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# Effect of learning methods and cognitive characteristics on preschoolers' online English attainment

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## Abstract

This research aims to explore the online English learning effects among preschoolers with different cognitive characteristics influenced by different learning methods and the interaction between cognitive characteristics and learning methods. Data are collected by using two 3 × 3 between-subject experiments. Wherein, 248 participants based on Embedded Figure Test are divided into Field Independence (FID), Field Mixed (FM), and Field Dependence (FM) in Study 1, while 247 participants based on the Go-No-Go task are divided into Higher self-control (HSC), Middle self-control (MSC), Lower self-control (LSC) in Study 2. Then, through random assignment, all participants enter three learning method groups, restudy (RS), restudy plus test (RST), and restudy plus test plus feedback (RSTF). In addition, all children were allowed to learn online on the iPad to test their learning outcomes by word recognition, picture-word matching, and picture book recognition tests. As seen from the results, FID children performed better than FM and FD children, but their learning outcomes were not affected by the learning methods. FM and FD children performed better when adopting the RSTF learning method. However, for children with different levels of self-control, no differences are found despite their learning methods. Given the above, the "fit/match" between children's cognitive style and online learning methods are effective in maximizing learning effects for preschoolers.

**Keywords** Cognitive style · Self-control · Learning methods · Online English learning

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## 1 Introduction

With the impact of COVID-19, it was unprecedented that almost all students from kindergarten to college switched to learning online. Online learning was defined as "learning experienced through the internet in an asynchronous environment where students engage with instructors and fellow students at their convenience with no need to appear online or in a physical space (Singh & Thurman, 2019)". Following the rapid development of mobile internet and artificial intelligence (AI) technology, an increasing number of learners and educators consider online learning to be a flexible, convenient, open, and shared form of learning. Meanwhile, online education platforms have mushroomed in recent years, advancing the development and promotion of online learning. Even before the outbreak of COVID-19, online learning gained widespread recognition among younger students in China, especially online English learning. Furthermore, many caregivers have realized the importance of English education, stirring up great enthusiasm for children to learn English. To make native English teaching resources easily accessible for children, many children choose to learn English online.

However, due to a lack of tracking children's progress and teacher–child interaction, online learning might not be helpful for all children learners (Steed & Leech, 2021) with different cognitive characteristics. The separation of teacher-students and more independent, open, and weakly controlled features of online learning determined that cognitive style and self-control are important characteristics affecting online learning outcomes (Chen & Liu, 2011; Chen & Macredie, 2010). As a relatively stable characteristic, learners' cognitive styles could play a more important role in online learning than in traditional classroom education (Liu & Ginther, 1999; Pavalache-Ilie & Cocorada, 2014) and influence learners' information processing (Lugli et al., 2017). Moreover, self-control has been well proven to promote student learning success. (e.g., Feldmann et al., 1995; Moffitt et al., 2011).

The flexibility of the course content made it available to learners of different levels and needs (Yeh & Lin, 2012), so developers may create a more refined setting on learning parts and links to realize the fine management of learners' learning steps and rhythms, such as how often to restudy and whether testing is effective. Seen from the existing studies on learning methods for different age groups, there is a testing effect whereby learners could obtain a better learning outcome than restudy even without feedback when they tested their knowledge immediately after learning (Roediger & Butler, 2010; Zhou et al., 2015).

However, in the view of Brewer and Unsworth (2012), not all learners could benefit from the same learning method. Person-environment fit theory indicates that when matching individual characteristics and environmental characteristics, people are more satisfied with the outcome they created and perform better (Kristof, 1996). Online learning environments were well suited to personalizing children's learning experiences (de Mooij et al., 2020), suggesting that if the visibility of time pressure is tailored to children's cognitive profiles, arithmetic performance could improve significantly in online learning environments. Nonetheless, very few studies have investigated the interaction between preschool children's cognitive characteristics and

learning methods on their learning attainment. Such research is essential because it will enable English course developers to develop courses more structurally and parents to guide children's learning more methodically based on their cognitive characteristics. Therefore, this study intends to provide an online English learning approach by considering preschoolers' cognitive styles. The research questions are formulated as follows:

1. How do preschool children with different cognitive characteristics perform in online learning?
2. How do preschool children perform with different learning methods in online learning?
3. What are the appropriate online learning methods for preschool children with different cognitive characteristics?

## 2 Literature review

### 2.1 Cognitive characteristics

Cognitive style comprises the relatively stable preferences and attitudes determining an individual's typical modes of perceiving, remembering, thinking, problem solving, decision making, and information processing (Chen, 2019). Previous studies have classified cognitive style into several types, such as field dependence (FD) and field independence (FID), which is the most typical cognitive style proposed by Witkin and Goodenough (1981). However, most people are in the middle of these two types, and those in the middle are characterized as field mixed (FM) (Liu & Reed, 1994). Learning behavior is affected by learners' cognitive styles (Thomas & Mckay, 2010). However, there is no consensus on which cognitive style is more appropriate for online learning. To date, studies on how cognitive style affects online learning have mainly focused on college students or primary, middle, and high school students (Chin et al., 2018; Lin et al., 2019; López-Vargas et al., 2017). For example, Lin et al. (2019) indicated that FID pupils performed better than FD pupils in math online learning. López-Vargas et al. (2017) examined the differences in online learning among 54 high school students with different cognitive styles and found that FID students performed better, which might be caused by the easy disorientation of FD learners and less affected by external cues for FID learners (Zhang, 2004) in an open internet environment. However, for preschoolers, there are very few studies about how cognitive style affects their learning attainment in the online learning environment. Li and Ju (2009) found that FID children performed better than FD children when they learned English in a traditional learning environment. Therefore, will FM children perform as FD or FID children, and do preschoolers exhibit the same trend in online learning when coping with the complex online environment?

Self-control reflects the ability of an individual to control his or her psychological state and behavior, and it has been suggested that it has a significant impact on individuals' learning outcomes from a young age. Wolfe and Johnson (1995) argued that

self-control was the most powerful predictor among 32 personality variables of the Jackson Personality Inventory (Jackson, 1976) and significantly contributed to students' academic performance. Studies have found that young children with a higher level of self-control may perform better and have more positive learning outcomes under traditional learning conditions (Mischel et al., 1989; Moffitt, et al., 2011; Shoda et al., 1990). For example, in the opinion of Blair and Razza (2010), preschoolers' self-control significantly predicts their early mathematics knowledge and reading ability (i.e., phonemic awareness and letter knowledge). Su and Wei (2013) also demonstrated that self-control ability predicted preschoolers' verbal ability. However, Ponitz et al. (2009) suggested that self-control could predict gains from the beginning to the end of the kindergarten year in math skills but not in vocabulary or print knowledge. Hence, self-control ability might affect the different aspects of learning in traditional learning. The past literature on the association of self-control ability and learning performance in online learning conditions has mainly focused on college students, and few studies have focused on preschool children. Therefore, it is unknown how self-control affects academic performance in online learning conditions for preschoolers.

### 2.2 Learning method

Recently, a great amount of evidence has shown that compared with restudy, tests are more useful and can affect learners' outcomes positively even without feedback (Roediger & Butler, 2010; Zhou et al., 2015), which is called the testing effect or the retrieval practice effect (Thomas et al., 2018). In addition, the test of learning content has been shown to increase learners' long-term retention and transfer of knowledge to new situations (Agarwal et al., 2012; Butler, 2010; Roediger & Karpicke, 2006; Weinstein et al., 2010). The elaborative retrieval hypothesis (Carpenter, 2009; Pyc & Rawson, 2010) claims that compared with restudy, test (retrieval practice) is a process that requires that a target be retrieved from memory; semantically related items may be activated while searching for the target information and become linked to the target item. Meanwhile, when feedback is added to testing, learners' academic performance is also improved. The inclusion of feedback strengthens learning and provides a formative component through which learners can monitor their accuracy, preventing erroneous learning (Roediger & Marsh, 2005). In addition, feedback leads to a "prediction-error" signal in the brain (Wilkinson et al., 2014), which catalyzes learning by switching brain regions relevant to long-term memory into a more receptive encoding rather than retrieval mode (Greve et al., 2017; Lisman & Grace, 2005). Therefore, when testing and feedback are added, a fine concept semantic network is formed for them (Carpenter, 2009, 2011).

However, few studies have addressed the issue that preschoolers can also benefit from testing. For example, Fritz et al. (2007) asked children to name seven toy pigs, such as Tinker, employing restudy and testing; the results suggested that, compared with restudy, children's test scores were significantly improved by testing. Kliegl et al. (2018) also found a testing effect when the cued-recall task was used, and when immediate feedback was provided during retrieval practice, the magnitude of the testing

effect was especially enhanced. Currently, there are very few studies on the testing effect for preschool children under real online learning conditions. Considering the testing effect for preschoolers in traditional learning, to make children's learning more effective, we explore the issue of "which learning methods are better for preschoolers under the online learning condition, is there also a testing effect for preschoolers?".

### 2.3 How do cognitive characteristics and learning methods affect online learning together?

Although many studies have noted that tests and tests with feedback are more effective for learners than repetitive study (Roediger & Butler, 2010; Roediger & Karpicke, 2006; Zhou et al., 2015), the more suitable learning method for learners with different characteristics is inconclusive. Bertilsson et al. (2020) showed no significant relationship between learning methods (test and restudy) and individual differences (e.g., personality traits or working memory capacity), which meant that for learners with different personality traits and working memory capacity, there was no difference when they adopted tests as their learning method. However, learners' characteristics might also affect their learning attainments when they adopt different learning methods (Agarwal et al., 2017; Brewer & Unsworth, 2012; Robey, 2019). For example, Agarwal et al. (2017) found that learners with lower working memory capacity performed better than those with higher working memory capacity when they adopted the learning method of testing. Brewer and Unsworth (2012) found that there was an interaction between personal ability and learning method; specifically, learners with lower general-fluid intelligence and lower memory ability performed better when they adopted the learning method of testing, but for learners with higher general-fluid intelligence and higher memory ability, no difference was shown when they adopted the learning method of testing or restudy.

Notwithstanding, recent studies have investigated the interaction between learners' characteristics (e.g., personality traits, working memory capacity) and learning methods (e.g., test, restudy), yet the results are still uncertain (Agarwal et al., 2017; Bertilsson et al., 2020; Brewer & Unsworth, 2012; Robey, 2019). The literature has stated the importance of the association between learning methods and different characteristics for learners to maximize learning efficiency, especially for college students. Although previous studies have focused on learning methods and cognitive characteristics, few studies have incorporated preschoolers' cognitive characteristics along with learning methods. Therefore, the current research combines cognitive characteristics (i.e., cognitive style and self-control ability) and learning methods (i.e., restudy, test, and test with feedback) to discuss which learning method is more suitable for preschoolers with different cognitive characteristics in their online English learning.

## 3 Study 1

In Study 1, we examined whether preschool children with different cognitive styles could perform differently in the online learning environment. Meanwhile, which learning method was better for them when they learned online, would there also be

a testing effect under an online learning environment for them? Furthermore, we examined which learning method was suitable for children with different cognitive styles. We employed an online learning task for preschool children. In this task, children learned an online lesson, which was then either restudy plus test (RST), restudy plus test plus feedback (RSTF) or restudy only (RS).

## 3.1 Method

### 3.1.1 Participants

All participants were 4- to 6-year-old children (N = 496). The mean age was 67.07 months (SD = 5.30; range 49–77 months), and 230 participants were girls; however, some children did not complete or take part in Study 1. The final number of participants was 248 (Mmonth = 67.49, SD = 5.48; range 49–77 months); 115 were girls (Mmonth = 67.59, SD = 5.34), and 133 were boys (Mmonth = 67.49, SD = 5.48). The sampling was based on convenience. Participants were recruited from three public kindergartens and one private kindergarten in an area in Shanxi Province, China. Informed consent was obtained by sending letters home to parents. The economic development level of Shanxi is at the middle level among all provinces of mainland China.

### 3.1.2 Material

Materials included the learning and test material and the cognitive style material.

**Learning material** Learning material was presented on an iPad and was selected from paid online beginner lessons from the Banma App (https://banmaapp.com/). It was developed by the Banma research and development team based on AI technology and science for children aged 3–8 in China. The curricula were taught entirely in English, and they were developed according to the rules of second-language English acquisition, the characteristics of children's language and cognitive development, domestic and foreign curricula, and examination standards. The Animal Sounds lesson used in this study contains five parts. Video time introduces the core vocabularies (cow, sheep, and horse) and sentences (I'm a cow; Mo, Mo; I'm a sheep; etc.) through a video of an animated scene in which two characters complete a chorus task by looking for animals, as shown in Fig. 1. Meanwhile, this section appears as a form of prerecorded video. Word time demonstrates the core vocabulary words one by one. Story time introduces the core sentences sentence by sentence. In speaking time, the participants need to recite the core vocabulary words and sentences, and children's pronunciation could be recorded into the system and scored with stars by AI technology to strengthen their enthusiasm for learning. Quiz time tests part of the core vocabulary and sentences that participants have learned and is scored with stars by AI technology. Children could operate the interface independently by tapping a green button "next" to the next section, such as from "video time" to "word


**Fig. 1** Learning material for online English learning

time". The lesson lasted approximately 15 min. Every child reviewed this lesson three times.

**Test material** The test materials were vocabulary cards and a picture book, which were used for the pretest and posttest. The test tasks were based on those developed by Sun (2003), and a team comprising one experienced kindergarten teacher, one English teacher, and two experts from psychology majors who developed these test tasks and formulated the grading criteria. Finally, the test tasks consisted of word recognition (WR), which examined whether children could name the picture correctly; picture-word matching (PWM), which examined whether children could match the vocabulary words and pictures correctly; and picture book recognition (PBR), which examined whether children could read the content of the picture book correctly. One experimenter noted the children's original answers on paper, and then three trained experimenters consisting of two graduate students from the English major and a graduate student from the psychology major gave them points according to the notes. Children received one point if they correctly answered the question; otherwise, they received "0". Children's final learning scores are the mean score of the three raters. The total WR, PWM, and PBR scores are 3, 3, and 6, respectively. The total test score is 12. The rater consistency reliability coefficient kappa is 0.97, while the consistency coefficients of WR, PWM, and PBR are 0.77, 0.80, and 0.76, respectively.

**Cognitive style material** The cognitive style material was selected from the original Embedded Figure Test (EFT) version developed by Zhang et al. (1981) and included 2 practice items and 10 formal items. On the test, the subject's task was to find a simple figure embedded in a more complex figure. Children were asked complete all 10 items in 10 min, and the simple figure was presented next to the complex figure at the same time to make the EFT easier. The score was the total number of correct responses on the 10 items. They received one point if they traced the figure correctly; otherwise, they received "0". Children were allowed a second attempt on items that were initially incorrect. The mean and standard deviation of these 10 selected items were 6.93 and 3.60, respectively, and the internal consistency coefficient was 0.73.

### 3.1.3 Design and Procedure

We used a 3×3 two-factorial between-subject design to cross cognitive style with the learning methods for Study 1. Two postgraduate students from English and psychology majors with the College English Test Band-6 certificate tested children individually in a quiet room located at their kindergarten. The dependent variable is the difference value between children's final test scores minus the pretest score.

In Study 1, the procedure consisted of three phases: the preparation phase, the learning phase, and the posttest phase.

**Preparation phase** All participants completed the EFT first. After summing their scores, they were divided into three types of cognitive styles based on their scores. Lower scores indicate field-dependent children, with 27% FD scores ranging from 0 to 4, and higher scores indicate field-independent children, with 27% FID scores ranging from 8 to 10. Children who fall in the middle of the scores are characterized as FM children (Liu & Reed, 1994); 46% of the participants were FM children whose scores were from 5 to 7. Then, the pretest of the core vocabulary and sentences from the online course was conducted to ensure that the children who attended the experiment had not mastered the online learning content; meanwhile, the children's English learning experience and phonological awareness were also tested as control variables.

**Learning phase** All the participants were randomly divided into three learning method groups (RS, RST, RSTF) (Fig. 2) based on their entry sequence in the study. In addition, they learned the online content—Animal Sounds—for the next three days.

On the first and second days, the three groups learned the lesson Animal Sounds first. Five minutes later, the RS group restudied the test content to ensure that all participants from different groups were exposed to the test material for the same amount of time; the RST group accepted a test only; and the RSTF group accepted a test with feedback on the correct answer.

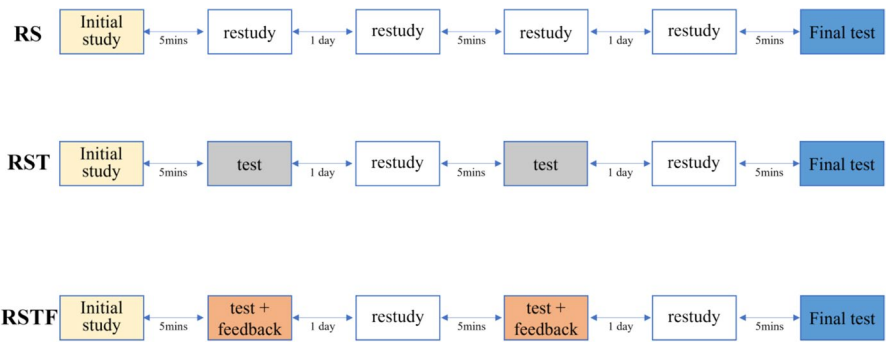


**Fig. 2** The learning procedure of RS, RST, and RSTF for preschool children

On the third day, all three groups learned the lesson on animal sounds first and took the final test five minutes later.

**Post Test phase** In the test phase, children were presented with the learning content through vocabulary cards and the picture book. Then, participants were asked to orally recall the vocabulary and sentences of as many of the study items as they could, in the order of WR, PWM, and PBR. The test phase lasted for approximately 4 min.

### 3.2 Results

First, we examined whether there were differences among the different cognitive styles and learning method groups on the children's pretest scores. The results showed that there were no differences among the children with different cognitive styles, $F(2, 245) = 0.40$, $p = 0.67$, or among different learning methods, $F(2,245) = 0.79$, $p = 0.46$, which meant there were no significant differences among the children across learning method groups. The mean scores of the pretest were 0.59, $SD = 1.00$. After studying the content three times, the children's mean difference values of learning score were 7.10, and the SD was 2.66, suggesting that children had mainly mastered the learning content. Variations in the children's differences across cognitive styles and learning methods are presented as follows (Table 1):

Then, we examined the effects of different cognitive styles and different learning methods on the online learning performance of preschoolers. Taking phonological awareness, English experience, children's age, and gender as control variables, a $3 \times 3$ (cognitive style × learning method) two-way ANOVA confirmed a main effect of cognitive style, $F(2, 234) = 3.72$, $p = 0.03$, partial $\eta 2 = 0.03$, and a further least significant difference (LSD) test reflected that FID preschoolers had higher academic performance than FM and FD preschool children. At the same time, there was no significant difference between FM and FD preschoolers, which meant that FID preschool children had better attainment than FM and FD children in the online learning environment. There was also a main effect of the learning method, $F(2, 234) = 11.71$, $p < 0.001$, partial $\eta 2 = 0.09$, indicating that the learning attainment

**Table 1** Children's difference in learning score values across cognitive styles and learning methods

| Learning method | Cognitive Style (N = 247) (M ± SD) | | |
|---|---|---|---|
| | FD | FM | FID |
| RS | 6.26 ± 3.14 (n = 23) | 5.50 ± 3.12 (n = 16) | 8.38 ± 2.02 (n = 39) |
| RST | 5.00 ± 1.73 (n = 27) | 6.47 ± 2.23 (n = 21) | 6.89 ± 2.99 (n = 36) |
| RSTF | 7.79 ± 2.64 (n = 28) | 7.41 ± 2.37 (n = 17) | 8.29 ± 1.94 (n = 41) |
| total | 6.32 ± 2.74 (n = 78) | 6.48 ± 2.63 (n = 54) | 7.90 ± 2.41 (n = 116) |

under the RSTF condition was higher than that under the RS and RST conditions (LSD was conducted), and there was no significant difference between the RS and RST conditions, suggesting that when children learned with tests and feedback, they obtained better learning outcomes. In addition, a significant interaction between the two factors emerged, $F(4, 233) = 2.59$, $p = 0.04$, partial $\eta 2 = 0.04$, suggesting that cognitive style affected the learning method differently.

Furthermore, Sidak was used to perform multiple comparisons (Fig. 3) examining what appropriate learning methods would be for children with different cognitive styles, showing that for FD preschool children, there was a significant difference among those learning methods, $F(2,234) = 6.64$, $p = 0.002$, partial $\eta 2 = 0.05$. Specifically, when they adopted the RSTF learning method, the difference in learning scores was significantly higher than that of the RST; however, there was no significant difference between the RS and RST groups or between the RS and RSTF groups, suggesting that FD children would benefit more from RSTF than from RST. For FM preschool children, there was also a significant difference among those learning methods, $F(2, 234) = 6.61$, $p = 0.002$, partial $\eta 2 = 0.05$. Specifically, compared with the RS condition, their difference values of learning scores were significantly higher under the RSTF condition, while there were no significant differences between the methods of RST and RSTF or between the methods of RS and RST, suggesting that FM children benefit more from RSTF than from RS. For FID preschool children, there was no significant difference among those learning methods,

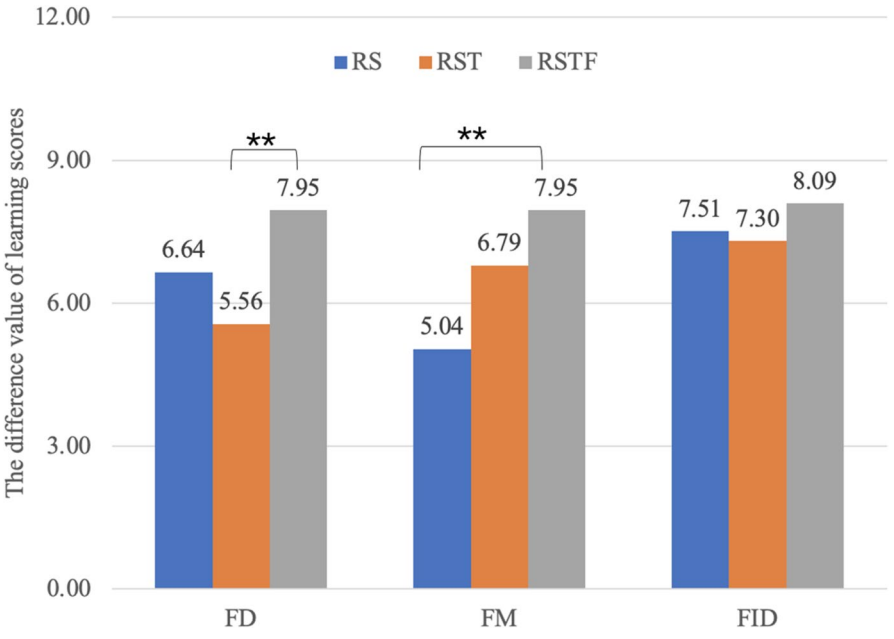


**Fig. 3** The difference values of learning scores for children with different cognitive styles under the RS, RST, and RSTF conditions

F (2, 234) = 1.98, p = 0.14, partial η2 = 0.02, suggesting that FID children perform better regardless of the kind of learning method.

## 4 Study 2

In Study 2, we examined whether preschool children with different levels of self-control abilities perform differently under the online learning environment. Furthermore, we examined which learning method was suitable for children with different self-control abilities. The learning task was the same as in Study 1.

### 4.1 Method

#### 4.1.1 Participants

All participants were children between the ages of 4–6 (N = 496), as in Study 1. However, some children did not complete or take part in Study 2; the final number of participants was 247 (Mmonth = 67.53 months, SD = 5.44; range 49–77 months), where 114 were girls (Mmonth = 67.45 months, SD = 5.58) and 133 were boys (Mmonth = 67.59 months, SD = 5.34). Data were collected from November 2020 to March 2021.

#### 4.1.2 Material

The materials included the learning and test material and the self-control test material. The learning and test material was the same as in Study 1.

**Self-control test material** Self-control was assessed using the Go-No-Go task, which measures children's response inhibition and has good validity (Li et al., 2018; Wiebe et al., 2012). Children were told to respond to the go stimulus (e.g., rabbit) by tapping the screen and not to respond to the no-go stimulus (e.g., tiger). For this task, children were instructed to tap the screen when they saw a rabbit and not to tap it when they saw a tiger. Next, three practice blocks with 5 go trials, 5 no-go trials, and 10 mixed trials were presented to children, and they were provided sound feedback during the practice blocks. Then, the children were presented with formal trials. There were 3 blocks for the formal test, with 25 trials for every block (80% rabbit trials, 20% tiger trials). A Go-No-Go ratio of 80% was selected because it has been used in previous studies (Howard & Okely, 2015). All trials were randomized by the application, and each trial disappeared from the screen after 1,500 ms. There was a 1,000 ms interstimulus interval, and the total task lasted approximately 6 min. The accuracy score of all tasks was the accuracy of the go trials multiplied by the accuracy of the no-go trials. The test was administered on the iPad using a webpage created by an application development company.

#### 4.1.3 Design and Procedure

A two-factorial between-subject design was conducted, wherein self-control ability was crossed with the learning methods in Study 2. The experimenters and dependent variable were the same as in Study 1.

There were also three phases in this study: the preparation phase, the learning phase, and the posttest phase.

**Preparation phase** All participants completed the Go-No-Go task first. After all the children finished the task, they were divided into three groups according to their scores, with 27% being the lower self-control (LSC) group scoring from 0 to 0.53, 64% being the middle self-control (MSC) group scoring from 0.54 to 0.91, and 27% being the higher self-control (HSC) group scoring from 0.92 to 1. Then, the pretest of the core vocabulary and sentences from the online course was conducted to ensure that the children who attended the experiment had not mastered the online learning content; meanwhile, the children's English learning experience and phonological awareness were also tested as control variables.

The learning phase and posttest phase were the same as those in Study 1.

### 4.2 Results

ANOVA was conducted to test whether there were differences among the levels of self-control and learning method groups on the children's pretest scores. The results showed that there were no differences among children across levels of self-control, $F(2, 244) = 0.90$, $p = 0.41$, or across learning methods groups, $F(2, 244) = 0.86$, $p = 0.42$, which meant there were no significant differences for the children from different groups. The total test score was 12, the pretest mean score was 0.57, and the SD was 0.99. After performing the exercise three times, the children's final test mean scores were 7.10, and the SD was 2.65, suggesting that the children had partially mastered the learning content. The values of the children's learning scores for different levels of self-control and learning methods are presented as follows (Table 2):

We examined the effects of different levels of self-control and learning methods on the online learning performance of preschoolers. After controlling for phonological awareness, English experience, and children's age and gender, a $3 \times 3$ ANOVA with factors of self-control (LSC, MSC, HSC) and learning methods (RS, RST, RSTF) (Table 3) was conducted, revealing a significant main effect of learning method, $F(2, 233) = 10.55$, $p < 0.001$, partial $\eta 2 = 0.08$, and a further LSD test indicated that the RS group and RST group had significantly lower scores than the RSTF group, but there was no significant difference between the RS and RST groups, which achieved the same conclusion as in Study 1. There was no main effect of self-control, $F(2, 233) = 0.58$, $p = 0.56$, partial $\eta 2 = 0.01$, which meant "there was no significant difference among the different levels of self-control", suggesting that self-control ability did not affect learning outcomes. In addition, no significant

**Table 2** Children's learning scores values for different levels of self-control and learning methods

| Learning method | Self-control levels (N = 246) (M ± SD) | | |
|---|---|---|---|
| | LSC | MSC | HSC |
| RS | 6.08 ± 2.90 (n = 24) | 7.67 ± 2.63 (n = 27) | 7.85 ± 2.77 (n = 26) |
| RST | 5.67 ± 2.37 (n = 28) | 5.48 ± 2.49 (n = 29) | 7.19 ± 2.43 (n = 27) |
| RSTF | 7.93 ± 2.45 (n = 29) | 8.07 ± 2.09 (n = 27) | 7.76 ± 2.29 (n = 29) |
| total | 6.60 ± 2.73 (n = 81) | 7.04 ± 2.65 (n = 83) | 7.60 ± 2.48 (n = 82) |

**Table 3** The ANCOVA results of children's online learning test scores across levels of self-control and learning methods

| Variable source | df | MS | F |
|---|---|---|---|
| Phonological awareness | 1 | 41.14 | 5.85** |
| English experience | 1 | 107.95 | 14.07*** |
| Gender (boy) | 1 | 4.05 | 0.83 |
| Age | 1 | 77.75 | 20.45*** |
| Self-control | 2 | 3.36 | 0.58 |
| Learning method | 2 | 58.91 | 10.55*** |
| Self-control × learning method | 4 | 9.21 | 1.48 |
| Error | 233 | 5.21 | |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

interaction between the two factors emerged, F (4, 233) = 1.48, p = 0.21, partial η2 = 0.03, suggesting that there was no difference for children across self-control levels when they learned English with different learning methods.

## 5 General Discussion

The present study aimed to determine online English learning attainment for preschoolers with different cognitive characteristics using different learning methods and explore the interaction between cognitive characteristics and learning methods in online learning conditions. The findings indicated that FID preschoolers performed better than FD and FM preschoolers. This is in line with the results conducted by Li and Ju (2009) in the traditional English learning environment and teenagers under the online learning condition by López-Vargas et al. (2017) and Lin et al. (2019); in other words, FID learners can separate relevant information from irrelevant information, are less affected by external cues (Zhang, 2004), and enjoy the convenience of the internet (Pavalache-Ilie & Cocorada, 2014). However, there is no difference in learning outcomes between FM children and FD children, which is not consistent with the study for college students found by Zeng et al. (2010) in a traditional learning environment. FD preschool children are easily distracted in the

online environment (DeTure, 2004), making it more difficult to process information and avoid learning environment effects (Hansen, 1995). For FM children, their cognitive style may remain at the developing stage, leading to the same learning outcome as FD children.

Both studies also demonstrated the main effect of the learning method. Learned from the results, the learning outcome of preschool children in the RSTF group was significantly better than that in the RST and RS groups, indicating that the testing effect emerged only when feedback was added to the testing. This was consistent with Fritz et al. (2007) and Kliegl et al. (2018), who indicated that when immediate feedback was provided during retrieval practice, the magnitude of the testing effect was especially enhanced, also suggesting that feedback during the test plays a critical role in children's learning outcomes. The elaborative retrieval hypothesis (Carpenter, 2009; Pyc & Rawson, 2010) claims that compared with restudy, in which children only need to repeatedly learn the information presented, test is a process that requires a target being retrieved from memory; semantically related items may be activated while searching for the target information and become linked to the target item. In addition, feedback leads to a "prediction-error" signal in the brain (Wilkinson et al., 2014), which catalyzes learning by switching brain regions relevant to long-term memory into a more receptive encoding rather than retrieval mode (Greve et al., 2017; Lisman & Grace, 2005). These findings lend empirical evidence of the testing effect that children will perform better when testing is added to the learning process under the online condition.

Further analysis found that there is no relation between FID preschool children's good performance and different learning methods. Jia et al. (2014) found that FID learners performed better under a high cognitive information load, which may give us a cue that under the online environment, which causes a lower level of arousal, learners need to separate the core learning content from the complex information to complete the learning of knowledge. FID children can process information more effectively and can have direct access to effective information without relying on external references. Hence, they can quickly understand and acquire key knowledge and achieve better results even if they simply repeat the study without providing more detailed operational tests and feedback in online learning conditions. FD and FM preschool children can obtain better learning outcomes only under the RSTF condition, and a clear trend could be found in the mean learning attainment. Although online learning provides rich learning content, it can make children lose their direction and prevent them from absorbing what they learn effectively. Thus, when testing and feedback are added, a fine concept semantic network is formed for them (Carpenter, 2009, 2011), making the process of learning the material more sophisticated and improving their memory and migration, which effectively improves the learning outcome. In the meantime, tests with feedback allow children to correct errors and be re-exposed to information that they cannot recall; then, they can process the learning material more effectively and acquire knowledge more directly. However, tests without feedback do not produce better learning outcomes, probably because it is difficult for them to search for core information, resulting in memory difficulties. This finding provides evidence in support of the importance of

children with different cognitive styles in online English learning, suggesting that online curriculum designers should consider the characteristics of cognitive style, and before the course begins, preschool children's cognitive style should be examined. Furthermore, appropriate learning methods can automatically be matched accordingly.

Nevertheless, we did not find a main effect of self-control or interaction between self-control and learning method, which was also one of the limitations of our study and was not consistent with previous studies that suggested that self-control was an important predictor of preschool children's performance (Wolfe & Johnson, 1995). Blair and Razza (2010) showed that self-control in traditional learning could significantly predict children's achievement in phonological awareness, vocabulary knowledge, etc. However, Ponitz et al. (2009) suggested that self-control predicted gains from the beginning to the end of the kindergarten year in math skills but not in vocabulary or print knowledge. The Go-No-Go task requires children to begin to react to the information presented to them (e.g., do not tap the screen when specific pictures are presented), and it is also a language-independent construct that taps into underlying mental processes rather than specific knowledge (Lonigan et al., 2017). Therefore, it is not surprising that self-control did not affect children's English learning outcomes. Currently, no evidence demonstrates that self-control and learning methods can affect online English learning together, and we have not drawn this conclusion. Self-control and learning methods may correspond to different information processing and play unique roles in children's learning processes, leading to the noninteraction of self-control and learning methods.

## 6 Limitations and future research

This study is limited to learning performance in preschool children for only several classes and a relatively small sample size. Although we controlled for gender and age when the data analysis was conducted, the conclusions we drew still need to be corroborated by other studies. Future studies are recommended to be conducted in the same and different settings for different age groups and different subjects to further generalize this study. Furthermore, although the present study indicated that self-control did not affect children's online English learning outcomes, the evidence is inconclusive and needs to be examined further. In addition, it is also likely that the multimethod measurement of the self-control task should be used in future studies. Moreover, preschool children's cognitive characteristics are rapidly developing during this stage and may change with age. Cognitive characteristics are measured only once by the method of experiment in this study; hence, future studies should explore whether learning outcomes are affected by cognitive characteristics and learning methods together at several time points and whether the effect emerges among different age groups, thereby providing more detailed evidence of the dynamic interaction between cognitive characteristics and learning methods.

## 7 Conclusion

To conclude, this research, cognitive style and learning method not only affected children's online English learning performance independently but also affected the learning effect together. Specifically, FID preschool children performed better than FM and FD children in the online learning condition, and they performed well regardless of the learning methods, while FM and FD children performed better only when they adopted learning methods with feedback-based testing. In addition, there is a testing effect for preschool children when learning online. However, self-control cannot affect their English online learning performance independently, nor can interaction with learning methods affect online learning performance. Furthermore, these findings may provide insights for online learning curriculum designers, and it is possible to help children learn better by adding tests and feedback in designing online learning steps and considering the characteristics of children's cognitive styles in the curriculum. Hence, it is important for parents to identify these FID and FM children before they start learning, leaving parents to provide more support for them and help them select more suitable online courses.

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**Data availability** The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to restrictions on their containing information that could compromise the privacy of research participants.

### Declarations

**Conflict of interest** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

Agarwal, P. K., Bain, P. M., & Chamberlain, R. W. (2012). The value of applied research: Retrieval practice improves classroom learning and recommendations from a teacher, a principal, and a scientist. *Educational Psychology Review, 24*(3), 437–448. https://doi.org/10.1007/s10648-012-9210-2

Agarwal, P. K., Finley, J. R., Rose, N. S., & Roediger, H. L. (2017). Benefits from retrieval practice are greater for students with lower working memory capacity. *Memory, 25*, 764–771. https://doi.org/10.1080/09658211.2016.1220579

Bertilsson, F., Stenlund, T., Wiklund-Hörnqvist, C., & Jonsson, B. (2020). Retrieval practice: Beneficial for all students or moderated by individual differences? *Psychology Learning and Teaching, 20*, 21–39. https://doi.org/10.1177/1475725720973494

Blair, C., & Razza, R. P. (2010). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*(2). https://doi.org/10.1111/j.1467-8624.2007.01019.x

Brewer, G. A., & Unsworth, N. (2012). Individual differences in the effects of retrieval from long-term memory. *Journal of Memory and Language, 66*, 407–415. https://doi.org/10.1016/j.jml.2011.12.009

Butler, A. C. (2010). Repeated testing produces superior transfer of learning relative to repeated studying. *Journal of Experimental Psychology Learning, Memory, and Cognition., 36*, 1118–1133. https://doi.org/10.1037/a0019902

Carpenter, S. K. (2009). Cue strength as a moderator of the testing effect: The benefits of elaborative retrieval. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 35*(6), 1563–1569. https://doi.org/10.1037/a0017021

Carpenter, S. K. (2011). Semantic information activated during retrieval contributes to later retention: Support for the mediator effectiveness hypothesis of the testing effect. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 37*(6), 1547–1552. https://doi.org/10.1037/a0024140

Chen, Q. (2019). *Contemporary psychology of education* (3rd ed.). Beijing Normal University Press.

Chen, S. Y., & Liu, X. (2011). Mining students' learning patterns and performance in web-based instruction: A cognitive style approach. *Interactive Learning Environments, 19*(2), 179–192. https://doi.org/10.1080/10494820802667256

Chen, S. Y., & Macredie, R. (2010). Web-based interaction: A review of three important human factors. *International Journal of Information Management, 30*(5), 379–387. https://doi.org/10.1016/j.ijinfomgt.2010.02.009

Chin, K., Lee, K., & Chen, Y. (2018). Using an interactive ubiquitous learning system to enhance authentic learning experiences in a cultural heritage course. *Interactive Learning Environments, 26*(4), 444–459. https://doi.org/10.1080/10494820.2017.1341939

de Mooij, S. M. M., Kirkham, N. Z., Raijmakers, M. E. J., van der Maas, H. L. J., & Dumontheil, I. (2020). Should online math learning environments be tailored to individuals' cognitive profiles? *Journal of Experimental Child Psychology, 191*, 104730–104730. https://doi.org/10.1016/j.jecp.2019.104730

DeTure. (2004). Cognitive style and self-efficacy: Predicting student success in online distance education. *American Journal of Distance Education, 18*(1), 21–38. https://doi.org/10.1207/s15389286ajde1801_3

Feldmann, S. C., Martinez-Pons, M., & Shaham, D. (1995). The relationship of self-efficacy, self-regulation, and collaborative verbal behavior with grades: Preliminary findings. *Psychological Reports, 77*(3), 971–978. https://doi.org/10.2466/pr0.1995.77.3.971

Fritz, C. O., Morris, P. E., Nolan, D., & Singleton, J. (2007). Expanding retrieval practice: An effective aid to preschool children's learning. *Quarterly Journal of Experimental Psychology (2006), 60*(7), 991–1004. https://doi.org/10.1080/17470210600823595

Greve, A., Cooper, E., Kaula, A., Anderson, M. C., & Henson, R. (2017). Does prediction error drive one-shot declarative learning? *Journal of Memory and Language, 94*, 149–165. https://doi.org/10.1016/j.jml.2016.11.001

Hansen, J. W. (1995). Student cognitive styles in postsecondary technology programs. *Journal of Technology Education, 6*(2), 19–33. https://doi.org/10.21061/jte.v6i2.a.2

Howard, S. J., & Okely, A. D. (2015). Catching fish and avoiding sharks: Investigating factors that influence developmentally appropriate measurement of preschoolers' inhibitory control. *Journal of Psychoeducational Assessment, 33*(6), 585–596. https://doi.org/10.1177/0734282914562933

Jackson, D. N. (1976). *Jackson personality inventory*. Research Psychologists Press.

Jia, S., Zhang, Q., & Li, S. (2014). Field dependence–independence modulates the efficiency of filtering out irrelevant information in a visual working memory task. *Neuroscience, 278*, 136–143. https://doi.org/10.1016/j.neuroscience.2014.07.075

Kliegl, O., Abel, M., & Bäuml, K.-H.T. (2018). A (preliminary) recipe for obtaining a testing effect in preschool children: Two critical ingredients. *Frontiers in Psychology, 9*, 1446–1446. https://doi.org/10.3389/fpsyg.2018.01446

Kristof, A. L. (1996). Person-organization fit: An integrative review of its conceptualizations, measurement, and implication. *Personnel Psychology, 49*(1), 1–49. https://doi.org/10.1111/j.1744-6570.1996.tb01790.x

Li, X., & Ju, H. (2009). Study on preschool children's cognitive styles in second language. *Foreign Language Research., 2009*(1), 53–57. https://doi.org/10.16263/j.cnki.23-1071/h.2009.01.012

Li, H., Subrahmanyam, K., Bai, X., Xie, X., & Liu, T. (2018). Viewing fantastical events versus touching fantastical events: Short-term effects on children's inhibitory control. *Child Development, 89*(1), 48–57. https://doi.org/10.1111/cdev.12820

Lin, H. X., Yang, Sh. F., & Du, X. J. (2019). Push strategies for mathematical online sample learning of primary school students. *e-Education Research., 40*(11), 8. https://doi.org/10.13811/j.cnki.eer.2019.11.017

Liu, Y. L., & Ginther, D. (1999). Cognitive styles and distance education. *Online Journal of Distance Learning Administration, 2*(3). https://ojdla.com/archive/fall23/liu23.pdf

Liu, M., & Reed, W. M. (1994). The relationship between the learning strategies and learning styles in a hypermedia environment. *Computers in Human Behavior, 10*(4), 419–434. https://doi.org/10.1016/0747-5632(94)90038-8

Lisman, J. E., & Grace, A. A. (2005). The hippocampal-VTA loop: Controlling the entry of information into long-term memory. *Neuron (Cambridge, Mass.), 46*(5), 703–713. https://doi.org/10.1016/j.neuron.2005.05.002

Lonigan, C. J., Allan, D. M., Goodrich, J. M., Farrington, A. L., & Phillips, B. M. (2017). Inhibitory control of Spanish-speaking language-minority preschool children: Measurement and association with language, literacy, and math skills. *Journal of Learning Disabilities, 50*(4), 373–385. https://doi.org/10.1177/0022219415618498

López-Vargas, O., Ibáñez-Ibáñez, J., & Racines-Prada, O. (2017). Students' metacognition and cognitive style and their effect on cognitive load and learning achievement. *Educational Technology & Society, 20*(3), 145–157. https://www.jstor.org/stable/26196126

Lugli, L., Ragni, M., Piccardi, L., & Nori, R. (2017). Hypermedia navigation: Differences between spatial cognitive styles. *Computers in Human Behavior, 66*, 191–200. https://doi.org/10.1016/j.chb.2016.09.038

Mischel, W., Shoda, Y., & Rodriguez, M. L. (1989). Delay of gratification in children. *Science (American Association for the Advancement of Science), 244*(4907), 933–938. https://doi.org/10.1126/science.2658056

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences - PNAS, 108*(7), 2693–2698. https://doi.org/10.1073/pnas.1010076108

Pavalache-Ilie, M., & Cocorada, S. (2014). Interactions of students' personality in the online learning environment. *Procedia - Social and Behavioral Sciences, 128*, 117–122. https://doi.org/10.1016/j.sbspro.2014.03.128

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*(3), 605–619. https://doi.org/10.1037/a0015365

Pyc, M. A., & Rawson, K. A. (2010). Why testing improves memory: Mediator effectiveness hypothesis. *Science, 330*(6002), 335–335. https://doi.org/10.1126/science.1191465

Robey, A. (2019). The benefits of testing: Individual differences based on student factors. *Journal of Memory and Language, 108*, 104029. https://doi.org/10.1016/j.jml.2019.104029

Roediger, H. L., & Butler, A. C. (2010). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning by taking memory tests improves long-term retention. *Psychological Science, 17*(3), 249–255. https://doi.org/10.1111/j.1467-9280.2006.01693.x

Roediger, H. L., & Marsh, E. J. (2005). The positive and negative consequences of multiple-choice testing. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31*(5), 1155–1159. https://doi.org/10.1037/0278-7393.31.5.1155

Shoda, Y., Mischel, W., & Peake, P. K. (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. *Developmental Psychology, 26*(6), 978–986. https://doi.org/10.1037/0012-1649.26.6.978

Singh, V., & Thurman, A. (2019). How many ways can we define online learning? A systematic literature review of definitions of online learning (1988–2018). *The American Journal of Distance Education, 33*(4), 289–306. https://doi.org/10.1080/08923647.2019.1663082

Steed, E., & Leech, N. (2021). Shifting to remote learning during COVID-19: Differences for early childhood and early childhood special education teachers. *Early Childhood Education Journal, 49*(5), 789–798. https://doi.org/10.1007/s10643-021-01218-w

Su, X. L., & Wei, Y. G. (2013). Effects of inhibitory control on preschoolers' verbal ability. *Studies in Preschool Education, 1*, 32–37. https://doi.org/10.13861/j.cnki.sece.2013.01.003

Sun, Y. Q. (2003). *Study on factors influencing children's English learning in multimedia environment*. Doctoral Dissertation, Beijing Normal University. http://etd.lib.bnu.edu.cn/Detail?dbID=5&dbCode=ETD1&sysID=48084

Thomas, P. R., & Mckay, J. B. (2010). Cognitive styles and instructional design in university learning. *Learning & Individual Differences, 20*(3), 197–202. https://doi.org/10.1016/j.lindif.2010.01.002

Thomas, R. C., Weywadt, C. R., Anderson, J. L., Brenda, M. P., & Mcdaniel, M. A. (2018). Testing encourages transfer between factual and application questions in an online learning environment. *Journal of Applied Research in Memory & Cognition, 7*(2), 252–260. https://doi.org/10.1016/j.jarmac.2018.03.007

Weinstein, Y., McDermott, K. B., & Roediger, H. L. I. I. I. (2010). A comparison of study strategies for passages: Rereading, answering questions, and generating questions. *Journal of Experimental Psychology: Applied, 16*(3), 308–316. https://doi.org/10.1037/a0020992

Wiebe, S. A., Sheffield, T. D., & Espy, K. A. (2012). Separating the fish from the sharks: A longitudinal study of preschool response inhibition. *Child Development, 83*(4), 1245–1261. https://doi.org/10.1111/j.1467-8624.2012.01765.x

Wilkinson, L., Tai, Y. F., Lin, C. S., Lagnado, D. A., Brooks, D. J., Piccini, P., & Jahanshahi, M. (2014). Probabilistic classification learning with corrective feedback is associated with in vivo striatal dopamine release in the ventral striatum, while learning without feedback is not. *Human Brain Mapping, 35*(10), 5106–5115. https://doi.org/10.1002/hbm.22536

Witkin, H. A., & Goodenough, D. R. (1981). Cognitive styles: Essence and origins. Field dependence and field independence. Psychological issues, (51), 1–141. issues, (51), 1–141. PMID: 7012884.

Wolfe, R. N., & Johnson, S. D. (1995). Personality as a predictor of college performance. *Educational and Psychological Measurement, 55*(2), 177–185. https://doi.org/10.1177/0013164495055002002

Yeh, S.-P. & Lin, C.-H. (2012). Identifying key success factors of e-learning in travel agents. *Pakistan Journal of Statistics, 28*(5), 565–572. http://ir.lib.isu.edu.tw/handle/987654321/15516

Zeng, X. Q., Liu, J. P., & Chen, M. R. (2010). The relationship between cognitive style and implicit/explicit memory. *Journal of Psychological Science*, *33*(1), 138–140. https://doi.org/10.16719/j.cnki.1671-6981.2010.01.031

Zhang, L. F. (2004). Field -dependence/independence: Cognitive style or perceptual ability? Validating against thinking styles and academic achievement. *Personality and Individual Difference, 37*(2), 1295–1311. https://doi.org/10.1016/j.paid.2003.12.015

Zhang, H. C., Meng, Q. M., & Zheng, R. C. (1981). Studies on cognitive styles: Role of individual differences in field-dependence in learning and visual after-effect. *Acta Psychologica Sinica, 13*(3), 53–58. https://journal.psych.ac.cn/xlxb/CN/Y1981/V13/I3/53

Zhou, A. B., Yang, T. C., Cheng, C., Ma, X. F., & Zhao, J. (2015). Retrieval practice produces more learning in multiple-list tests with higher-order skills. *Acta Psychologica Sinica*, *47*(7), 928–938. https://doi.org/10.3724/SP.J.1041.2015.00928