Implicit Learning in ADHD Preschool Children

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Abstract

The aim of this study is to analyze the process of implicit learning in ADHD preschool children. We designed 2 experiments in which we used an artificial grammar task as an implicit learning procedure. In the first experiment, we examined whether preschool children can acquire implicit knowledge using the artificial grammar task. Our results showed that preschool children could learn implicitly the rules for the task. In the second experiment, we compared implicit learning performance of the artificial grammar task in normal preschool children and ADHD preschool children. We found statistically significant differences ($t= -2.68$, $p<0.01$) between the two groups suggesting that normal children perform better than ADHD children in implicit learning of artificial grammar.

Key-words: ADHD, implicit learning, preschool children.

The aim of the present study is to investigate implicit learning processes in ADHD children. We considered this study important for two reasons. At a theoretical level, the majority of studies on implicit learning are done on adults and inferences from those studies are made to children without taking in account the developmental characteristics. Methodologically, early evidence of ADHD may be discovered by analyzing the implicit learning processes in preschool children.

Attention deficit hyperactivity disorder (ADHD) is the most common neurobehavioral disorder of childhood and it is also among the most prevalent chronic health conditions affecting school-aged children. The main symptoms of ADHD include inattention, hyperactivity and impulsivity (American Psychiatric Association, 1997). Because the exactly etiology of ADHD it is unknown, the diagnostic criteria and clinical picture of ADHD have been modified in time as a result of progress in the theoretical study of the disorder. Diagnostically, for example, the Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria were modified in succeeding editions. The second edition of DSM referred to ADHD as a "hyperkinetic reaction of childhood"; DSM-III changed the diagnostic category of Hyperkinetic reaction of childhood to Attention Deficit Disorder (ADD) that stressed on attentional symptoms.
The third edition of the DSM (DSM-III; APA, 1987) conceptualized the disorder as a unidimensional construct. However, critics argued that this single factor conceptualization of ADHD could increase rates of diagnostic errors (Atkins, Pelham & Licht, 1985). More precisely Lahey (1988) argued that a unidimensional symptom list might increase the rate of false positives for ADHD diagnosis by increasing the number of heterogeneous response patterns that could be used to meet the minimum diagnostic criteria.

As a result of these criticisms, the DSM-IV proposed a multidimensional model of ADHD. Exploratory factor analytic studies found that two dimensions of ADHD consistently emerged. The first factor has been labeled inattention and the second has been labeled impulsivity-hyperactivity (Bauermeister et al., 1995; Brito, Pinto, & Lins, 1995; Pelham et al., 1992).
Studies from developmental and cognitive psychology brought a lot of information concerning the "socio-cognitive map" of ADHD children. Children with ADHD are most likely to experience problems in intellectual development, motor development, speech and language

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development, memory and planning rule-governed behavior, self regulation of emotion (Barkley, 1998), academic performance, adaptive functioning (Zentall, 1993; Barkley, 1998). Furthermore, it was shown that ADHD children suffer from poor academic performance, delayed speech (Hartsough & Lambert, 1985; Szatmari et al., 1989), and delayed internalization of language (Rosenbaum & Baker, 1984). ADHD children also display deficiencies in memory and planning, especially working memory (Beker, 1994). Studies investigating nonverbal working memory found that children with ADHD are less proficient at reproducing increasingly lengthy and novel sequences of simple movements than are normal children (Mariani & Barkley, 1997). For example, researchers focused on forethought and planning used the Tower of Hanoi (TOH) in order to assess planning abilities in ADHD children; those studies showed that ADHD children perform more poorly than normal children at TOH task (Weyandt & Willis, 1994). TOH involves mental planning and strategies selection before and while undertaking the motor execution of the task. Similar problems, like the Tower of London task or Mazes have demonstrated deficits in planning and in selection of correct strategies in ADHD children.

All the above results concern explicit processes. It is now well known that the ADHD children perform lower on explicit learning tasks than non ADHD children.

However, implicit learning in ADHD is not well documented. The most cited definition of implicit learning refers to learning the links between stimuli without a deliberate attempt to learn. In contrast, explicit learning occurs when there is an active engagement in conscious strategies to discover the rules underlying a task (O'Brien Malone & Maybery, 1998). We reviewed the relevant research concerning implicit learning in children and we found little empirical research on this topic. The majority of the studies on implicit learning in children attempted to infer results obtained using adult participants.

How implicit processes can influence cognitive abilities?

Implicit processes can have an influence on cognitive abilities in two ways. The first refers to language acquisition and the second refers to strategy selection in problem solving.

Language acquisition

It is known that language acquisition in childhood is done by implicit learning of grammar rules (Chomsky, N., 1966; Miller, A. 1958; Miller, A. 1968). This means that the child does not learn to speak correctly by learning explicitly the rules of language; he implicitly learns the rules of grammar. Congruent with this statement we can infer that if a child has problems in implicit learning processes we can expect that this problem can influence language acquisition. In this case, we will observe on the explicit level (e.g., by the modality in which the child use the rules of language) problems in language. We should also examine implicit processes in children with language problems.

Strategy selection

As we outlined in the previous section ADHD children show a serious strategic deficit in cognitive tasks. Some research (Wong, 1985) suggests that strategic deficit are not related to strategic knowledge but to the deficits of the strategy selection processes. We believe that metacognitive deficits in strategy selection is an important factor for low cognitive performance of the ADHD child.

How are these functions related to implicit learning? According to Nhouyvanisvong and Reder (1998), strategy selection mechanisms are governed by the implicit process of rapid feeling of knowing. When subjects are confronted with a problem in less than 1500 ms subjects select a strategy based on their rapid feeling of knowing. Using the "Game show" experimental paradigm, Schunn at al. (1997) concluded from several experiments that rapid feeling of knowing and indirect strategy selection is based on the familiarity of the keys founded in the terms of the problem, not on the accessibility of the target (Koriat,1993).

Schunn at al. (1997) presented subjects familiar arithmetic problems such as 29 X 32. The subjects were asked to choose a strategy (compute or retrieve form memory) as quick as possible. At the beginning of the experiment subjects realized that the best choice is to compute the answer. As exposure to these problems increased, retrieval of the answer became an efficient strategy for some of the problems. The experimenters manipulated the problems in such a way that some problems resembled earlier problems that were exposed before, multiple times, only changing the operation (29 X 32, 29 + 23). If feeling of knowing is based on partial retrieval of the problem then subjects would have chosen to calculate these problems because no answers were stored in memory. The results showed that familiarity with the terms of the question infused rapid feeling of knowing.

Reder (1987) showed rapid feeling of knowing occurs every time we are confronted with a problem in order to regulate strategy selection. These findings combined with the results of Lovett and Anderson (1994) which show that strategy choice is influenced by history of success and current context in problem solving. This suggests that strategy selection is based on implicit learning.

The question that we raise is the following: how is implicit learning processed in ADHD preschool children? Taking into account the cognitive-behavioral and neuropsychological characteristics of ADHD children, and also the studies from implicit learning, we found two lines that could argue the processes of implicit learning in ADHD children. We will present in the next section each of them.

First, it has been argued that implicit learning should be more robust to neuropsychological insults (Reber, 1992) than explicit learning. Reber (1992) noticed that cognitive systems appearing earlier in the course of evolution should show greater robustness to neuropsychological injuries when compared with more recently evolved systems. Specifically, he suggested that implicit learning should be robust in the face of disorders that undermine explicit processing. If this hypothesis is valid then we should not find differences in implicit learning in normal children and ADHD children. It is known that ADHD children show neuropsychological impairments and if the Reber hypothesis can be extend to the ADHD children, this means that we will not find differences in implicit learning between normal children and ADHD children.

Another line of research targets the dissociation of the explicit and implicit abilities arguing for the evolutionary utility of implicit learning. According to Borstein (1989) the preference for familiar items in mere exposure experiments minimize the risk of potential danger in unfamiliar situations. Concomitantly, studies concerning the famous Natural Language Mystery (Miller, 1968) also suggest that artificial grammar learning and generative thinking predates the advent of language (Mathews & Cochran, 1998). These findings suggest that implicit learning is a basic generative cognitive process predating language and consciousness.

Within the evolutionary paradigm there are two lines of research both of them studying the effect of experimental manipulation on explicit and implicit processes. Manza, Power et al. (1996) tested divided attention manipulation's effect on implicit learning. Results found low reproduction performance in the divided attention group compared to the full attention group, but as dissociation paradigm predicted no differences were found on the implicit task as a consequence of attention manipulation.

The dissociation hypothesis had been tested on ADHD subjects. Reber (1992) suggested that another evidence for the evolutionary framework would be the preserved implicit abilities and the impaired explicit abilities of ADHD subjects as a consequence of the neurological dysfunction.

Experimental evidence has not supported this hypothesis. Manza, Moretti et al. (1996) compared a group of college students with self reported ADHD to a non-ADHD (control) group. The performance on an artificial learning task supported the dissociation prediction by showing no difference between the two groups on the implicit task. However the performance of the two groups did not differ significantly on the explicit reproduction task. Unfortunately these results can not be taken as evidence as 83 % of the participants were taking some form of stimulant medication to regulate their condition.

Second, recent research (Fletcher et al, 2000) found differences in implicit learning between normal children and mentally retarded children. Contrary to the IQ proposition (Reber, 1993) that the implicit learning system should demonstrate invariance on intellectual level, Fletcher et. al (2000) found that implicit learning as well as explicit learning varied with intellectual level; the results showed that mental age is critical to implicit learning. Those differences can be found

in implicit learning in ADHD children if we take into account some similarities in cognitive and executive functions between mentally retarded children and ADHD children.
This statement should explain the poor performance on language acquisition found in ADHD children. As Barkley (1998) argued "ADHD children are more likely to have more specific problems in their speech development than do normal children" (p. 101). If ADHD children have problems in language acquisition we should find problems in implicit learning. We will test this hypothesis in our second experiment using an artificial grammar task as a task for implicit learning.

A third possibility exists in which the performance of ADHD children should be superior to that of normal children. Due to their impaired explicit processes one should think that ADHD children not only have preserved implicit processes but as a compensation of their neurological dysfunction these children my have a more developed implicit ability. This hypothesis has not yet any empirical or experimental support.

The present study is designed to compare the performance of ADHD preschool children with normal children in implicit learning of an artificial grammar task.

EXPERIMENT 1

This experiment had two purposes. The first one is to replicate earlier studies showing that children could acquire knowledge implicitly based on learning of an artificial grammar task. The second purpose is to confirm the implicit learning of artificial grammar in the task that uses symbols instead of letters.

Our hypothesis is that children exposed to a string of artificial grammar symbol will learn implicitly the rules in comparison with children who were not exposed to the artificial grammar task.

Method

<u>Participants</u>
The participants were 20 preschool children. Of this sample 6 (30%) were boys and 14 (60%) were girls. The age of participants ranged from 5 to 7 years, with an average of 5.9 years (SD= 0.6). Participants were selected randomly from 10 kindergarten classes. Based on teacher report, we selec ted only those children without any manifestations of behavior or academic problems.

The children were randomly and equally placed into one of two conditions:
(1). Control - 3 boys and 7 girls.
(2). Experimental - 3 boys and 7 girls.

<u>Materials</u>
An artificial grammar task was used as a modality of testing implicit learning. Based on the artificial grammar system we generated the grammatical stimuli.

Grammatical stimuli
The grammatical stimuli were strings of symbols between four and six symbols in length generated by the artificial grammar shown in Figure 1.

To generate any permissible sequence, one starts at input level (left side in the Figure 1) and follows any path leading to state, picking up stimuli along the way. A grammatical item begins when we enter an input symbol, each transition produces a letter, and the item ends when it is reached output state (from the right side in Figure 1). Based on this system we generated 47 grammatical items. From those items we used 23 items in a learning phase and 24 items in a test phase. The items for each phase were selected randomly.

Non-grammatical stimuli
The non-grammatical stimuli were created by changing the correct sequence of the symbol string; we simply replaced a symbol in a grammatical string with a symbol that was not permissible in that location. Twenty-four non-grammatical strings of symbols were created and used in the test phase.

Based on those rules, the learning phase had a total of 37 grammatical items, 14 of them were presented twice in the task and 23 of items once (see Appendix 1 for the entire description of learning phase). The test phase had a total of 24 pairs of items. Each pair contained a grammatical stimulus and a non grammatical stimulus (see Appendix 2 for the entire description of test phase).

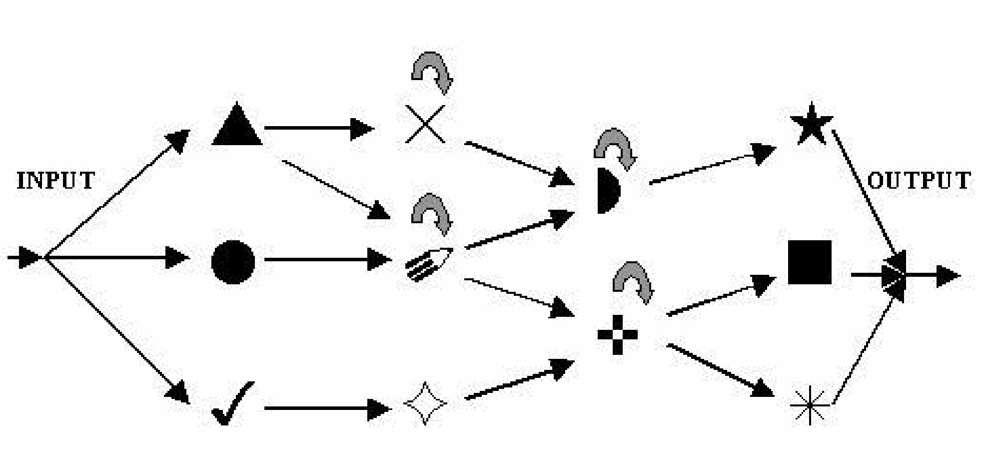

Figure 1. The artificial grammar system used in experiment 1.

Procedure

The experiment had two phases: a learning phase and a test phase. The subject from the experimental group took both phases and subjects from the control group took only the test phase.

In the learning phase the children were presented with a set of grammatical stimuli and were asked to label each symbol of any item. Each item was presented individually. At this point children were not aware that the stimuli they were studying were generated by a complex rule system. Once the learning phase ended, participants from both groups took the test phase. In the test phase, subjects were presented with a novel set of stimuli. This time their task was to rate the preference for an item between two (one grammatical and one non-grammatical). There were 24 pair items. The grammatical items from the test phase were distinct from the grammatical item from the learning phase.

Results

The number of total grammatical stimuli chosen by the subject was count for learning phase. For each item we score 1 if the subject chose the grammatical stimulus and 0 if the subject chose the non-grammatical stimulus. It were 24 pair of items and the maximum score being 24 (if a subject chose only grammatical items). The results of the experiment are presented in Table 1. The results are the shown in Figure 2.

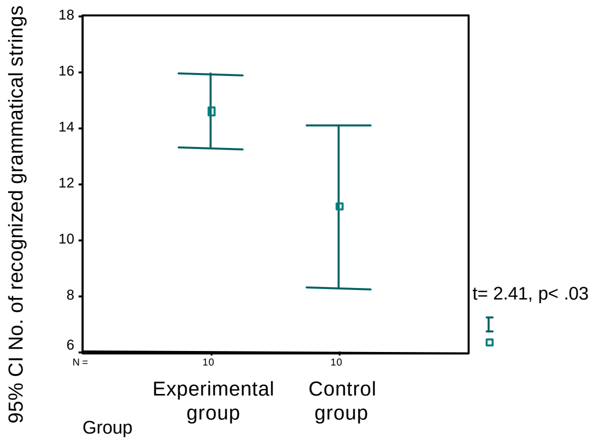

Figure 2. The differences in test phase between the two groups

Subjects	*Experimental group* (N=10)	*Control group (N=10)*
Grammatical items	m = 14.60 SD = 1.83	m = 11.20 SD = 4.04

Table 1: Mean of the subject's grammatical items chose in test phase

The difference between the groups in test phase is significant (t = 2.41, p = 0.03, df =18) concerning the number of grammatical items chosen. Subjects from the experimental group that saw the grammatical items in learning phase preferred significantly more often the grammatical stimuli in comparison with control subjects.

Discussion

It seems clear from the above results that children provided higher liking rating level when the items conformed with grammatical structure, compared to those items that violated the structure of the grammar. Our results are consistent with previous research that has demonstrated the efficacy of implicit learning of an artificial grammar.

We had to take into account the developmental processes in preschool children in order to work with an artificial grammar task. As a result, in our experiment we used symbols instead of letters as components of the artificial grammar task. The significant differences between the control and experimental group show that the younger children learn implicitly rules of artificial grammar in a task using symbols.

EXPERIMENT 2

The purpose of this experiment was to test differences in implicit learning between normal children and ADHD children. As we discussed in the theoretical part, we expected two possible results: 1) based on the first argumentation that we presented we should obtain no statistically significant differences between ADHD and normal children; 2) based on the second argumentation, ADHD children should perform poorly in implicit learning of an artificial grammar task than normal children.

Method

<u>Subjects</u>
The subjects were 40 preschool children. Of this sample 22 (55%) were boys and 18 (45%) were girls. The age of participants ranged from 5 to 7 years, with an average of 5.7 years (SD= 0.7).

The children were placed into one of two conditions:
(1). 20 Normal children (8 boys and 12 girls). Based on teacher report, we selected only those children without any manifestations of childhood (behavioral or academic) problems.
(2). 20 ADHD children (14 boys and 6 girls). In order to identify ADHD children we used a semi-structured interview with the teachers based on DSM-IV ADHD criteria; we selected only those children who satisfied all the DSM-IV criteria for ADHD.

<u>Materials</u>
We used the same artificial grammar system as in Experiment 1 in order to test implicit learning processes.

<u>Procedure</u>
First, in the learning phase each group read each symbol of grammatical stimuli. Each of the 37 grammatical items was presented individually in a manner so that the child could see only one item at a time. In the test phase, the child rated his preference for a stimuli by choosing between 2 stimuli: one grammatical and one non-grammatical.

Results

The number of total grammatical stimuli chosen by the subject was counted for the learning phase. For each item we scored 1 if the subject chose the grammatical stimulus and 0 if the subject choused the non-grammatical stimulus.

The results of the experiment are presented in the Table 2.

Subjects	*Normal children (N=20)*	*ADHD children (N=20)*
Grammatical items	m= 13.55 SD= 3.56	m = 11.05 SD = 2.16

Table 2: Mean of the subject's grammatical items chose in test phase

The differences between normal children and ADHD children were statistically significant ($t= -2.63$, $p< 0.01$). The differences are graphically presented in Figure 3.

The normal children rated on test phase a greater number of grammatical items than ADHD children. Based on these results, we concluded that there were statistically differences in implicit learning of artificial grammar tasks between normal children and ADHD children.

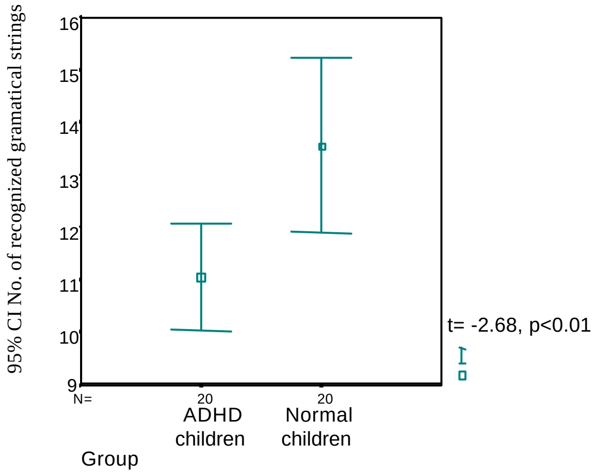

Figure 3. The differences in test phase between the two groups

General Discussion

The main purpose of the present article was to investigate the process of implicit learning in preschool children using an artificial grammar learning task. We conducted two experiments in order to attain this purpose. In the first experiment we found that preschool children can acquire implicitly knowledge about an artificial grammar system. Our results are consistent with other research (see Perruchet & Vinter, 1998) that show the efficacy of learning an artificial grammar system. In the first experiment we confirm those results in children too.

In the second experiment we tested the characteristics of implicit learning in normal and ADHD children. We used an artificial grammar task in order to test the implicit learning. The results shown significant differences between the two groups in learning an artificial grammar structure. Those results are not consistent with the studies that sustain any differences in implicit learning between normal subject and neuropsychological impaired subjects (Reber, 1992). It is known that ADHD children have neurological dysfunction. In that case, based on what Malone & Maybery suggested (1998): "implicit compared to explicit learning should be more robust to neuropsychological insult" (p. 37) we should obtain no differences in ADHD children compared with normal children in implicit learning of artificial grammar task. But our results shown that ADHD children perform poorly in implicit learning on artificial grammar task than normal children. There are no other similar experiments in the literature that tested the implicit processes in ADHD children and we can not compare our results with another.

Our results are consistent with the results obtain by Fletcher et al. (2000) regarding the sensitivity of mental age in children implicit learning. We can say that a developmental deficit, as ADHD, is also sensitive for implicit learning.

The results we obtained can be explained by taking in account the neurological basis of implicit learning and the neurological impairments found in ADHD children. Curran (1995) in an article investigating the neurological basis of implicit sequence learning, found that dysfunction in the basal ganglia has critical effects on implicit learning. Basal ganglia include a group of forebrain nuclei (for example the caudate, putamen and globus pallidus) and some closely related major brain stem structures (substantia nigra and red nucleus). Lesions of these regions in humans produces movement impairments (Rosenzweg & Leiman, 1989) and attention related problems (Brown & Marsden, 1991). Barkley (1998) cited a core of literature studies that describe the neurological basis in ADHD children and concludes that "the final common pathway appears to be the integrity of the prefrontal cortical - striatal network" (p. 176). We can see now that dysfunction at the striatal level may be responsible, at least in part, for deficiencies in implicit learning.

Questions remain about the modularity of implicit systems. If we consider implicit learning is a modular process, how can we explain that ADHD children perform poorly in artificial grammar task that normal children? We suggest taking into account developmental characteristics. It is likely the case that in preschool children those processes are developing and are not modular.

Further studies should be conducted to generalize our results to the entire processes of implicit learning in ADHD preschool children. We used only one type of implicit learning task: the acquisition of artificial grammar. It should be useful to test the characteristics of preschool implicit learning processes on other types of tasks (for example, sequence learning or interactive tasks).

Also it will be useful to investigate the process of implicit learning by a diversity of tasks in normal preschool children and in other childhood disorders (autism, for example) in order to build a coherent theory of the development of implicit learning.

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APPENDIX 1

THE ITEMS USED IN THE EXPERIMENTS 1 AND 2 IN LEARNING PHASE

▲	✕	◗	★		
✓	✧	✣	■		
●	✏	✣	✳		
▲	✏	✣	✳		
●	✏	✣	✳		
✓	✧	✣	■		
✓	✧	✣	✣	■	
▲	✏	✏	✣	■	
▲	✏	✣	✣	■	
●	✏	✏	◗	★	
▲	✏	✣	✣	✳	
▲	✏	✏	✣	✳	
●	✏	◗	◗	★	
▲	✏	✣	✣	✳	
●	✏	◗	◗	★	
✓	✧	✣	✣	■	
▲	✏	✣	✣	■	
●	✏	✏	◗	★	
▲	✏	✏	✣	■	
●	✏	✏	✏	✣	■
▲	✏	◗	◗	◗	★
●	✏	✏	◗	◗	★
✓	✧	✣	✣	✣	■
▲	✏	✏	◗	◗	★
●	✏	✏	◗	◗	★
▲	✏	◗	◗	◗	★
●	✏	✏	✏	✣	■
▲	✏	✏	✏	◗	★
▲	✏	✏	✣	✣	■
▲	✏	✏	✏	✣	■
✓	✧	✣	✣	✣	■
▲	✏	✣	✣	✣	■
▲	✏	✏	✣	✣	✳
▲	✏	✏	◗	◗	★
▲	✏	✏	✣	✣	■
▲	✏	✏	✏	✣	✳
▲	✏	✏	✏	✣	■

APPENDIX 2

THE ITEMS USED IN THE EXPERIMENTS 1 AND 2 IN TEST PHASE

1.	● ✎ ✣ ■	× ◗ ◗ ★
2.	■ ★ ✓ ✎	▲ ✎ ✣ ■
3.	▲ ✎ ◗ ★	● ✎ ✎ ★
4.	✓ ✧ ◗ ★	✓ ✧ ✣ ✳
5.	● ✎ ✎ ✣ ■	▲ × × × ★
6.	× × ● ▲ ✎	● ✎ ✣ ✣ ■
7.	● ✎ ✎ ✣ ✳	✎ ◗ ■ ★ ★
8.	✓ ✓ ✧ ✣ ■	● ✎ ✣ ✣ ✳
9.	▲ × × ◗ ★	✎ ◗ ★ ■ ✓
10.	◗ ◗ ★ ■ ✣	▲ × ◗ ◗ ★
11.	▲ ✎ ✎ ◗ ★	✓ ✧ ✧ ✣ ✳
12.	■ ✣ ✣ ✧ ✳	✓ ✧ ✣ ✣ ✳
13.	● ✎ ✣ ✣ ✣ ■	× × ✎ ▲ ✣ ✧
14.	✳ ✓ ✎ ● ◗ ★	● ✎ ✣ ✣ ✣ ✳
15.	● ✎ ✣ ✣ ✣ ✳	✧ ✎ ▲ ● ★ ✳
16.	✧ ● ▲ × ◗ ✳	● ✎ ✎ ✣ ✣ ✳
17.	● ✎ ✎ ✎ ✣ ✳	● ★ ✧ ✣ × ✓
18.	▲ ✎ ✧ ◗ ◗ ×	▲ × × ◗ ◗ ★
19.	▲ × × × ◗ ★	✓ ● ✎ ✎ ◗ ◗
20.	▲ ✎ ✎ ✎ ✣ ★	▲ × ◗ ◗ ◗ ★
21.	● ✎ ◗ ◗ ◗ ★	✓ ✧ ✧ ✧ ✣ ✳
22.	✓ ✧ × ✎ ★ ●	● ✎ ✎ ✎ ◗ ★
23.	✓ ✧ ✣ ✣ ✣ ✳	✧ ✧ × ▲ ✎ ◗
24.	▲ ✎ ● ✎ ✣ ✳	● ✎ ✎ ✣ ✣ ■