Visuospatial Working Memory Advantage in the Oroqen: Effects of Ecological Environment and Mode of Production (Postprint)

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Abstract

With Oroqen and Han Chinese high school students as participants, this study employed simple storage tasks and complex span tasks while introducing material complexity variables to investigate differences in visuospatial working memory capacity between the two ethnic groups and to explore the influence of ecological environment and production modes on visuospatial working memory capacity. Results indicated that Oroqen students performed significantly better than their Han Chinese counterparts on all four visuospatial working memory tasks, and that the structure, quantity, and path of material presentation did not affect the visuospatial working memory advantage observed in Oroqen students. Overall, the study demonstrates that the ecological environment and production modes sustained by the Oroqen people for thousands of years have become important ecological variables that influence the visuospatial working memory capacity of their descendants.

Full Text

Abstract

Working memory refers to a system of temporary holding and manipulation of information during the performance of a range of cognitive tasks, such as comprehension, learning, and reasoning. According to Baddeley (1974), the architecture of working memory comprises four separated components, namely, phonological loop, visual-spatial working memory, central executive, and episodic buffer. The visual-spatial working memory is involved in the temporary retention of visual-spatial information.

The Oroqen is one of the oldest ethnic groups in northeast China. Most Oroqens live in the Oroqen Autonomous Banner in the Greater Hinggan Mountains. The area is bestowed with rich resources with a variety of wild animals. For generations, the Oroqens lived a life of hunting and fishing in the forests. They went on hunting expeditions in groups. Researchers explored the ecological environment and mode of production that affected the performance of cognition. The present study aims to explore whether the natural environment, which has formed the Oroqen' s hunting culture and hunting-gathering stage of economic production, affects their visual-spatial working memory.

In Experiment 1, four experiments were conducted to investigate the effect of the ecological environment and mode of production on the visuospatial working memory Oroqens. Oroqen (n = 32) and Han (n = 30) high school students performed simple storage and complex visual-spatial span tasks. Simple storage tasks were distinguished into three presentation formats: (i) visual, which involved maintaining irregular figures; (ii) spatial-sequential, which involved maintaining sequentially-presented locations; and (iii) spatial-simultaneous, which involved maintaining patterns of locations. The results proved that Oroqens performed significantly better than Hans in all the four visual-spatial working memory tasks.

In Experiment 2, the Corsi block test presented in a computer was employed to investigate whether the structural, quantitative, and path complexity influenced the visual-spatial working memory of Oroqen (n = 30) and Han (n = 30) students. Results showed that superiority of the Oroqen on visual-spatial working memory still persisted when the memory materials differ in terms of difficulty.

In summary, the ecological environment and mode of production have a significant impact on visual-spatial working memory. The Oroqen people' s ecological environment and traditional mode of production have become a genetic factor that may affect the visual-spatial working memory of their offspring.

Keywords: Oroqen nationality; ecological environment; mode of production; culture; visual-spatial working memory

Introduction

Memory is a high-level cognitive activity. Baddeley and Hitch (1974) proposed the concept of working memory, suggesting that working memory involves not only immediate recall of presented items but also the preservation and processing of information. Working memory plays an important role in higher-level cognition and is closely related to students' academic achievement, representing the core of human cognitive processes (Baddeley, 2003). Working memory comprises four subsystems: phonological loop, visual-spatial working memory, central executive, and episodic buffer (Allen, Hitch, Mate & Baddeley, 2012; Baddeley, Allen & Hitch, 2011). Visual-spatial working memory receives and processes information from sensory memory or long-term memory, and utilizes processed information for complex activities such as spatial orientation, spatial movement, mental imagery, and drawing.

Visual-spatial working memory was initially viewed as a single system (Baddeley & Hitch, 1974; Baddeley, 2003). Subsequent research demonstrated the separability of visual object memory and spatial memory, supported by neuropsychological and developmental psychology studies (Hamilton, Coates & Heffernan, 2003; Lanfranchi, Cornoldi & Vianello, 2004; Nee et al., 2013). Mammarella, Pazzaglia and Cornoldi (2008) examined elementary school students using structural equation modeling of working memory, finding that measuring visual-spatial working memory structure should employ different simple storage tasks and complex span tasks. Simple storage tasks are divided into visual tasks, simultaneous spatial tasks, and sequential spatial tasks, while complex span tasks require participants to simultaneously remember and process visual-spatial information. The primary basis for distinguishing types of visual-spatial working memory lies in information content format and the degree of attentional control involvement. Mammarella, Borella, Pastore and Pazzaglia (2013) confirmed with adult participants that visual tasks, simultaneous spatial tasks, sequential spatial tasks, and complex span tasks best fit the visual-spatial working memory model.

Differences in visual-spatial working memory capacity represent a hot topic in this research field. Researchers have explored the influence of age (Brown, 2016), gender (Hamilton, Coates & Heffernan, 2003), physiological factors (Lanfranchi, Cornoldi & Vianello, 2004; Milligan & Cockcroft, 2017), language ability (Blom, Boerma, Bosma, Cornips & Everaert, 2017), cognitive style (Li & Zhou, 2006), and other factors on visual-spatial working memory capacity. However, the influence of ecological environment, mode of production, and ethnic culture on visual-spatial memory cannot be ignored. Research indicates that ecological environment, mode of production, and ethnic culture influence cognitive style and scene perception (McKone et al., 2010; Nisbett & Cohen, 1996; Nisbett, Peng, Choi, & Norenzayan, 2001; Oishi & Talhelm, 2012; Qiao & Zhang, 2015; Sharon et al., 2009; Talhelm et al., 2014). This raises the question: do ecological environment and mode of production, along with their derived culture, influence human visual-spatial working memory capacity?

The influence of ecological environment on human psychology manifests in various aspects (Wu & Jin, 2008). Through interaction with the environment, humans incorporate ecological environmental factors into their cognitive structures, leading to different groups in different ecological environments having different worldviews. Ecological environment constrains modes of production, which together influence human cognitive structures, forming unique ethnic cognitive structures. These ethnic cognitive structures, as part of ethnic culture, guide and constrain how younger generations perceive the world. Linnell, Caparos, de Fockert and Davidoff (2013) compared the attention and working memory abilities of Himba people living in grasslands versus cities, finding that urban Himba had better working memory capacity but showed decentralized processing in spatial attention, while grassland Himba could still focus more on targets. Uskul, Kitayama and Nisbett (2008) found that farmers and fishermen emphasizing interdependent social orientation showed more holistic processing than hunters emphasizing independent social orientation: in classification tasks, farmers and fishermen tended toward relationship-based classification, while hunters tended toward rule-based classification. Talhelm et al. (2014) proposed the "rice theory," suggesting that significant environmental and climatic differences between northern and southern China led to different crop cultivation histories. Compared with people from wheat-growing regions, those from rice-growing regions adopted more holistic thinking patterns and exhibited more collectivist characteristics.

Culture is a unique evolutionary form of humanity, closely related to cognition. Culture and cognition provide mutual perspectives: culture can be studied from a cognitive perspective, and cognition can be studied from a cultural perspective (Wu & Chen, 2007). Ethnic cognition is closely related to ethnic culture. Ethnic culture influences ethnic cognition, which in turn becomes part of ethnic culture, influencing the formation of ethnic culture. Wang, Chen, Wang and Liu (2005) confirmed that education level influences human brain cognitive function. Yang (2007) summarized research from different countries and regions, finding that culture influences not only perception but also memory and thinking. In cross-cultural research, independent variables mainly focus on ecological environment, mode of production, ethnic culture, social structure, and education (Shao, 2012).

Evidence from evolutionary theory, psychology, linguistics, and cognitive anthropology indicates that culture influences cognition not in a domain-general manner but in a domain-specific manner. Specific culture promotes the development of related abilities (Wu & Chen, 2007). Since the 1980s, Chinese psychologists have explored the influence of ecological environment and culture on ethnic cognition, producing many valuable findings. For example, Fu, Zhou, Li and Feng (1999) found that ecological environment, mode of production, and culture influence ethnic cognitive style. Zheng and Chen (1995) found that ecological environment and mode of production affect food storage degree, social structure tightness, socialization tendency, and modernization, which influence cognitive operation and cognitive style. Zheng and Chen (1996) found that hunting and urban ecological environments and modes of production exert ecological pressure that promotes the formation of abstract cognitive style, while fishing, nomadic, and farming ecological environments and modes of production lead individuals toward concrete cognitive style. Xie et al. (2008) found that color culture influences color perception and recognition of black and white among Yi, Bai, Naxi, and Han university students.

People in different ecological environments adopt different modes of production, have different living conditions and experiences, and their memory is influenced by ecological environment and mode of production, thus showing uniqueness. Since non-literate societies lack written records and information storage, they often develop strong memory abilities. For example, many ethnic groups without their own written language preserve their history through oral transmission across generations. Even among university students, cultural differences in memory ability have been found. Cultural influences on memory manifest in many aspects, from memory for specific materials (Ross & Miller, 1970), serial position effects (Yang, 2007), age of acquisition for autobiographical memory (Mullen, 1994), to self-reference effects (Zhu & Zhang, 2001) and group-reference effects (Yang & Huang, 2007), all showing significant cultural differences.

This study investigates the influence of ecological environment and mode of production on visual-spatial memory ability, selecting the Oroqen nationality, which has distinctive ecological environment and mode of production, as the research subject. The Oroqen is one of China' s minority ethnic groups with small population, distributed in Inner Mongolia and Heilongjiang provinces. In 2010, the Oroqen population was 8,659. The Oroqen language belongs to the Tungusic branch of the Manchu-Tungusic language family of the Altaic language system, and has no written form (Guan, Wang & Guan, 2014). For generations, the Oroqen people have been nomadic hunters, supplemented by fishing, gathering, and household handicrafts. It was not until 2001 that Oroqen hunters finally laid down their hunting rifles. This hunting-gathering economy is rare among minority nationalities in China at the primitive social formation stage. The existence of hunting-gathering economy is inseparable from the ecological environment. The Oroqen is a forest people who hunted nomadically in the Greater and Lesser Hinggan Mountains region. Here, over 90% of the land is covered by forests with more than 500 plant species. The vast forests not only provide habitats and breeding grounds for a wide variety of wild animals but also abundant food for herbivores and carnivores, with over 50 species of rare birds and animals (Meng, He & Guan, 2016). Through long-term hunting and gathering practices, the Oroqen mastered hunting-gathering knowledge, skills, and methods, understood the habits of wild animals and plants, became familiar with mountains and rivers, and developed marksmanship that never missed, earning them the title of "Hunting God" in the Greater Hinggan Mountains region. Since the 1960s, foreign anthropologists have investigated hunting and gathering peoples such as the Kung Bushman, Eskimo, and Australian Aborigines; Chinese anthropologists have also published research reports on fishing and hunting peoples including the Hezhen, Kucong, Ewenki, and Oroqen (Zhuang, 2006). However, most researchers conducted investigations from an anthropological perspective, with very few psychological studies. Selecting the Oroqen nationality as the research subject and comparing it with the Han nationality, which differs greatly in ecological environment and mode of production, can highlight the role of ecological environment and mode of production.

The research hypothesis is that compared with Han people, the Oroqen people, under unique ecological environments, have developed unique modes of production and ethnic culture that positively influence their visual-spatial working memory ability.

Experiment 1: Differences in Visual-Spatial Working Memory Between Oroqen and Han Students

Participants

Sixty-two high school students from the Oroqen Autonomous Banner in Hulunbuir City, Inner Mongolia Autonomous Region, aged 16-18 years (M = 17, SD = 0.83). Among them, 32 were Oroqen students (14 males, 18 females) and 30 were Han students (12 males, 18 females). All participants came from the same ethnic middle school, had similar learning and living environments, studied in the same classes, and had average academic performance. Final exam scores from the semester before the experiment: Oroqen students' Chinese language scores: M = 77.84, SD = 15.35; Han students' Chinese language scores: M = 81.97, SD = 11.57. Oroqen students' mathematics scores: M = 48.47, SD = 13.67; Han students' mathematics scores: M = 50.60, SD = 15.88. t-tests showed t_Chinese(60) = 1.19, $p > 0.05$, t_Math(60) = 0.57, $p > 0.05$. Participants had normal or corrected-to-normal vision. Oroqen and Han students had the same language background, being monolingual. Oroqen students could not speak or understand their native language; their first language was Chinese, and they could speak Mandarin fluently and read Chinese books.

Procedure and Scoring Method

The study considered both presentation format of visual-spatial tasks and attentional control demands, selecting different simple storage tasks and complex span tasks. Simple storage tasks were distinguished into three types: object working memory task (remembering irregular figures), simultaneous spatial task (remembering simultaneously presented spatial locations), and sequential spatial task (recalling sequences of spatial locations). Complex span tasks required participants to simultaneously remember and process visual-spatial information. Following foreign research practices (Mammarella, Borella, Pastore, & Pazzaglia, 2013; Mammarella, Pazzaglia, & Cornoldi, 2008; Miyake et al., 2000), task span levels increased sequentially in each experiment, starting at 2 stimuli. Under each span level, there were 3 trials. The experiment terminated if participants could not pass two trials at the same span level. If participants successfully passed two of three trials, the span level increased by one. Before each experiment, participants practiced 3 trials with 2 figures.

Apparatus

The experiment was conducted in a soundproof and light-shielded laboratory. Participants completed four visual-spatial working memory experiments with order balanced using Latin square design. To eliminate fatigue errors, participants rested for 2-3 minutes after completing every two experiments. The entire experiment lasted approximately 1 hour. For scoring, each span level was assigned corresponding points (e.g., span level 2 = 2 points, span level 3 = 3 points). The final score was the sum of points for 3 correctly recalled items at the highest span level achieved. For example, if a participant correctly answered two items at span level 3 and one item at span level 4, the total score would be 3+3+4 = 10.

All four tasks were conducted in individual laboratories, programmed with E-Prime 2.0 software, presented randomly on a LENOVO computer with a 17-inch color LCD monitor (resolution: 1024×768, refresh rate: 60 Hz). The screen background was white, with viewing distance approximately 60 cm from the screen center. Data were analyzed using SPSS 18.0 (the same for all analyses).

Design and Tasks

A 2 (ethnicity: Oroqen/Han) × 4 (experimental task: object working memory task/simultaneous spatial task/sequential spatial task/complex span task) mixed design was employed, with ethnicity as a between-subjects variable and experimental task as a within-subjects variable. The dependent variable was participants' performance on the four visual-spatial memory tasks.

Object Working Memory Task A fixation point "+" was first presented at the center of the screen for 1500 ms, followed by 2-9 irregular figures presented sequentially at the fixation location in random order, with no repeated figures under the same span. Irregular figures were black, sized 2 cm × 2 cm. Alternative figures are shown in Figure 1 [Figure 1: see original paper]. Each figure was presented for 1000 ms, followed by a 500 ms blank screen, during which participants were instructed to remember each figure' s shape. After figure presentation, a 4×4 matrix of irregular figures was presented at the center of the screen, requiring participants to use a mouse to select the figures they had just remembered. In the matrix, each figure measured 2 cm × 2 cm, with 0.5 cm spacing between figures, covering a spatial range of 9.5 cm × 9.5 cm. Under each span level, irregular figures occupied different positions in the matrix to prevent participants from developing special memory strategies.

Simultaneous Spatial Task A fixation point "+" was first presented at the center of the screen for 1000 ms, followed by a 5×5 grid matrix at the fixation location. Different numbers of red dots (increasing from 2 to 19) were randomly presented simultaneously in the 25-grid matrix for 2000 ms. The presentation order of red dots avoided forming special shapes that would facilitate perceptual organization. Participants were instructed to remember the dots' locations. After a 1000 ms blank screen, an empty grid matrix was presented, requiring participants to use a mouse to select the previously remembered dot positions.

Sequential Spatial Task The Corsi Block-tapping Test was administered via computer, using black-edged white cubes (1 cm × 1 cm × 1 cm) to replace physical blocks. A fixation point "+" was first presented for 1000 ms, followed by a 5×5 grid matrix at the fixation location. After participants clicked the "Start" button at the bottom of the screen, different numbers of white cubes turned black sequentially at a rate of 1000 ms per cube, with quantities increasing from 2 to 19. After presentation, participants used a mouse to click the cubes that had turned black in the correct sequence. Upon completion, participants clicked the "Start" button again according to on-screen prompts for another sequence test. The spatial positions of target cubes did not form clear structures, making perceptual organization difficult.

Complex Span Task The complex span task required participants to simultaneously remember and process visual-spatial information. Materials consisted of letter R stimuli at different rotation angles, including both normal and mirror images in equal proportions. Each letter R had 7 rotation angles: 45°, 90°, 135°, 180°, 225°, 270°, and 315° clockwise from the upright position, totaling 14 stimuli, each sized 2 cm × 2 cm. The experimental procedure was as follows: a fixation point "+" was presented at the center of the screen for 1000 ms, followed by a letter R rotated to a certain angle at the fixation location for 1500 ms. Participants were required to judge as quickly as possible whether the letter was normal or mirror-reversed, pressing the F key for normal and J key for mirror images (key assignments were reversed for half the participants). While making this judgment, participants had to remember the letter' s rotation angle. Participants had a maximum of 3000 ms to respond, followed by a 500 ms blank screen before the next rotated letter appeared. Letter presentation span increased from 2 to 9 letters. After completing a span series, a asterisk-like grid representing different directions was presented at the center of the screen, requiring participants to use a mouse to sequentially select each letter' s rotation angle at that span level (as shown in Figure 2 [Figure 2: see original paper]). Under the same span, letters were presented randomly without repeated angles.

Results

The experimental results are shown in Figure 3 [Figure 3: see original paper].

A 2 (ethnicity) × 4 (task type) mixed ANOVA revealed a significant main effect of ethnicity, $F(1, 60) = 28.89$, $p < 0.001$, $p^2 = 0.33$. Oroqen students performed significantly better than Han students. The main effect of task type was also significant, $F(3, 180) = 158.20$, $p < 0.001$, $p^2 = 0.73$. Post-hoc Bonferroni tests found that simultaneous spatial task performance ($M = 22.63$) was significantly higher than other tasks, $ps < 0.001$; sequential spatial task performance ($M = 17.32$) was significantly higher than object working memory task ($M = 10.48$) and complex span task ($M = 9.03$), $ps < 0.001$; object working memory task performance was significantly higher than complex span task, $p < 0.01$. The interaction between ethnicity and task type was not significant, $F(3, 180) = 0.62$, $p > 0.05$.

Correlation analysis showed a significant correlation between simultaneous spatial task and sequential spatial task performance, $r = 0.40$, $p < 0.01$, indicating similarity between the two tasks. However, because spatial locations were presented sequentially requiring participants to maintain previously presented locations in mind for some time, sequential spatial tasks demanded higher attention than simultaneous spatial tasks. Correlations between object working memory task and simultaneous spatial task ($r = 0.07$), sequential spatial task ($r = 0.23$), and complex span task ($r = 0.20$), as well as between simultaneous spatial task and complex span task ($r = 0.16$) and between sequential spatial task and complex span task ($r = 0.15$), were all non-significant, $ps > 0.05$. This suggests that object working memory tasks, spatial tasks, and complex span tasks measure different aspects of visual-spatial working memory.

Experiment 2: The Influence of Material Complexity on Visual-Spatial Working Memory

Experiment 1 considered both visual-spatial task format and attentional control demands, selecting three simple storage tasks and one complex span task. The results showed that Oroqen students performed better than Han students across all four tasks, demonstrating clear advantages. Can this advantage be generalized to more ecologically valid tasks? The Oroqen live in virgin forests with dense vegetation and complex terrain. What is visible includes structural complexity, quantitative complexity, and path complexity. Living in such an ecological environment requires superior visual-spatial working memory ability. This ability may enable the Oroqen to show even greater advantages in complex visual-spatial working memory tasks. Empirical evidence also shows that Oroqen people never get lost when walking in forests and often serve as guides during road construction in the Greater Hinggan Mountains region, acting as "living maps." Therefore, following the paradigms of Kessels et al. (2000) and Li and Zhou (2006), Experiment 2 used computer-presented Corsi block-tapping tasks and introduced material complexity variables to explore whether structural complexity, quantitative complexity, and path complexity affect the visual-spatial working memory advantage of the Oroqen.

Experiment 2a: Structural and Quantitative Complexity

Participants Sixty high school students from the Oroqen Autonomous Banner in Hulunbuir City, Inner Mongolia Autonomous Region, aged 16-18 years ($M = 17$, $SD = 0.79$). Among them, 30 were Oroqen students (12 males, 18 females) and 30 were Han students (12 males, 18 females). Other participant information was essentially the same as in Experiment 1, and none had participated in Experiment 1.

Design A 2 (ethnicity: Oroqen/Han) × 2 (structural complexity: matrix/random) × 2 (quantitative complexity: low quantity/high quantity) mixed design was employed. Ethnicity was a between-subjects factor, while structural complexity and quantitative complexity were within-subjects factors. The dependent variable was participants' visual-spatial working memory span, defined as the maximum spatial sequence participants could correctly remember.

Materials and Apparatus Materials adapted the classic Corsi block-tapping task into a computer program, using black-edged white cubes (1 cm × 1 cm × 1 cm) to replace physical blocks, presented against a white background. Quantitative complexity was divided into low quantity (9 cubes) and high quantity (16 cubes). Structural complexity was divided into matrix and random conditions. Matrix condition meant cubes formed 3×3 or 4×4 matrices (see Figure 4a [Figure 4: see original paper]), while random condition meant cubes were randomly distributed (see Figure 4b). The experiment was conducted in individual laboratories using the same apparatus as Experiment 1.

Procedure Four conditions were administered with order balanced using Latin square design. The experiment began with the low-quantity matrix condition: a fixation point "+" was presented for 1000 ms, followed by a 3×3 grid matrix at the fixation location. After participants clicked the "Start" button at the bottom of the screen, different numbers of white cubes turned black sequentially at a rate of 1000 ms per cube, with quantities increasing from 2 to 9 cubes. After presentation, participants immediately used a mouse to click the cubes that had changed color in the correct sequence. Upon completion, participants clicked the "Start" button again according to on-screen prompts for another sequence test. The spatial positions of target cubes did not form clear structures, making perceptual organization difficult. The procedure for other experimental conditions was identical. The program employed a self-terminating principle, increasing memory load until participants could no longer immediately and accurately reproduce the remembered information. Sequence length started at 2 and maximum was 9 stimuli. There were 3 trials under each span level, with different sequences of cube blackening. If participants passed 2 of 3 trials, sequence length increased by 1 and testing continued at span level 4, and so on. If participants could not pass 2 trials at each span level, the computer prompted termination. Before the experiment, participants practiced with 3 trials at span level 2.

Results The experimental results are shown in Figure 5 [Figure 5: see original paper].

A 2 (ethnicity) × 2 (structural complexity) × 2 (quantitative complexity) mixed ANOVA revealed a significant main effect of ethnicity, $F(1, 58) = 15.29$, $p < 0.001$, $p^2 = 0.20$. Oroqen students'memory capacity ($M = 6.27$) was significantly higher than Han students ($M = 5.58$). The main effect of structural complexity was significant, $F(1, 58) = 5.35$, $p < 0.05$, $p^2 = 0.08$. Working memory span in matrix condition ($M = 6.06$) was significantly higher than in random condition ($M = 5.80$). The main effect of quantitative complexity was significant, $F(1, 58) = 26.05$, $p < 0.001$, $p^2 = 0.30$. Working memory span in low-quantity condition ($M = 6.17$) was significantly higher than in high-quantity condition ($M = 5.68$). All interaction effects were non-significant, $ps > 0.05$.

Thus, both Oroqen and Han students showed structural complexity and quantitative complexity effects on visual-spatial working memory span. Compared with random patterns, participants remembered block positions better in structured conditions. As the number of blocks increased, memory span decreased. This is because, compared with random conditions, structured conditions provided well-organized structural information that facilitated perceptual organization. Moreover, when fewer blocks were presented, each block' s position on the screen was clear and distinct, with high discriminability between target and non-target blocks, requiring less processing resources and allowing more capacity for active rehearsal of target blocks, thus improving memory performance. As block quantity increased, each block' s position became ambiguous, requiring more precise encoding of target locations and more processing resources, consequently reducing memory performance. However, under all four conditions, Oroqen students' visual-spatial working memory span was significantly superior to Han students.

Experiment 2b: Path Complexity

Participants Sixty high school students from the Oroqen Autonomous Banner in Hulunbuir City, Inner Mongolia Autonomous Region, aged 16-18 years (M = 17, SD = 0.79). Among them, 30 were Oroqen (12 males, 18 females) and 30 were Han (12 males, 18 females). Other participant information was essentially the same as in Experiment 1, and none had participated in Experiment 1 or Experiment 2a.

Design A 2 (ethnicity: Oroqen/Han) × 2 (path complexity: simple/complex) mixed design was employed. Ethnicity was a between-subjects factor, and path complexity was a within-subjects factor. The dependent variable was participants' visual-spatial working memory span.

Materials and Apparatus Materials adapted the classic Corsi block-tapping task into a computer program, using black-edged white cubes (1 cm × 1 cm × 1 cm) to replace physical blocks. Twenty-five cubes were presented in a 5×5 matrix format against a white background at the center of the screen. Block movement paths featured symmetry, continuity, and repetition, constituting stimulus redundancy. Symmetry meant the spatial pattern generated by arrow movement was symmetrical horizontally, vertically, or along the 45° axis of the matrix. Continuity meant the path formed by target cubes had no crossings. Repetition meant part of the arrow movement sequence could be transformed. Path complexity was determined by stimulus redundancy. If part of a stimulus could be predicted from other parts, the stimulus had redundancy and low path complexity. Simple paths referred to simple spatial configurations between target cubes that were easy for perceptual organization, containing at least one redundant stimulus (Figure 6a [Figure 6: see original paper]). Complex paths referred to complicated spatial configurations between target cubes that were difficult for perceptual organization, containing no redundant stimuli (Figure

6b). The experiment was conducted in individual laboratories using the same apparatus as Experiment 1.

Procedure Participants underwent both simple path and complex path conditions, with order balanced between participants. The experiment began with a fixation point "+" for 1000 ms, followed by a 5×5 grid matrix at the fixation location. After clicking the "Start" button at the bottom of the screen, different numbers of white cubes turned black sequentially at a rate of 1000 ms per cube, with quantities increasing from 2 to 9 cubes. After presentation, participants used a mouse to click the cubes that had changed color in the correct sequence. Upon completion, participants clicked the "Start" button again for another sequence test. The program employed a self-terminating principle, increasing memory load until participants could no longer immediately and accurately reproduce remembered information. Sequence length started at 2 and maximum was 9 stimuli. There were 3 trials under each span level, with different sequences of cube blackening. If participants passed 2 of 3 trials, sequence length increased by 1 and testing continued at span level 4, and so on. If participants could not pass 2 trials at each span level, the computer prompted termination. Participants first practiced with 3 trials at span level 2.

Results The experimental results are shown in Figure 7 [Figure 7: see original paper].

A 2 (ethnicity) × 2 (path complexity) mixed ANOVA revealed a significant main effect of ethnicity, F(1, 58) = 8.53, p = 0.005, $p^2 = 0.13$. Oroqen students' working memory span (M = 5.42) was significantly higher than Han students (M = 4.84). The main effect of path complexity was significant, F(1, 58) = 13.12, p = 0.001, $p^2 = 0.18$. Working memory span in simple path condition (M = 5.38) was significantly higher than in complex path condition (M = 4.87). The interaction between ethnicity and path complexity was not significant, $p > 0.05$.

Thus, both Oroqen and Han students showed path complexity effects, with memory performance depending on the spatial configuration of paths. Memory for simple paths was better than for complex paths. Due to different numerical sequences, target blocks generated different paths (spatial configurations). In simple paths, the spatial configurations between sequentially presented target blocks had redundancy and clear structure, facilitating perceptual organization. In complex paths, spatial configurations between sequentially presented target blocks lacked clear structure, making perceptual organization difficult. However, regardless of path complexity, Oroqen students' visual-spatial working memory ability was significantly better than Han students.

General Discussion

This study investigated the influence of ecological environment and mode of production on visual-spatial working memory ability. Using Oroqen and Han high school students as participants and employing simple storage tasks, complex span tasks, and material complexity variables, the study examined differences in visual-spatial working memory ability between Oroqen and Han students. Results showed that Oroqen students performed significantly better than Han students on all four visual-spatial working memory tasks. The structure, quantity, and path of material presentation did not affect the Oroqen students' advantage in visual-spatial working memory ability.

Influence of Ecological Environment on Oroqen Visual-Spatial Working Memory Advantage

Berry' s (1967) ecology-culture-behavior model views human behavior from ecological and cultural perspectives, proposing that ecological pressure is the driving force and molding factor of culture and behavior. Ecological variables constrain, force, and nourish cultural forms, which in turn shape human behavior. That is, certain ecological environments lead to certain cultural forms, and certain ecological and cultural forms jointly shape individuals, producing certain behavioral patterns. These behavioral patterns enable better adaptation to ecological environment and culture, and even influence and change them. This theory can well explain many research findings. For example, Turnbull (1961) studied BaMbuti pygmies in the Ituri forest and found that local residents could not well judge distant objects, as they had not developed perceptual constancy. This was because BaMbuti lived in jungles without open vistas and had never seen distant scenery; the ability to observe distant objects was unnecessary for them. The Oroqen' s visual-spatial working memory advantage can also be explained from an ecological perspective. The Greater and Lesser Hinggan Mountains region where the Oroqen live has dense forest vegetation with diverse plant communities. In virgin forests, various beasts and birds inhabit, wild plants grow, and rivers and marshes abound with fish (People' s Government of Oroqen Autonomous Banner, 2014). Therefore, the Oroqen' s ecological environment contains complex natural spatial patterns and rich natural biological patterns.

The ecological environment of their residence constrains the orientation of the Oroqen nationality's cognitive structure. The forest environment and cold northern ecological pressure require the Oroqen to develop strong independence and high-level spatial analysis skills, fostering good visual-spatial working memory ability. Oroqen participants were adolescent students who received more education than their predecessors and needed to solve abstract problems, thus developing good executive functions closely related to visual-spatial working memory (Miyake et al., 2000; Miyake & Friedman, 2012). In summary, the forest environment endows the Oroqen with unique ways of cognizing the world. Natural adaptation constrains the Oroqen to make cognitive selections and orientations that meet environmental needs, thus forming unique cognitive functions.

Mode of Production as a Mediating Factor of Ecological Environment' s Influence on Cognition

The influence of ecological environment on cognition is mediated by mode of production. Different ecological environments and modes of production require different skills, thus creating cognitive ability differences. Based on sources of food and living materials needed for human survival, modes of production can be categorized into hunting-gathering, shifting cultivation, nomadic herding, and intensive agriculture. Different ecological environments lead to different modes of production, cultural customs, and memory types (Dong, 2006). For example, embroidery, paper-cutting, and batik activities require people to remember flowers, birds, fish, insects, natural landscapes, and human expressions and postures, thus developing excellent image memory ability among ethnic minorities. Hunters and herders have unique abilities to distinguish animal species, health status, and tracks based on animal scents. Long-term interaction with animals develops unique olfactory memory ability among nomadic peoples. Before agricultural cultivation and livestock breeding emerged, hunter-gatherers were widely distributed worldwide. However, with the development of cultivation and breeding, agricultural and pastoral areas expanded. By the early 20th century, nomadic hunting peoples had been squeezed into small areas unsuitable for farming and herding. In China, ethnic groups engaged in gathering and hunting include the Hezhen, Kucong, Ewenki, and Oroqen (Zhuang, 2006).

The ecological environment composed of forests, grasslands, rivers, and canyons determines the Oroqen' s hunting-gathering mode of production, which in turn determines their social structure, consciousness structure, and living customs. Due to special environmental influences, livelihood requirements, or occupational cultivation, people frequently use certain senses to perceive specific objects, resulting in unique structures or characteristics in their intelligence composition. For the Oroqen, good visual-spatial memory ability is necessary for hunting and gathering activities. A good hunter or efficient gatherer needs rich geographical knowledge and knowledge of plants and animals, effectively distinguishing and remembering terrain, river branches, and species of animals and plants. Therefore, millennia of hunting and gathering in forests have created the Oroqen' s unique visual-spatial memory ability. Gardner (2008) proposed the concept of "naturalist intelligence" —the ability to recognize plants, animals, and natural environments in nature, such as distinguishing plants and animals, identifying geological features and climate, clarifying seasonal changes, and identifying directions and magnetic poles. People with strong naturalist intelligence excel in hunting, farming, and biological sciences. Obviously, the Oroqen possess high-level naturalist intelligence, of which visual-spatial working memory ability is an important component.

Different modes of production generate different cultures. People create culture in different ways under different environments and endow culture with different characteristics. Culture in turn shapes human beings. Malinowski believed that culture has functions; culture is a set of tools whose purpose is to satisfy needs (Fei, 1995). Each culture has directionality. Different cultures create different cognitive structures. The Oroqen maintained a hunting-based economy supplemented by fishing, gathering, and household handicrafts until liberation. The Oroqen' s visual-spatial working memory ability advantage also serves to meet their needs. Through long-term hunting and gathering practices, the Oroqen developed hunting-gathering wisdom. They are skilled hunters, known as "Hunting Gods of the Hinggan Mountains." While hunting, they also gather wild vegetables, fruits, plant tubers, fungi, medicinal materials, and bird eggs (Song, Wang & Chen, 2008). In summary, through millennia of practice, the Oroqen created unique hunting-gathering culture, developed ecological consciousness for harmonious coexistence with nature, possessed distinctive cognitive abilities, and formed unique ecological civilization. Qiao, Zhang and Li (2017) showed that economic factors shape ethnic culture and cognitive style. In the Oroqen' s 60 years of settled life, social changes have been rapid, causing individuals to experience huge cross-generational changes within their lifecycles, yet the influence of ecological environment and traditional mode of production on cognitive function persists.

Conclusion

Exploring the influence of ecological environment and mode of production on cognition is a common concern for ethnology, anthropology, and psychology. Previous Oroqen research mostly used field surveys, historical literature research, and cross-cultural comparison approaches. This study revealed the Oroqen' s visual-spatial working memory advantage through experimental methods, verifying the rationality of cultural-ecological theory. The study demonstrates that ecological environment, mode of production, and ethnic culture have important influences on visual-spatial working memory ability, indicating that memory is both a physiological and cultural event. Different ethnic groups develop their own physiological and behavioral characteristics through adaptive interactions between production behaviors and ecological environments, achieving dynamic balance between their needs and environmental supplies.

Compared with Han students, Oroqen students have obvious advantages in visual-spatial working memory ability. Ecological environment and mode of production are important factors influencing visual-spatial working memory ability.

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