Long-term memory and levels-of-processing in autism

Motomi Toichi*a, Yoko Kamio b

* Division of Child & Adolescent Psychiatry, Case Western Reserve University/University Hospitals of Cleveland, Cleveland, OH, USA
b Department of Psychiatry, Faculty of Medicine, Kyoto Graduate University, Kyoto, Japan

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Abstract

Prior studies reported that long-term memory (LTM) was basically unimpaired in individuals with autism. However, people with autism have been found to perform worse than ability-matched controls when verbal materials to be remembered are semantically related. In normal subjects, semantic processing of verbal materials facilitates LTM better than 'shallow' (phonological or perceptual) processing, which is known as the levels-of-processing effect. In this study, the relationship between LTM and semantic processing was investigated using a levels-of-processing task. In Study 1, a levels-of-processing task was conducted on healthy volunteers, which confirmed the levels-of-processing effect with our task. In study 2, the same task was conducted on autistic subjects with mild or no mental retardation and ability-matched controls. The levels-of-processing effect was confirmed in the control group. Although overall performance in the two groups was comparable, the levels-of-processing effect was not found in the autistic group. LTM resulting from perceptual processing was better in the autistic group than in the control group, indicating superior 'rote memory' in individuals with autism. Furthermore, the pattern of correlations between LTM performance and cognitive measures differed greatly between the two groups. The lack of the levels-of-processing effect, which has not been reported in other psychiatric or neuropsychological conditions, suggests an abnormal relationship between semantic memory and episodic memory in individuals with autism. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Episodic memory; Autism; Levels-of-processing; Semantic memory

1. Introduction

Experimental studies on long-term episodic memory (LTM) in autism have reported inconsistent results. Some studies (e.g. [8]) found impairment in LTM, but others [5,6,28,45] did not. On the other hand, most studies reported evidence for impairment in LTM when verbal materials to be remembered were semantically or contextually related. For example, performance of free recall was worse in autistic subjects than ability-matched controls when items to be remembered were arranged to make a meaningful sentence [17,31,38,55], or items were semantically related, as members of the same semantic category (such as 'fruit' or 'animals') [23,35,49]. These findings suggest that facilitation of LTM by semantic information was reduced in autistic subjects. This seems to lead to two possible explanations. One is that autistic subjects have problems in semantic processing due to impairment in semantic memory. However, findings in most studies on semantic memory in autism have not supported this possibility. Although three studies [17,27,53] found a decrease in performance for category fluency in autistic subjects, one study [9] did not. In studies using a category judgement task [47,48], performance in autistic subjects was similar to age- and ability-matched controls. Furthermore, semantic processing was found to be unimpaired in studies using a Stroop paradigm [10,16] and in studies that examined word association [50,52]. The other possibility is that there is an abnormal relationship between long-term episodic memory and semantic memory in individuals with autism. Interdependence between episodic memory and semantic memory has been confirmed mainly in studies with children ([1,33] for review). Semantic processing (the use of semantic memory in encoding) of verbal materials facilitates LTM for the materials better than 'shallow' (phonological or perceptual) processing, which is known as the levels-of-processing effect [14]. The levels-of-processing effect is a robust phenomenon, and it has been confirmed in children of first and second graders [20,21,34] as well as healthy adults, and even in patients with amnesia [11,12]. In this study, we investigated the relationship between episodic memory and semantic memory in subjects with autism using a levels-of-processing task.

* Corresponding author, Tel.: +1-216-344-1942; fax: +1-216-344-3983.
E-mail address: motomii@uhr.hmeu.ac.jp (M. Toichi).

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2. Study 1

2.1. Subjects

Subjects were 48 healthy volunteers (22 men, 26 women) who were recruited from among undergraduate students of Shiga University.

2.2. Materials

The task employed in this study was basically similar to that by Craik & Tulving [14]. A word list was developed from verbal materials in the records of the interviews with the high-functioning autistic subjects who participated in the subsequent study. Thirty nouns were drawn from the list as targets to be studied. There were three 'levels' (graphical, phonological, and semantic) of questions about a target. A question at a graphical level concerned the type of character (Katakana or Hiragana; both are syllabary for writing Japanese) in which a target word was written. In the original levels-of-processing task, a question about the type of letter (upper case or lower case) was used to induce graphic processing. Although Japanese letters have no such distinction, the processing induced by the questions used here was considered to be equivalent in demanding graphic (perceptual) discrimination of letters. A question at a phonological level concerned the pronunciation of a target word. A question at a semantic level concerned the meaning of a target word. There were two (yes/no) answer types at each level, producing six potentially (three levels X yes–no) different questions for each target (Table 1). Of the 30 questions about the targets to be studied, 10 questions (half were yes type, and half no type) were of graphical type, 10 of phonological type, and the remaining 10 of semantic type. Six lists, each consisting of 30 questions, were developed by substituting a question about each target for another within six alternatives. Furthermore, four kinds of word lists, each containing 30 targets and 60 distractors, were prepared for recognition test. All four contained the same 90 words, which were printed on one side of a sheet, but the positions in their arrangement differed among the four. Thus, there were 24 (six study X four recognition) task conditions. In a test trial, six additional pairs of question and target, which did not appear in the recognition list, were presented before (three pairs) and after (three pairs) the 30 relevant pairs in order to eliminate possible primacy and recency effects. The verbal materials used in the task were all common nouns among Japanese adolescents and adults.

2.3. Methods

One of the 24 task conditions was assigned to each of the 48 subjects, with two subjects performing under the same condition. In a study phase, subjects first read a question in a booklet (8 s), and a target printed on a card was presented by an experimenter (2 s). Then they were asked to answer yes or no within 5 s following the target presentation. The same procedure was repeated until the last item without break. Subjects in this phase did not know a recognition test would follow. Immediately after the study phase, a recognition list was given to subjects, and they were asked to choose 40 words that they judged to be 'old' within 5 min.

2.4. Results

When an answer (yes or no) to a question was incorrect, the item was excluded from the analysis. Error rates were very low (0.8, 0.2, and 0.6% for SL, PL, and GL, respectively). Performance at the semantic level (SL) was better than that at the phonological level (PL), which was, in turn, better than that at the graphic level (GL). A level X answer type repeated-measures analysis of variance (ANOVA) revealed a significant main effect of level ($F = 72.5, P < 0.0001$), but neither the main effect of answer type ($F = 1.6, \text{n.s.}$) nor the level X answer type interaction ($P = 0.1, \text{n.s.}$) was significant. Post hoc comparisons (Fisher's LSD) showed there was a significant difference between any two of the three levels ($P < 0.0001$ between SL and PL, $P < 0.0001$ between SL and GL, $P = 0.0006$ between PL and GL). This indicates that the subjects showed the levels-of-processing effect in our task. Since there was no correlation between the error rate and performance, the levels-of-processing effect could not be accounted for by a trade-off between accuracy of answers and efforts to remember (the subjects were not instructed to remember in the study phase) (Fig. 1).

2.5. Discussion

Although there were minor differences in methodology between the original and our task, the levels-of-processing effect was clearly elicited by the task used here. The effect of answer type was not significant in this study as in Experiment 1 of the original study by Craik and Tulving [14]. A significant effect of answer type, with yes type producing better performance than no type, was found in Experiment 2.

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Table 1

<table>
<thead>
<tr>
<th>Level</th>
<th>Target: 'gya-u-nya-a' (milk) in the Katakana character</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Graphic</strong></td>
</tr>
<tr>
<td>Yes</td>
<td>Is the word written in the Katakana character?</td>
</tr>
<tr>
<td>No</td>
<td>Is the word written in the Hiragana character?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Phonological</strong></td>
</tr>
<tr>
<td>Yes</td>
<td>Is the pronunciation similar to 'nya-u-nya-a'? (meme)?</td>
</tr>
<tr>
<td>No</td>
<td>Is the pronunciation similar to 'nya-ku-a'? (table)?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Semantic</strong></td>
</tr>
<tr>
<td>Yes</td>
<td>Is it a drink?</td>
</tr>
<tr>
<td>No</td>
<td>Is it milk?</td>
</tr>
</tbody>
</table>

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of the same study, where a larger number of targets were used than in Experiment 1. The lack of the effect of answer type in our study seems to be attributable to a longer presentation of targets and a relatively small number of items (30 targets and 60 distractors) employed in our task. There was a slight tendency of ceiling effects in the performance at SL. This suggests that there might be a greater levels-of-processing effect with our task than was found here. However, this would not be detrimental to the subsequent study, because performance on this task was expected to be generally lower in the subjects in Study 2, and because the greater the potential of our task to elicit the levels-of-processing effect, the better for our purpose of examining the effect.

3. Study 2

3.1. Subjects

Subjects were 20 autistic individuals (18 men, 2 women) and 20 controls (18 men, 2 women) who were matched for age, for a non-verbal reasoning ability on Raven’s colored progressive matrices (RCPM) [40] or standard progressive matrices (SPM) [39], and for verbal and performance IQ on the Japanese version of the Wechsler Adult Intelligence Scale (Revised) [46] or the Wechsler Intelligence Scale for Children (Revised) [25].

The autistic group consisted of high-functioning autistic adolescents and adults whose verbal IQ was not less than 60. The diagnosis of autism ("autistic disorder") was made according to the DSM-IV [2] by two child psychiatrists (the authors) based on the interview with the subjects, information from their parents, teachers, or counselors of a Public Employment Center for the Handicapped, and clinical record during childhood, when available. All subjects in this group had a history of apparent delay or idiosyncrasy in language in infancy, and showed apparent autistic traits such as lack of eye contact, verbal idiosyncrasies, and obsessive or ritualistic behaviors during the interviews for diagnosis. They were all free from physical diseases or psychiatric problems other than those associated with autism, and they were taking no medication. The control group consisted of non-autistic students of special schools for learning difficulties and volunteers who were recruited from among college students or applicants for consultation at a Public Employment Center for the Handicapped. None of the control subjects had neurological or psychiatric problems. No known etiology was found concerning mental retardation, if present, in this group. All subjects above 18 years of age and the parents of those less than 18 years of age gave written informed consent to participate in this study. The characteristics of the subjects are given in Table 2.

3.2. Materials and methods

The same materials and methods as Study 1 were employed. One of the 24 task conditions was assigned to each subject, so that the task conditions for the 20 subjects differed from one another in each group. Trials were run individually.

3.3. Results

3.3.1. The levels-of-processing effect

Error rates for GL, PL, and SL were 2.5, 10.0, and 2.0% in the autistic group, and 1.0, 1.0, and 3.0% in the control group, respectively. There was no apparent trade-off between performance for recognition and accuracy of answers. There was a significant difference in terms of the number of errors between the two groups only for PL (Fisher’s exact P = 0.005). High error rates for PL in the autistic group were due to the answers in two subjects in this group. They responded "no" to almost all questions at PL using their own idiosyncratic criteria for phonological similarities, which was confirmed by their report after the trial.

Preliminary analyses using a group × level × answer type ANOVA revealed that there were no significant main effects of answer type, and that answer type did not interact with any other variables. Therefore, this factor was not considered further. A group × level repeated-measures ANOVA revealed a significant main effect of level (F = 20.7, P < 0.0001), but the main effect of group was not significant (F = 1.6, n.s.). The group × level interaction was highly significant (F = 10.1, P = 0.0001), indicating a difference in the effect of level between the two groups. Post hoc comparisons (Fisher’s PLSD) revealed that there was a significant
difference between SL and PL (P < 0.001) and between
SL and GL (P < 0.0001) in the control group indicating
the levels-of-processing effect in this group. Unlike in
the control group, there were no significant differences between
any two of the three levels in the autistic group, indicating
an absence of the levels-of-processing effect. When com-
parisons were made between groups, the autistic group per-
formed better than the control group at GL (P < 0.01), but
the two groups did not differ significantly in performance at
SL or PL (Fig. 2).

3.3.2. Relationships between performance and cognitive
variables
The only correlation found in the control group was a
strong inverse correlation between performance at PL and
RCPM scores. In the autistic group, performance at GL
significantly correlated with VIQ, and with RCPM scores.
There was also a significant positive correlation between
performance at SL and RCPM scores in the autistic group
(Table 3).

3.4. Discussion
While the control group showed the levels-of-processing
effect, like the subjects in Study 1, this effect was not
found in the autistic group. Performance at GL was sig-
ificantly better in the autistic group than in the controls,
which suggests superior rote memory in autistic subjects.
Average performance was lower at SL and higher at PL
in the autistic group, but the differences between the two
groups did not reach significance. Therefore, the lack of
the levels-of-processing effect in the autistic group may be
attributable mainly to increased performance at GL, and
possibly to a lack of the advantage in LTM for SL over PL,
which was present in the control group.
While the levels-of-processing effect has been confirmed
not only in healthy adults but also in children of school
age [20,21,34], the reduction of the effect was reported
in children below 10 years old [26,30,54]. In such sub-
jects, the development of semantic memory, as well as
that of episodic memory, was immature [11,13] for review),
which may result in insufficient semantic elaboration in
encoding. The autistic subjects in this study, however, were
adolescents and adults with average verbal IQ above 80.
Furthermore, previous studies that examined knowledge
about semantic categories suggested intact semantic mem-
iory in autistic subjects [47,48]. Recent studies that examined
word association also suggested unimpaired semantic pro-
cessing in high-functioning autistic adolescents and adults
[50,52]. Therefore, the lack of the levels-of-processing
effect in autistic subjects does not seem to be attributable to
an underdevelopment of semantic memory.
An alternative explanation for the lack of levels-of-pro-
cessing effect is a deficient relationship between semantic
memory and episodic memory in autistic subjects, which
has been repeatedly suggested in studies that examined the
phenomenon of “organization” [17,31,38,55] or semantic
clustering in free recall [23,49]. In these studies, semantic
relationship between items failed to facilitate LTM for these
items, suggesting that semantic memory may not contribute
to episodic memory in autistic subjects. There are several
other findings suggesting interdependence between episodic
memory and semantic memory, such as the influence of
meanings of words on LTM [26,36] and “false memory”
[15,45]. Interestingly, a recent study on false memory [7]
reported that autistic subjects showed less false recogni-
tion than controls for lure items that had not been presented.
In the study, word lists were made to induce false memory for
the lure items by semantic relationship between items. The
better discrimination for semantically related false items
also suggests a decrease in the influence of semantic mem-
iory on episodic memory. Therefore, it is plausible that the
lack of the levels-of-processing effect found in this study
may be attributable, in part, to an impaired relationship
between semantic memory and episodic memory.
A secondary finding was a difference between the two
groups in the pattern of correlations between performance in
our task and other cognitive abilities. In the autistic group,
LTM resulting from graphic processing was significantly
correlated with RCPM scores and with VIQ. Considering
that both LTM due to graphic processing and RCPM scores
rely on non-verbal visual function, their correlation seems

Table 3
Relationships between cognitive variables and performance in
the levels-of-processing task

<table>
<thead>
<tr>
<th>Level</th>
<th>Autistic</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VIQ</td>
<td>PQ</td>
</tr>
<tr>
<td>Graphic</td>
<td>0.57**</td>
<td>0.28</td>
</tr>
<tr>
<td>Phonological</td>
<td>0.38</td>
<td>0.32</td>
</tr>
<tr>
<td>Semantic</td>
<td>0.33</td>
<td>0.42</td>
</tr>
</tbody>
</table>

* Standardized correlation coefficients are presented. VIQ: verbal IQ; PQ: performance IQ; RCPM: raw scores on the Raven's colored prog-
resive matrices or scores converted from those on the standard progressive matrices.
** P < 0.05.
*** P < 0.01.
plausible. The unexpected correlation between LTM due to graphic processing and VIQ might suggest a possibility that verbal abilities in autistic subjects may rely heavily on their superior rote memory of what they perceive. An additional regression analysis revealed that there was a significant correlation between VIQ and RCPM scores in the autistic group ($r = 0.62, P = 0.006$) but not in the control group ($r = -0.04, n.s.$), which also suggests a possible difference in the nature of verbal abilities between the two groups.

Another interesting finding was a significant correlation between LTM at SL and RCPM scores in the autistic group. In this study, a correlation between recognition performance and cognitive measures is generally stronger in the autistic group, and performance at SL would be possibly correlated also with PIQ or VIQ if examined in a larger number of autistic subjects. However, RCPM score is the only cognitive measure that has consistently been found to correlate with performance related to semantic processing in autistic subjects, but not found in controls in previous studies [50–52]. Therefore, this finding seems to suggest that semantic processing in autistic subjects involves, at least partially, other variables or visuo-spatial operations, which may be less effective in facilitating LIQM for verbally meaningful materials than ordinary semantic processing. An inverse correlation between RCPM scores and performance at PI found in the control group seems inexplicable. Although the correlation might reflect a possible antagonism in non-autistic subjects between phonologically mediated verbal processing and non-verbal logical operations, this finding, as well as other correlations mentioned above, needs to be examined further in a larger number of subjects.

Individuals with autism, regardless of intellectual abilities, have been known to be good at such abilities as “calendar calculation” (to figure out the day of the week for a date given) and mnemonics for digits or proper names [29,32,44], both of which are less meaningful than other verbal materials like common nouns. Interestingly, it has been reported that a mechanical elaboration (calendar calculation) of verbal materials (dates) facilitated LTM for autistic subjects [22]. This might be related to an unusual relationship between episodic memory and semantic memory as well as the unique semantic processing suggested in this study.

Neuroimaging studies consistently reported an activation of left dorsolateral prefrontal cortex in encoding (for review [18]), and this area has been found to be involved also in semantic processing (for review [19]). Furthermore, the involvement of left dorsolateral prefrontal cortex in facilitation of LTM due to semantic processing was confirmed in a study that used a levels-of-processing task [24]. On the other hand, neuropsychological studies suggested impaired prefrontal lobe function in autistic subjects (137, for review). Therefore, the lack of the levels-of-processing effect in autistic subjects might be related to possible dysfunction of the prefrontal lobe in autism. However, autopsych studies have found abnormality mainly in amygdala and related limbic structure [3,4,42], but not in the prefrontal cortex. Neural mechanisms explaining the difference in the levels-of-processing effect between autistic and non-autistic subjects remains to be investigated.

4. Conclusion

The unusual performance in a levels-of-processing task, that is, a lack of the levels-of-processing effect in spite of overall good performance, has not been reported in other psychiatric or neuropathological conditions. Along with the difference in the pattern of correlations between memory performance and cognitive abilities, this finding suggest an abnormal relationship between episodic memory and semantic memory in individuals with autism.

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