comparing a group of young adults with an older adults group. We found that there is not a significant difference in performance between young and old adults groups $t(38) = .261$, $p = .795$. These results suggest that the contextual cueing effect is preserved through the lifespan.

Resumen

Nuevos estudios sugieren que el control cognitivo interfiere en procesos automáticos e implícitos, incluyendo la creatividad, resolución de problemas y aprendizaje estadístico. Adicional a esto, varios estudios han comprobado que el control cognitivo disminuye a medida que las personas envejecen, por lo tanto, los procesos automáticos e implícitos son favorecidos. Esta investigación busca determinar el efecto que tiene el bajo control cognitivo en el desempeño de tareas de aprendizaje contextual implícito, comparando un grupo de adultos jóvenes con uno de adultos mayores. Encontramos que no existe una diferencia significativa en el desempeño de la tarea "Contextual Cueing" entre el grupo de adultos jóvenes y adultos mayores $t\ (38) = .261$, $p = .795$. Estos resultados sugieren que el efecto "contextual cueing" es preservado a lo largo de la vida.

Introduction

People have limitations to process natural day-to-day information, which can be constantly competing for attention; it is overwhelming and most of it irrelevant to achieve goals. To face this challenge, cognitive systems use complex mechanisms to filter irrelevant information (Pashler, 1998; Yanyis, 1998).

The ability to limit attention, generally referred to as "cognitive control", contributes to improve the performance on goal-driven tasks, enhancing the accomplishment of different day-to-day chores (Eich et al., 2016). This process enhances attention known as "top down" which prepares and applies goal-directed selection for relevant stimuli.

However, several lines of evidence indicate that there are functions that require little to no cognitive control. According to Amer, Campbell & Hasher (2016), poor cognitive control reinforces some types of learning, memory, and problem-solving context skills. One example of the effects of this ability is language acquisition in infants, given that they are able to extract and interpret a complex auditory stimuli structure, learning a new language faster than adults.

Thus, low levels of cognitive control can increase performance on open-ended tasks that require information from different sources, like contextual cueing (Chung & Jiang 1998). Chun and Jiang (1998) studied contextual cueing by examining how visual context is learned and how it affects visual processing. They developed a visual task that consist on presenting displays containing one target (letter "T") embedded among distractors (a letter "L" rotated on 90°,180°,270°). Half of the displays were made of an arbitrary configuration of elements while the remaining displays kept the initial configuration. This study proved that the repetition of an invariant configuration can form an implicit visual memory, which guides the attention towards a specific target. Consequently, this contextual learning allows the subject to predict target locations.

Furthermore, several studies have attempted to identify the brain regions involved in contextual cueing and cognitive control. On one hand, Preston and Gabrieli (2008) have shown evidence that contextual cueing relies on the mediotemporal lobe cortex and the hippocampus, both critical regions for associative memory (Chun & Phelps 1999). On the other hand, according to Eich, Qolamrea & Yaakov (2017) cognitive control activity has been associated with superior parietal lobe activation, becoming a set of frontoparietal regions that regulate income of sensory information and decrease the disruptive effect of irrelevant stimuli (Amer, Campbell & Hasher 2016).

Taking aging as a model of varying cognitive control (Amer, Campbell & Hasher 2016) young adults evidence high levels of cognitive control and old adults present a diminished performance on tasks that imply cognitive control. This study seeks to contribute to the understanding of memory-guided attention, by identifying if performance on the contextual cueing task is significantly better in old adults rather than in young adults.

Problem Statement

Cognitive control is a process that remains in continual change and development during the lifespan of every individual. This process has been largely studied on both older and younger adults. Several studies have found that younger adults have the ability to concentrate on a particular goal, to attend selectively to stimuli and make decisions in line with current tasks (Craik & Bialystok 2006).

The frontal lobes are among the first cortical areas to be impaired in aging. Therefore, implicit processes are favored and frontally mediated executive functions show a gradual decline in the course of aging (Amer, Campbell & Lynn Hasher 2016).

Cognitive control processing has been largely studied in both older and younger adults. Several studies have found significant differences regarding cognitive control and implicit processes between old and young adults, but there are not studies about age-related differences on implicit context-dependent memory (Craik & Bialystok 2006).

Performance in the contextual cueing task is enhanced when the individual favors implicit processes such as implicit contextual memory (Chun & Phelps 1999). Therefore, the present study aims to identify whether performance in the contextual cueing task is enhanced when the subject has low cognitive control, using aging as a model of reduced control.

Research Question

Are there age-related performance differences in the contextual cueing task?

Hypothesis

Performance in the contextual cueing task is significantly higher in older adults than in younger adults.

Null hypothesis

There is no significant difference in contextual cueing task performance in old and young adults.

Justification

Contextual learning is a process that has only been recently studied. This process occurs unbeknownst to ourselves, and through it, we forge spatial memories with the purpose of finding regularities, similarities, or patterns on our daily context to guide our behavior towards a successful interaction with our environment (Chun & Phelps, 1999).

In order to evaluate contextual learning, Chun and Jiang (1998) created the contextual cueing task. This task seeks to examine how learning visual contexts can guide attention towards a relevant target, which they operationalized as the contextual cueing effect. Said task has been used on several studies regarding control subjects, amnesic patients, and patients with hippocampal damage in order to assess and understand the complex mechanisms underlying the contextual cueing effect. One of the many hypotheses they made about the contextual cueing effect's performance involved cognitive control influence (Chun & Jiang, 1998). According to these authors, low cognitive control would lead to a better performance on the task; this implies that people with lower cognitive control, like infants or older adults, would have an advantage creating contextual memories. Nevertheless, there are not many studies that seek to identify whether cognitive control plays an important role in contextual cueing task performance. Moreover, older adults are characterized by memory and learning processes difficulties and this population is projected to represent 16,7% of the Latin American and Caribbean population by 2030 and 25,1% by 2050 (CEPAL, 2013). In conclusion, we consider that this study is relevant to contribute to the general knowledge about contextual learning and memory-guided attention as well as how these processes operate in populations of older adults.

Objectives

General objective

Identify performance differences in young and old adults in the contextual cueing task.

Specific objectives

- Record reaction times and correct response percentages in the Contextual Task Cueing Task and Posner cueing task.
- Compare the differences between reaction times and percentages of correct responses per group of participants.

Background of the study

Implicit learning has been studied over past decades by different authors (Hasher, Zacks & May, 1999; Chun & Jiang 1998; Robinson & Unsworth 2017). Recent studies suggest that visual memory and implicit learning can conduct attention towards relevant aspects of a scene (Chun & Jiang 1998).

Furthermore, according to Hasher, Zacks & May (1999), inhibitory selection performance decreases during the life span and plays a critical and causal role in age-related memory deficits. Older adults have a decreased ability to inhibit stimuli during encoding (Eich et al 2016), and this increases performance on implicit learning processes. One of the base studies for this theory was carried out by Chun & Phelps (1999); they administered the contextual cueing task to amnesic patients (age range 41 to 55 years) who had hippocampal damage confirmed by MRI. All patients scored a mean of 99 in the Weschler Adult Intelligence Scale, 50-57 in the Weschler Memory-Scale Delay subtest, and normal in the Wisconsin card sorting task of frontal lobe functioning compared to a group of 10 control subjects. They found that amnesic patients didn’t evidence the contextual cueing effect, which proves the importance of the hippocampus and its surrounding medial temporal lobe structures in implicit contextual encoding and also reinforces the idea that implicit learning guides attention towards specific locations.

Following studies have adopted this theoretical framework. For instance, Peterson & Kramer (2001) analyzed the role of recognition and guidance on contextual cueing by monitoring eye movements. The sample consisted of eighteen students (6 males and 12 females), who answered the contextual cueing task while being eye monitored by Eyelink tracker; this tracker recorded pupil size, head motion, and response time. They found that contextual cueing is automatic and doesn’t require specific patterns to guide attention towards new information and it happens before any conscious recognition.

Moreover, prior theories about implicit learning and cognitive control have been closely tied to the contextual cueing paradigm. Chun & Jiang (1998) suggest that executive functions could play a causal role on poor performance in the contextual cueing task, given that strong inhibition mechanisms would inhibit untrained locations in old configurations.

Recent research is oriented towards providing an empirical basis of executive function organization, such as the study conducted by Miyake et al. (2000), which examined the three frequently postulated executive functions: Shifting information, updating responses, and inhibition. For this purpose, they used a hundred and thirty-seven college students and applied a set of frequently used executive tasks: Tower of Hanoi, Winsconsin card sorting, and random number generation. Using factor analysis, they determined that the three executive functions are correlated to each other. In short, executive functions that enhance cognitive control, such as shifting information, updating responses, and inhibition, can become a downside on performance for implicit tasks.

Furthermore, a large number of researchers have studied perceptual and memory inhibition in adults. Eich et al. (2016) studied the time line where inhibition can occur in memory processing and how it could affect memory decline. They concluded that older adults have a lower ability to inhibit items from their memory, and that difference was even bigger when subjects had to inhibit irrelevant information. The sample was 23 young adults and 22 clinically healthy older adults. On the first task, subjects completed two behavioral tasks engaging memory and perceptual inhibition. In both tasks four words were presented, two in red and two in blue proceeded by a test probe. Subjects were instructed to remember the colors, which appeared right before the word set, causing the inhibition of irrelevant stimuli. Later, on the memory recognition task, the instruction was given after the stimuli display. Subjects were requested to answer by pressing the "1" key if the answers matched the requested instruction and "0" if they did not match. Memory and inhibition task blocks were alternated among sixteen trials. Answers and response times were analyzed using ANOVA. These results indicate that decreased cognitive control could benefit performance for implicit memory tasks.

A year after, a group from Columbia University, Eich, Qolamreza, Razlighi & Stern (2017) implemented the same instrument to study perceptual and memory inhibition in adults. The study was oriented to find if differences on individual performances could be attributed to cortical thickness of a specific area. For this purpose, they used both behavioral tasks applied on their previous study (Eich et al, 2016) while applying fMRI on a sample of twenty-one clinically healthy older adults (male and female). They found that lower memory inhibition is linked with reduced cortical thickness in the ventral lateral prefrontal cortex (VLPFC).

Therefore, even though a large number of studies have analyzed both implicit tasks and cognitive control in older adults, not many of them have investigated age as a performance variable. Chun & Jiang (1998) hypothesized that high cognitive control could be one of the main reasons why subjects had a poor performance on implicit contextual memory, and several studies (Amer, Campbell & Lynn Hasher 2016; Eich et al 2016; Hasher, Zacks, & May, 1999) support that old adults have lower cognitive control than young adults. Consequently, in this study we are interested in assessing the effect of age on performance in implicit contextual memory. We hypothesized that performance in the contextual cueing task would be higher in old adults rather than in young adults. Additionally, we measured the effect of age on involuntary attention and attentional focusing, to determine differences in levels of cognitive control in older adults and young adults. We also hypothesized that cognitive control levels, measured as involuntary attention, would be higher in old adults, and attentional focusing would be higher in young adults.

Theoretical Framework

Attention

Attention is a complex neurobiological process that enables subjects to filter relevant stimuli from their day to day scenes, allowing them to adjust their behavior in order to achieve goals (Purves et al, 2008).

The parietal and frontal region, including the visual cortex and motor-related processing areas in the frontal lobe, have an important role in attentional control and maintenance. Attention is controlled by two factors: stimulus salience and task goals (Rosen, Stern, Michalka, Devaney & Somers, 2015).

In the first one, attention is exogenous and also known as bottom-up, given that external stimuli dictate orienting and higher cognitive processes. Attentional shifts are often triggered exogenously by novel stimuli in the environment that happen suddenly or are outstanding, such as a sound, smell or an abrupt movement. Those shifts of attention result in enhanced detection or discrimination of said stimuli, that occurs reflexively through increased activity in the corresponding regions of the sensory cortex. This type of attention is supported by the right ventral system (Purves et al, 2008).

Regarding task goals, attention is endogenous or top down. It’s a less automatic process that relies on internal representations to orientate attention. On visual spatial attention tasks, there is higher activity in the extrastriate cortex that reflects a “preparatory bias”, due to top-down neural signals from the dorsal frontoparietal network that favor the attended location (stimuli to be attended) (Rosen, Stern, Michalka, Devaney & Somers, 2015).

On a day to day basis, both attentional systems, the right ventral system and the dorsal frontoparietal network, come together interacting with the goal of acting as an alerting system to direct attentional neural processing (Purves et al, 2008). This statement suggests the existence of an attentional mechanism that processes and discriminates stimuli through the incorporation of endogenous and exogenous attention.

However, recent studies have brought to light how multiple memory systems, such as explicit and implicit memory, can also control attention: this system is known as memory-guided attention. Memory-guided attention works through an indirect (mnemonic processing) or direct (brain regions affect perceptual processing) route. This mechanism affects attentional focus through implicit contextual memory and sensitivity to prior experience (Rosen, Stern, Michalka, Devaney & Somers, 2015).

Implicit memory

According to Purves, et al.,(2004) “Memory refers to the encoding, storage, and retrieval of learned information”. These authors divide the concept of memory in two main categories: explicit and implicit memory.

Explicit memory refers to the storage of information that is available for consciousness. On the other hand, implicit memory is a category that covers different kinds of processes that do not require conscious contents/effort. According to Purves, et al., (2008) there are three main categories of implicit memory: priming, skill learning, and conditioning. Priming is the change in performance as a consequence of past experiences, and it can be direct or indirect depending on the relation between the stimuli that produce priming and the stimulus produced. Priming is resistant to brain damage, aging, and dementia. Skill learning, on the other hand, requires extensive experience, practice, and perceptual and motor operations; it depends on the basal ganglia and cerebellum structures. Finally, conditioning is the generation of novel responses increased by repetition; this concept is divided into classical and operant conditioning.

Implicit memory supports several cognitive processes, such as context-related memory. According to Baddeley, Eysenck & Anderson (2009) context memory is the unconscious ability to recall environmental information. This process is related to statistical learning where the subject identifies contextual patterns and evokes significant information to be used on a day to day basis. One example of context memory is when people try to retrace their steps after having a long walk, and unbeknownst to the subject, attention and learning structures are identifying and recording significant information that might be helpful in the future.

Cognitive control

Cognitive control is defined as the ability to suppress distractions (sensory information or task-irrelevant stimuli) and selectively focus attention to goal-relevant information.

This ability is regulated by the frontoparietal regions, more specifically the right dorsolateral PFC. (Amer, Campbell & Hasher, 2016).

There are many advantages of increased cognitive control: it allows individuals to preserve pertinent information while dismissing irrelevant items from interfering with working memory and blocking competing memories from memory retrieval processes (Amer, Campbell & Hasher, 2016). Also, it enhances the ability to choose important data in goal-relevant tasks and diminish the impact of distractors, regulating intuitive judgment and decision making.

Nevertheless, reduced cognitive control can gain the upper hand in implicit stimulus-driven tasks. According to Gratton, Lee, Nomura & D'eposito (2013), implicit recognition memory is activated for visual stimuli when cognitive control is reduced, and in implicit settings, these memories are encoded holistically, which means that the encoding process is done without any straightforward strategies.

Furthermore, performance in the detection of statistical patterns in encoded information is significantly higher when subjects have less cognitive control, proving that, in some types of learning, reduced control leads to better results (Aslin, R.N., 2014). Language is a complex assembly of stimuli and, given that infants have an immature PFC and are beginning to develop cognitive control processes, the implicit task of extracting structures from language is greatly benefited (Aslin, R.N., 2014).

Regarding problem solving, recent studies showed that subjects with superior cognitive control fall behind subjects with less cognitive control (measured by working-memory capacity) on mathematical exercises that can be solved using elementary methods; low cognitive control subjects were capable of executing more simple strategies rather than complex algorithms (Beilock, S.L. and DeCaro, M.S., 2007).

Cognitive control through age

To be able to implicitly locate statistical patterns ingrained in observed stimuli is surely one of the greatest advantages of reduced cognitive control or deactivation of the PFC. Taking into account that infants and older adults evidence reduced PFC activation and are more likely to get distracted by incoming stimuli than younger adults, examining cognitive change through the human lifespan is an accurate way to compare performances of higher and reduced levels of cognitive control in implicit stimulus-driven tasks (Amer, Campbell & Hasher, 2016).

There is evidence that, in older adults, cognitive control performance in tasks that require learning new information and minimize age-related forgetting can be improved using the broader attentional field and tendency to process distractors as a tool, adopting reduced cognitive control as an upside for learning (Biss et al. 2013).

Subsequently, Tsvetanov, Mevorach, Allen & Humphreys (2013) examined the interplay between exogenous and endogenous attention by studying the effect of aging over the ability to select stimuli according to their saliency. For this purpose they compared a sample of 24 young and 19 older adults over a selective attention task. The study demonstrates that the ability to inhibit high salient distractors to process low salient targets decreases across the lifespan. In other words, older adults' endogenous attention was further impaired than young adults by incongruent distractors. This finding is congruent with the inhibition deficit theory proposed by Lustig, Hasher & Zack (2007) that states that older adults are less capable of inhibiting irrelevant information. Nevertheless, this study proves that the inhibition deficit in older adults also affects non-spatial selection of local and global forms.

Spatial cueing

The environment is filled with an overwhelming amount of information contending for perceptual awareness (Chun 2000). Even though people attend to critical elements from visual scenes to guide their attention, salient visual cues are not always present in natural scenes. Subsequently, the attentional system relies on other alternatives such as visual context, an element that is influenced by salient information and past experiences; commanding which objects in the visual field should be processed and which should be ignored (Chun, 2000). Furthermore, another function of context is to reinforce recognition of scene-related objects, for instance an office context enhances the perception of a computer. Context also participates in the facilitation of perceptual encoding and identification of object positions.

Moreover, the contextual cueing paradigm (Chun & Jiang 1998) has three main proposals: First, "visual context guides the deployment of visual attention" which suggests that certain contextual components are prioritized upon irrelevant stimuli; implying that humans have the ability to identify meaningful visual patterns in their environment, which determines the way attention would be directed. Second, “contextual knowledge is acquired through implicit learning processes”, this implies that contextual learning is automatic, it occurs without intention of learning, and it is not accessible to awareness. The third proposal states that “memory for contextual information is instance-based” (Logan 1998 cited by Chung & Jiang, 1998), which purposes that automaticity is determined by retrieval of past experiences.

Additionally, several studies have attempted to identify the brain structures in charge of contextual memory using different mapping methods (Cohen & Eichembaum 1993; Chun & Phelbs 1999; Preton and Gabrieli, 2008). Through said mapping methods, they found that the medial temporal lobe and the hippocampus have a major role in contextual cueing, due to its relation to memory processes and binding facilitation of cue configurations (Chun 2000). Furthermore, recent lines of evidence suggest that hippocampal damage generates difficulties in encoding and retrieval of contextual information (Chun, 2000); these findings were also supported by Chun & Phelps (1999) who studied contextual cueing in amnesic patients with medial temporal damage, by applying the contextual cueing task developed by Chun & Jiang (1998).

In short, Chun & Jiang (1998) provide a paradigm about contextual cueing, in which implicit learning and contextual memory have a major role; optimizing cueing and guiding attention towards relevant goals. Attention mechanisms select significant environmental information which leads to optimized learning through time as we interact more frequently with contexts; this process generates visual patterns that minimize the probability of directing attention toward distractors. In other words, contextual information drives memory processes by emphasizing certain stimuli according to past experiences.

Statistical learning

Statistical learning is the general ability to learn about environmental regularities without intention, consciousness or awareness (Fisher & Aslin, as cited by Schwab, 2016), it allows people to establish new routines, social behaviors (Turkbrowne, as cited by Schwab, 2016) and explains how subjects establish a cause-effect relation between events of daily situations (Griffiths & Tenenbaum, 2005 as cited in Campbell et al, 2012). According to Fiser & Aslin (2002) statistical learning processes are controlled by a group of cells in the primary visual cortex and lateral geniculate nucleus.

Even though previous studies have attempted to demonstrate statistical learning, few of them have investigated the conditions where said learning occurs. On a study conducted by Baker, Olson & Behrmann (2004) the effect of attention and perceptual grouping over statistical learning of visual shapes was investigated. For this purpose, they recruited a sample of twenty-four undergraduate and graduate students from Carnegie Mellon University. Subjects were presented with two kinds of stimuli that consisted of shapes that were connected by a bar or disconnected. Connectedness was hypothesized to act as a significant variable that could be easily found over daily natural scenes. Participants were required to indicate the location of the presented stimuli. They found that subjects had a better performance finding connected stimuli, proving that statistical learning is not only a passive process but can also be affected by connectedness.

Several studies have attempted to trace statistical learning origins through the lifespan Saffran, Aslin, & Newport, 1996; as cited by Campbel et al., 2012) finding that 8-month-old infants are capable of identifying sequences between familiar words, but have a poor performance with unfamiliar words. This study underlies de importance of cognitive control on this specific kind of learning. These authors have also hypothesized that a lower cognitive control could improve statistical learning for unexpected stimuli, and in that order of ideas, older adults would have a higher performance in this kind of learning.

Moreover, Fiser & Aslin (2002) studied how infants could use conditional probabilities from natural images in order to develop complex visual representations. For this purpose, they tested a sample of 9-month-old infants over three tests based on the habituation paradigm firstly proposed by Fantz (1964), which describes the occurrence of habituation and recognition over visual responsiveness to context patterns. They found that 9-month-old infants were sensitive to co-occurrence frequency of elements in natural scenes, and that predictability between different elements can be found in conditional probability relations over different context elements. These findings suggest the existence of a unified mechanism to develop internal representations.

Furthermore, subjects differ on the capacity to ignore irrelevant stimuli and this capacity decreases with age (Hasher & Zacks, as cited by Campbell et al, 2012). Generally, higher distractibility would lead to lower performance on certain tasks; however, distractibility can become a benefit, binding distractors with occurring targets using associative information to improve memory performance on implicit tasks (Campbell, Hasher & Thomas, as cited by Campbell et al, 2012). According to Campbell et al, 2012, older adults present higher levels of statistical learning than younger adults, not only encoding more irrelevant information than younger adults (Kim et al;Rowe et., al 2006 as cited in Campbell et al 2012) but also presenting associations between co-occurring distractors and targets. Nevertheless, performance differences can also be explained due to individual differences, age-related deficits, and the different kinds of stimuli used on studies (Campbell, Zimerman, Healey, Lee, & Hasher, as cited by Schwab, 2016).

Variables

Independent variables

- Epoch: A group of five sets made of 20 blocks of 24 displays each on the contextual cueing task. There are four epochs, for this study we contrasted epoch 1 (first five sets of the test) vs epoch 4 (last five sets of the test).
- Age: Subject age range is divided into two groups: young adults (ages 18 to 26), and older adults (ages 61 to 75).
- Context: Items configuration on every display on the contextual cueing task; it can be "New" or "Repeated". New

configurations are randomly generated while repeated configurations maintain the same locations for distractors and have the same layout throughout blocks.

Dependent variables

- Reaction time: Measured in milliseconds, it refers to the amount of time it takes a participant to locate the target on the contextual cueing task, determine its orientation and answer by pressing the correspondent key on the keyboard.
- Attentional focusing: The capacity to focus attention on cues that are relevant to the task performed (endogenous attention). Measured by the contrast of incongruent response time with congruent response time on the Posner cueing task.
- Involuntary attention: It refers to a change in attention when unexpected stimuli appears (exogenous attention). Its measured by the contrast of congruent response time with uncued response time on the Posner Cueing task.
- Contextual Cueing Effect: The difference in reaction time between repeated and new configurations collapsed across epochs 3 and 4 (Chun & Phelps, 1999)

Method

Design and type of study

A mixed 2x2x2 experimental design was used to identify the influence of three independent variables: epoch (3 vs 4), Context (new vs repeated) and age (young vs older adults), over a dependent variable: reaction time on the contextual cueing task. Then, contextual cueing was measured by establishing the difference between performance of new and old conditions after the latter half of the session (epoch 3 and 4) as mentioned on Chun and Phelps (1999). Finally, the relation between age over the contextual cueing effect, age over involuntary attention, and age over attentional focus, was analyzed.

Subjects

For this study, we used a sample of twenty (20) young adults, ages 18 to 25 (10 male and 10 female) average age: 21 years old, enrolled in a Health Sciences faculty undergraduate program from the Universidad Autónoma de Bucaramanga, and twenty (20) older adults, ages 61 to 75 (11 male and 9 female) average age: 66 years old, with minimum technical education level, took part in the experiment. All participants were right handed and had normal or corrected-to-normal visual acuity.

Tasks

Participants performed two tasks: Contextual cueing task, developed by Chun & Jiang (1998) executed on Matlab software (version 7.10.0; The MathWorks Inc.2010). And the Spatial Cueing task developed by Posner (1980).

Contextual Cueing task

Subjects were presented with a display composed by 12 items, 1 target ("T" stimuli) and 11 distractors ("L" stimuli) on a gray background (figure 1).

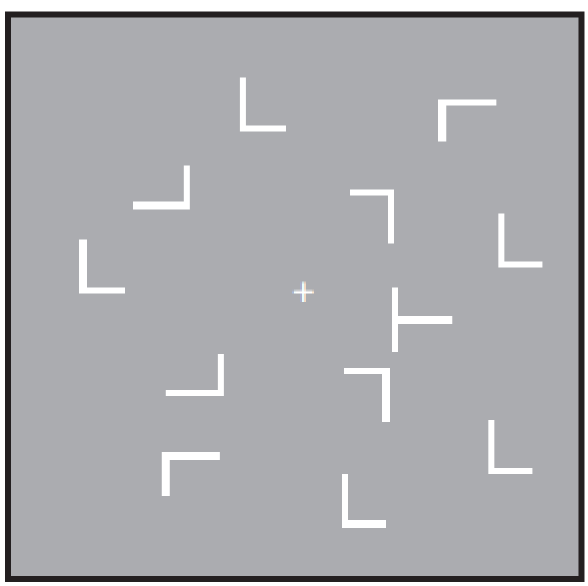

Figure 1. **Contextual cueing task display. Reprinted from Implicit memory influences the allocation of attention in visual cortex, by J S Johnson, G F Woodman, E Braun & S J Luck (2007) Psychonomic Bulletin & Review, 14(5), 834-839.**

They were instructed to locate the target and mark its orientation; the T stimulus was randomly rotated 90° to the right or left on each display. Each item size was 2.3°x2.3° with a minimal separation of 2°. Distractor targets were presented and were also randomly rotated (0°, 90°,180°, 270°), both were located on an invisible 8x6 matrix display. Distractor configuration remained the same on repeated displays and were newly generated on novel displays. Trials were presented on a ThinkVision L197 19-inch Wide Monitor placed 50 cm in front of the participants.

To start the task, subjects press the space bar. Then a cross appears in the middle of the screen and after a time lapse of 500 mts, the first array of stimuli emerges. Participants search the target and determine if the target is pointing left or right. If the target is pointing left participants press the "c" key and if it´s pointing right they press the "m" key. 20 blocks of 24 intermixed displays are presented; each block is composed by twelve new and twelve repeated displays. A pause of 10 seconds is given after each block presentation. After block

20, a set of 12 old and 12 new configurations is presented and subjects are requested to indicate if they had already seen the display or if it is a new configuration. Each session lasts 25 minutes.

Posner Cueing task

Subjects are positioned 50 cm in front of the ThinkVision L197 19-inch Wide Monitor, they are instructed to fixate their attention on a cross in the middle of the screen and to press the letter "A" on the keyboard every time that a letter "X" stimulus appears. Before the letter "X" appearance, an arrow is displayed to point the direction where the appearance is most likely to happen, whether left, right, or both directions, as it is observed on figure 2. The task is composed by 200 trials, the time delay between the cue and the stimulus is randomly assigned. Each session lasts 15 minutes.

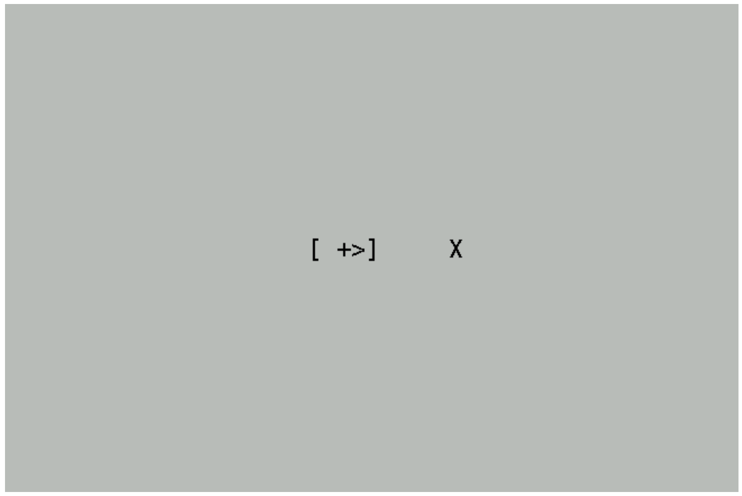

Figure 2. **Posner cueing task display.**

Procedure

Participants enter the laboratory and receive a brief introduction about the purposes of the experiment. Then, they sign an informed consent in which they agree to participate in the experiment; it ensures the confidentiality of the information provided. Before the experiment begins, participants complete the Edinburgh Handedness Inventory (Oldfield, 1971) to ensure their Right-handedness. After confirming their right-hand domain, the instructions video of the Contextual Cueing task plays, in which they are requested to locate the target ("T" stimulus) and indicate its orientation by pressing the letter

"C" if it’s oriented to the left and the letter "M" if it’s oriented to the right. Then, any type of doubt about the task procedure is clarified. After ensuring that the monitor, chair, and chin rest are properly adjusted so participants’ gaze is orientated to the center of the screen in a distance of 50 cm, subjects start the task by pressing “space”. Once the epoch 4 is finished, they are presented with a series of displays and have to identify if the displays are new or repeated. Once the task is completed, participants are instructed about the Posner cueing task, which lasts 15 minutes. They start by focusing their attention on a cross in the middle of the screen and pressing the letter "A" each time the letter "X" appears on the screen. Previous to the letter “X” stimulus, an arrow appears on the screen indicating the probable target location (right, left, or both sides with equal probability). The application of the whole experiment lasts about 45 minutes.

Data Analysis

In the first place, we performed an Analysis of Variance (ANOVA) using Matlab software (version 7.10.0; The MathWorks

Inc.2010 Software) to establish the relation between reaction times (dependent variable) over epoch, context, and age (independent variables) in order to determine the contextual cueing effect. Also, a T-test was applied using the same software, to identify the relation between age over the contextual cueing effect, age over involuntary attention, and age over attentional focusing. Involuntary attention and attentional focusing measures were obtained by comparing the valid, invalid, and neutral time responses on the Posner cueing task.

Results

A 2x2 factorial within-subjects ANOVA was conducted on reaction times (RT) by each group: young and older adults, with Context (new vs repeated) and Epoch (3 vs 4) as the independent variables.

A significant main effect of Context on Reaction time was found on both age groups: Young adults $F\ (1, 19) = 15{,}627$, $p = 0{,}000853$ and older adults $F\ (1, 19) = 4.5604$, $p = 0.046$, indicating that reaction times were faster for repeated context

(Mean Young Adults=1,04) (Mean Old Adults=1,7) than for new context (Mean Young Adults=1,1) (Mean Old Adults=1,75).

Similarly, the main effect of Epoch on reaction times was significant on both age groups: Young adults F (1, 19) = 50,274, p = 0,000000959 and older adults F (1, 19) = 75.8886, p = 0,0000000462, indicating that reaction times were faster for Epoch 4 (Mean Young Adults=0,95) (Mean Old Adults=1,51) than for Epoch 3 (Mean Young Adults=1,19) (Mean Old Adults=1,94).

On the contrary, context (new vs repeated) x Epoch (3 vs 4) interaction was not significant on any of the age groups: Young adults F (1, 19) = 2,1942, p = 0,1549 and older adults F (1, 19) = 0.7788, p = 0,3885. Context and Epoch influence reaction times independently from each other on both groups.

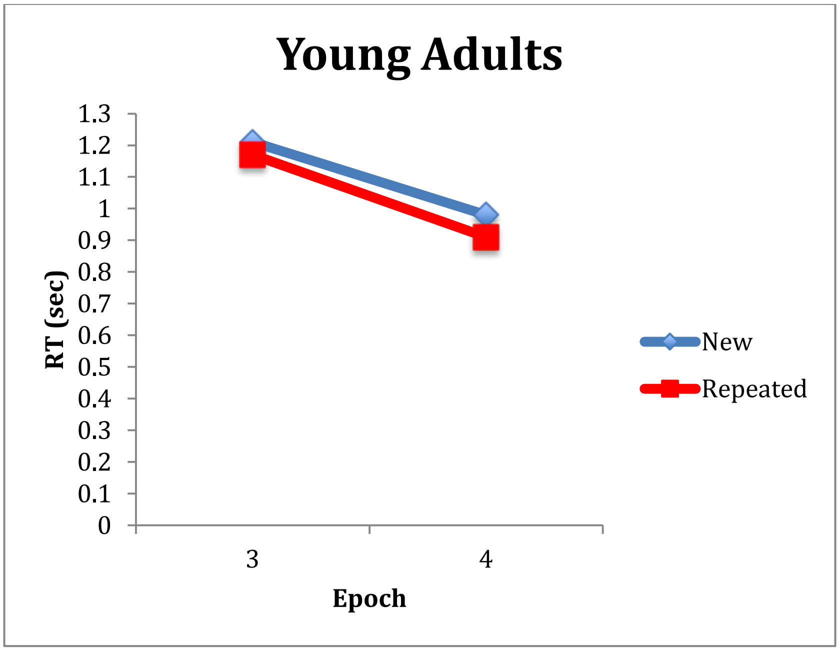

Figure 3. Reaction time of epoch 3 and 4 in younger adults.

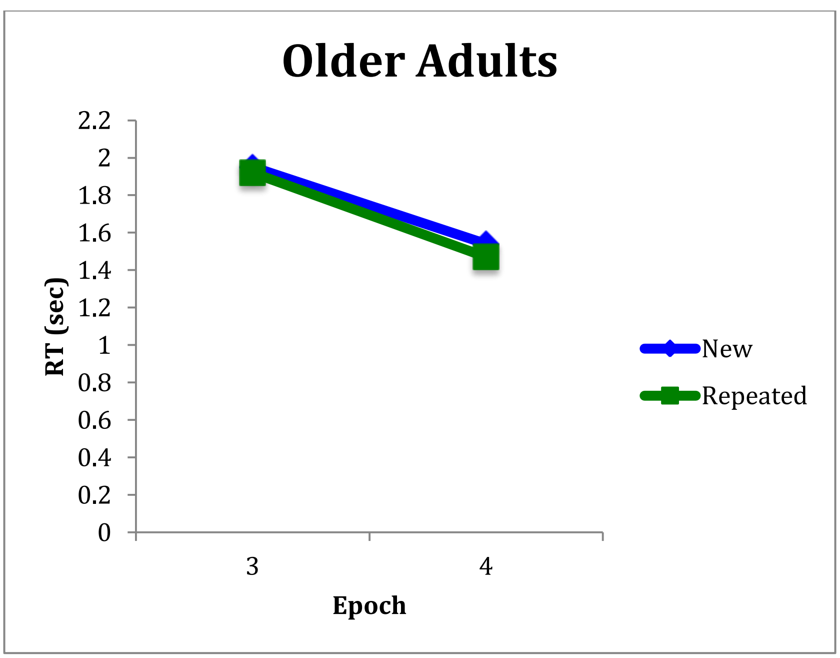

Figure 4. Reaction time of epoch 3 and 4 in older adults.

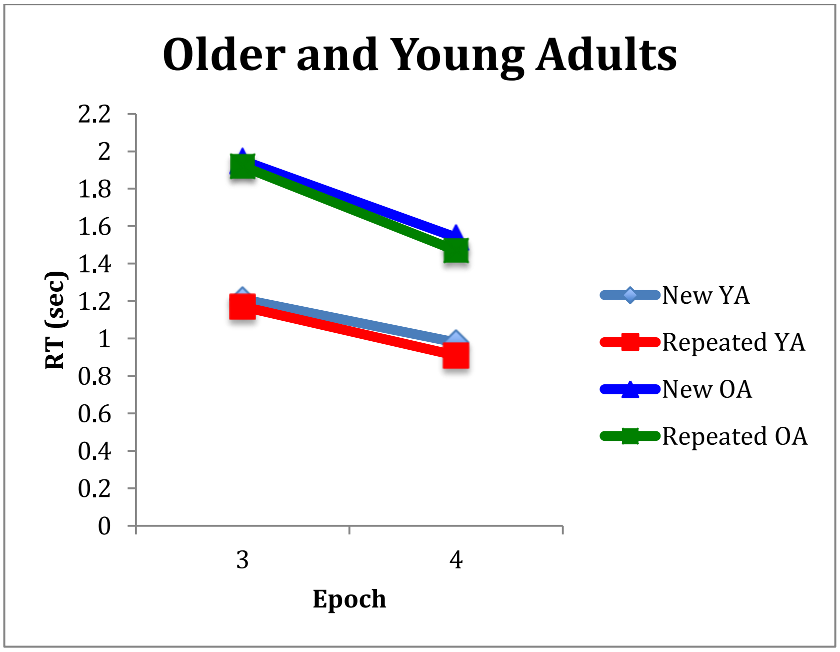

Figure 5. **Reaction times of epoch 3 and 4 in young and older adults.**

An independent-samples *T-test* was conducted to compare the contextual cueing effect for young (58.45±52.3) and older adults (53.05±76.23), as observed on figure 5. There was not a significant difference in the scores t (38) = .261, p = .795. This indicates that age did not have a representative effect on contextual cueing.

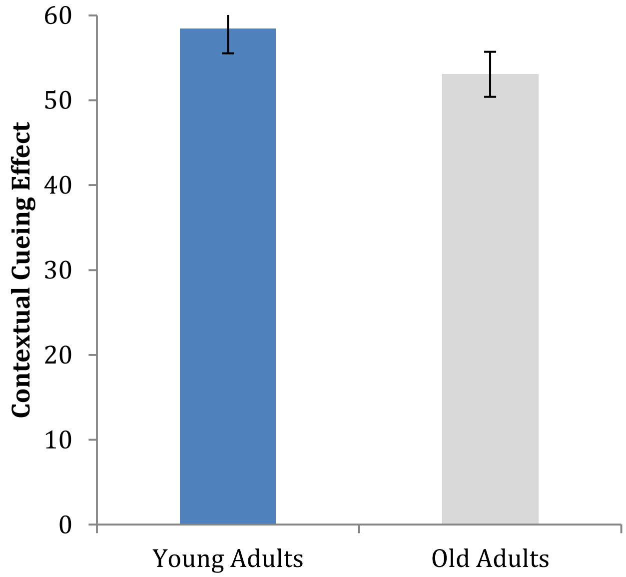

***Figure 6.* Contextual Cueing Effect in young and older adults.**

Furthermore, an independent-sample *t-test* was conducted to compare involuntary attention for young (52.01±86.3) and older adults, (64.43±155.25), as shown in figure 6. There was not a significant difference in the scores (38) = -.313, p = .756, indicating that age did not have a representative effect on involuntary attention.

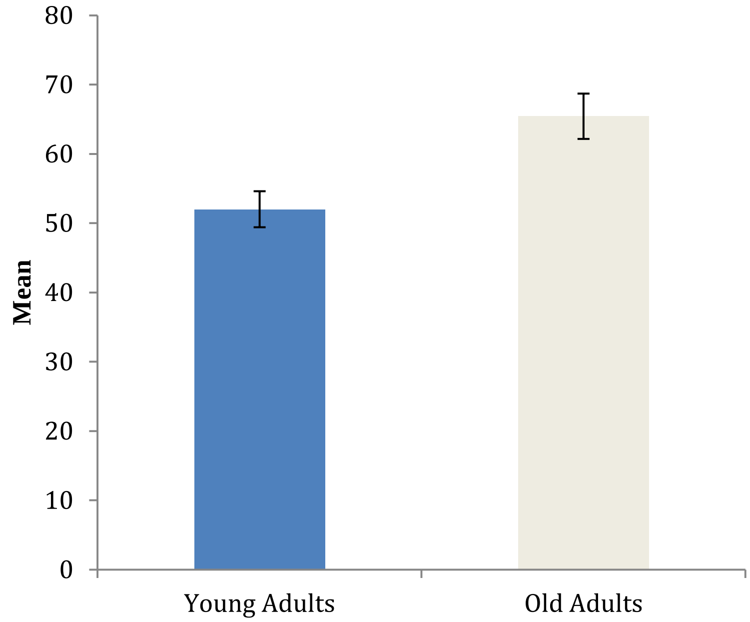

***Figure* 7. Involuntary attention on young and older adults.**

Finally, an independent-sample *t-test* was conducted to compare attentional focusing for young adults (-9.46±50.35) and older adults (-35.26±97.77), as observed in figure 7. There was not a significant difference in the scores t (38) = 1.049, p = .301. This indicates that age did not have a representative effect on attentional focusing.

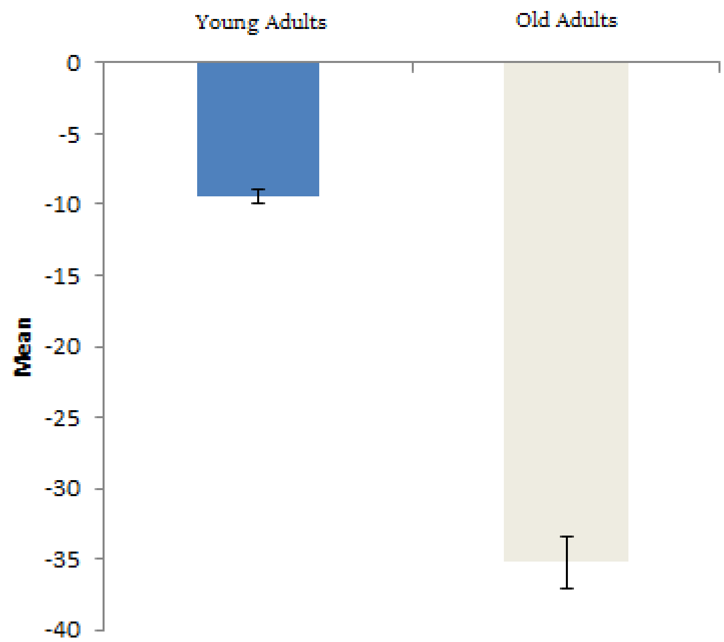

***Figure 8.* Attentional focusing on young and older adults.**

Discussion

As mentioned above, this study aimed to identify performance differences of young and older adults on the contextual cueing task, in order to observe how age affects performance on implicit contextual memory. Several lines of evidence have proven that older adults tend to have lower cognitive control because the frontal regions of the brain that support cognitive processes are the first to be impaired with aging (Craik &

Bialystok, 2006). On implicit tasks like the contextual cueing task, statistical learning and 'bottom up' attention are favored in subjects with diminished cognitive control (Amer, Campbell & Lynn Hasher 2016; Eich et al 2016; Hasher, Zacks, & May, 1999.). However, according to our results, there was no significant difference on performance by groups in the contextual cueing task.

Taking this into account, our results do not coincide with Chun & Jiang's (1998) hypothesis that suggests that diminished cognitive control would ameliorate performance on the Contextual Cueing Task. Nevertheless, the contextual cueing effect was observed in the difference between reaction times on epoch three and four in all participants of both groups (figure 3 and 4), suggesting that the contextual cueing effect and statistical learning is preserved through people's lifespan.

Taking into consideration that our results indicate that the repetition of context configurations can create an implicit contextual memory which could guide attention to process a specific target and to allow the subject to make predictions about its environment, these results could be extrapolated to other psychology fields in order to create strategies to improve teaching and learning processes for older adults.

Furthermore, as observed in figure 4, reaction times on both epoch 3 and 4 and on new and repeated contexts were faster for young adults than for older adults. This suggests that, although the contextual cueing effect was equal for both groups, young adults evidence faster response times, implying greater motor learning.

Besides, none age-related performance difference was found on involuntary attention and attentional focusing on the Posner Cueing Task, contradicting the strong body of evidence that states that older adults have better involuntary attention (exogenous attention) and young adults have superior attentional focusing (endogenous attention) (Amer, Campneell & Hasher ,2016).

Conclusion

This study aimed to find performance differences between older adults and young adults in contextual cueing, in order to provide more information regarding implicit contextual memory through age. Taking into account that there is not much literature on the subject and that researchers are just now beginning to understand the complex process that involves the contextual cueing effect, this study is relevant for further comprehension of this matter. Regardless that we did not find a significant difference between performances on none of the groups, based on our results we can suggest that contextual cueing is maintained through the human lifespan; nevertheless we recommend that the sample be increased in future studies. Also, it would be interesting to observe individual differences through a longitudinal study performed with subjects starting young adulthood and all through their aging.

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