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*Article*

# Category-Based Effect on False Memory of People with Down Syndrome

**False Memory in Down Syndrome**

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**Abstract:** People with Down syndrome (DS) have a trisomy of chromosome 21 and deficits in verbal memory but preserved visuospatial perception. Verbal memories are related to semantic knowledge. Little is known about the organization of semantic knowledge in people with DS. Possible differences in the number of false memories induced by nominal and verbal themes were examined. In the study phase, word lists with semantically related associates were presented. In the recognition phase, participants made judgments on whether each word had been represented previously. Differences in the processing of nominal and verbal theme lures were observed. When processing nominal theme lures, people with DS showed delayed false positives. When processing verbal theme lures, people with DS showed no differences. Similar patterns have been observed in people with DS when processing nominal and verbal theme associates. People with DS have delayed recognition of associates. When processing unrelated words, they showed higher false positives than controls. Further analyses of the themes revealed differences in false positives across syntactic categories among groups. People with DS showed a delayed recognition of associates and deviance in recognizing unrelated words in the nominal and verbal categories. People with DS were delayed in terms of nouns, but deviated with verbs in associated and unrelated words. People with DS showed distinct patterns in processing nominal and verbal lures, suggesting that they formed false memories differently. People with DS develop a deviant semantic structure. Category-based interventions for people with DS should be implemented to improve their semantic knowledge.

**Keywords:** Down syndrome; false memory; concept formation; nouns; verbs

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### What This Paper Adds?

This study examined concept formation in the semantic knowledge of people with Down Syndrome (DS) by using a false memory paradigm. Concept formation creates the basis of discourse comprehension and the foundation of social cognition. This study confirmed atypical patterns of people with DS in processing lures and unrelated words, but delayed performance on associates. Moreover, asymmetrical processing of semantic concepts based on syntactic categories has been observed. Impaired semantic features of concepts and deficient linkages among semantic concepts in people with DS have been proposed to account for their deviance in lexical semantic processing. Future interventions should highlight the fundamental knowledge of the lexical semantics of people with DS to enhance their development.

## 1. Introduction

People with Down syndrome (DS) have genetic disorders of chromosome 21, with common trisomy of the upper or lower arm. The reported etiology constitutes approximately one in 700 live births according to the Center for Disease Control and Prevention in 2024, and it is one of the most severe congenital disorders according to the World Health Organization in 2023. Due to this genetic deficit, people with DS are mentally retarded and have abnormal cognitive ability with poor language but relatively good visuospatial ability (Arias-Trejo & Barròn-Martìnez, 2017). Furthermore, they present typically developed implicit memory and explicit memory impairment (Vicari, Bellucci, & Carlesimo, 2000). People with DS have protruded tongues, slanted eyelids, short limbs and trunk (Bull, 2020). People with DS are more receptive than those with expressive language skills (Andreou & Katsarou, 2016). However, the way by which people with DS integrate semantically related words into coherent concepts remains unknown. This was the main focus of this study.

Examining ambiguities in people with DS, Hsu (2019) revealed deviant semantic knowledge in processing ambiguous words in contexts. People with DS showed the lowest accuracy in integrating ambiguities into preceding contexts, suggesting less capability in selecting the correct interpretation of ambiguities. In grouping semantic related concepts, people with DS showed deviancy in priming picture backgrounds (e.g., a sports store) and picture objects (e.g., a pair of snickers vs. a pair of high heels; Hsu, 2016). While people with Williams syndrome (WS) and the mental-age (MA) controls primed only the semantic-related pairs, people with DS primed both semantic-related and -unrelated pairs. This finding indicates that people with DS have coarser semantic organization compared to the controls. Hsu (2016) examined comprehension of figurative words embedded in contexts in people with DS, testing both forward and backward reasoning. The first was examined through clauses expressing cause and consequence, in this order, such as, "Sponge Bob would like to eat the candies on a shelf. He asked for help from Squidward Tentacles, but Squidward Tentacles dampened Sponge Bob's enthusiasm" (original Chinese text: 海绵宝宝想吃柜子上的糖果，找章鱼哥帮忙，结果被章鱼哥泼冷水). The last three characters formed a phrase with the figurative meaning "to dampen one's enthusiasm" and the literal meaning "to pour cold water on someone." Backward reasoning was examined through linked clauses expressing consequence resulted from a cause (in this order); for example, "Daxung failed the exam this time. His mother often reminded him to study hard, but Daxung was inattentive to his mother's reminders" (original Chinese text: 大雄这次考试不及格，妈妈平常叫大雄认真读书，大雄都把妈妈的话当作耳边风). The sentences could only be comprehended when the participants understood the figurative meaning of the words. The results revealed that people with DS were deviant in processing backward reasoning and delayed in processing forward reasoning through comprehending ambiguities at sentential final positions.

Studies showed that syntactic categories develop asymmetrically in people with DS. People with DS aged 4–7.11 years old were observed delayed in verbs compared to nouns and adjectives in a study with Peabody Picture Vocabulary Test (4$^{th}$ Edition) (Loveall, Channell, Phillips, Abbeduto, & Conners, 2016), suggesting deficient lexical knowledge on verbs. While people with DS showed a similar extent of accuracy in terms of adjectives and nouns, MA controls showed better accuracy for nouns than adjectives. This finding confirms the delayed development of verbs and distinct processing of adjectives in people with DS. Inferential language use through storytelling provides further evidence of the impairment of syntactic categories in people with DS. In the subtype of inference use embedded with character actions or attempts in the story—such as (1) prediction of actions [e.g., the frog *is going to jump* into the salad], (2) emotional behaviors [e.g., she *yells* at the frog], (3) goal-achieving actions [e.g., he *tried* to catch the frog], and (4) descriptions of actions [e.g., the frog *jumped* in the pocket])—the results revealed that people with DS were worse than typically developing controls. Similar pattern was observed in another subtype of inference use embedded with internal state reference (1) character thought or belief inference [e.g., she *noticed* the frog in the salad], (2) character preferences or needs [e.g., he *wants* to catch the frog], (3) character perceptions [e.g., he *sees* the frog in the saxophone], (4) reference to character personality [e.g., the *nice* woman], and (5) emotion states [e.g., the waiter was *mad*]); the results revealed that people with DS were worse than TD controls. In other subtypes of inference use in (1) negation [e.g., he *did not* know where the frog was], (2) location [e.g., he drove us *home*], (3) possession [e.g., the frog got in *his* pocket], and (4) role [e.g., *Dad* paid the man]), people with DS were worse than those with fragile X syndrome, even when the MLU was matched. People with DS and the TD controls at their MA level showed no significant differences (Ashby, Channell, & Abbeduto, 2017). These findings suggest that people with

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DS have impaired lexical knowledge of verbs, nouns, and adjectives. While the purpose of this study was to investigate how people with DS integrate semantically related words into coherent concepts, a minor aim was to examine whether the concept integration in semantic knowledge would be influenced by syntactic categories, namely nouns and verbs, in people with DS.

## 2. Method

### *2.1. Participants*

Twenty people with DS diagnosed with trisomy 21 in hospitals were recruited. Typically, developing controls were individually matched with people with DS based on chronological age (CA) and mental age (MA) using the Wechsler Scale of Intelligence for Children (WSIC, Chinese version, China). The matching criteria for the typically developing controls were within the range of 6 months older or younger than those with DS. All participants were right-handed native speakers of the Chinese language. The mean age of CA in people with DS and CA-matched controls was 17.7 years old; the mean age of MA in people with DS and MA-matched controls was 9.4 years old. Age variations yielded no significant differences between people with DS and CA-matched controls or MA-matched controls (see Table 1).

Twenty college students were recruited to ensure the validity of the materials that could form the gist concepts. Another 40 college students (20 each) participated in generating noun and verb stimuli (20 each). Another 40 college students participated in rating the noun and verb stimuli (20 each). This study was approved by the Institutional Review Board of the School of Foreign Languages at Hunan University (20210628000003).

**Table 1.** Background Information of Participants.

| Tasks | Groups | N (F:M) | CA | CA Range (SD) | MA | MA Rang (SD) |
|---|---|---|---|---|---|---|
| Category-Based False Memory Tasks | CA | 20 (9:11) | 17.7 | 9.9-22.7 (3.9) | --- | --- |
| | MA | 20 (9:11) | 9.4 | 4.5-14.7 (3.0) | --- | --- |
| | DS | 20 (9:11) | 17.7 | 9.4-22.10 (3.9) | 9.4 | 4.4-14.5 (3.0) |
| | College Students | 20 (10:10) | 23.5 | 18.8-26.11 (2.4) | --- | --- |
| Generating Task | College Students for Nouns | 20 (10:10) | 22.6 | 18.7-27.9 (2.6) | --- | --- |
| | College Students for Verbs | 20 (10:10) | 21.4 | 18.1–31.1 (3.5) | --- | --- |
| Rating Task | College Students for Nouns | 20 (10:10) | 22.0 | 19.0–26.11 (2.7) | --- | --- |
| | College Students for Nouns | 20 (10:10) | 22.8 | 19.0–26.7 (2.4) | --- | --- |

*Note.* CA, chronological age-matched controls; MA, mental age-matched controls; DS, people with Down syndrome; SD, standard deviation; F, female; M, male.

### *2.2. Materials and Design*

Roediger and McDermott's (1995) classic false memory paradigm was used as the research method. Twenty lists of nouns and verbs (ten each) were generated. Each participant completed two phases: study and recognition. In the study phase, ten semantically related associates were randomly presented to the participants. In the recognition phase, three types of words were presented consecutively for participants to judge whether they had heard the words in the study phase: (1) semantically related non-presented lures, (2) previously presented old words, and (3) semantically unrelated non-presented new words. Each participant listened to 100 words in the study phase and 90 words in the recognition phase. Among the 90 words used in the recognition phase, thirty words were studied and 60 were not. In each word list, the words in the second, sixth, and tenth positions were chosen as the studied words. Thirty semantically related lures and 30 semantically unrelated words were composed of non-studied words. These twenty-word lists of nouns and verbs were tested as separate tasks in the receiving experiment with their own study and recognition phases.

### *2.3. Word-Generating Task*

Words are generated in several ways in order to search for the best noun stimuli. Initially, the experimenters collected 84 nouns that were familiar to participants in daily lives from cartoons, comic books, the Baidu search engine, and frequent scenarios in which children engaged, such as *amusement park, bathroom*, and *barber shop*. Twenty college students (10F/10M, mean CA = 22.6, SD = 0.6, age range = 18.7-27.9) were asked to write down as many associative words as possible related to each noun without a time limit. The experimenters collected all the associative words generated by the participants. A total of 19207 associative words generated from 84 candidate nouns were collected, with an average of 229 associative words per noun. The top 12 associates were chosen as semantically related words based on the percentage of the top 12 associative words. Synonyms of any associates were semantically grouping as the same word; hence, the frequency of the same semantic field was cumulative (e.g., bing1-ji1-ling2 [冰激凌] "ice cream" and bing1-bang2 [冰棒] "ice stick"). The frequency ratio was calculated by dividing the total frequency of all associates by the frequency of the top 12 associates collected from all participants. Finally, the high ranking nouns and the 12 most frequently associated with each noun were rated based on their semantic closeness in the syntactic category-based false memory study of nouns.

The selection procedure for verb stimuli was similar to that for the noun stimuli. Initially, eighty-five verbs were screened to generate associative words from cartoons, comic books, the Baidu search engine, and frequent activities that children engaged in (e.g., doing housework or celebrating birthdays). Another 20 college students (10F/10M, mean CA = 21.4, SD = 3.5, age range = 18.1-31.1) were recruited to write down as many associative words as possible related to each verb without a time limit. In total, 18344 associative words were generated from the 85 selected verbs, with 216 associative words per verb. The verb stimuli were ranked based on the ratio of the total frequency of all associates to the frequency of the top 12 associates. Any associative word with similar meaning in its semantic field was counted as the same word to avoid redundancy (e.g., 洗衣服 [xi3-yi1-fu2] and 洗衣 [xi3-yi1] both mean "doing laundry"). Hence, ten high ranking verbs and the 12 most frequently associated verbs were rated based on semantic closeness in a syntactic category-based false memory study of verbs.

### *2.4. Word Rating Task*

A word-rating task was conducted to determine which pairs of lures and associates were the best stimuli. For each syntactic category, the top two most strongly related associates were taken as lures, while the remaining 10 semantically related words were taken as associates, and then the three semantically unrelated words paired with the corresponding nouns or verbs were rated by college students (20 participants for nouns, 20 participants for verbs).

One hundred and fifty pairs of noun stimuli, including 20 pairs of nominal lures, 100 pairs of nominal associates, and 30 pairs of nominal unrelated words, were judged from the highest 5 to lowest 1 based on participants' own intuition toward the semantic relatedness of the pairs. For example, 医院-医生 ("hospital-doctor") received the highest rating of 5 because of strong semantic relatedness, but 家具店-零食 ("furniture store-snack") received the lowest rating of 1 due to semantic irrelevance. The rating results revealed high values on semantic relatedness among three types of words in nouns: 4.78 (SD = 0.43) for nominal lures, 4.28 (SD = 0.57) for nominal associates, and 1.29 (SD = 0.61) for nominal unrelated words [lures vs. associates, $t(199) = 13.75$, $p < 0.001$; lures vs. unrelated words, $t(199) = 64.30$, $p < 0.001$; associates vs. unrelated words, $t(199) = 52.86$, $p < 0.001$].

Another hundred and fifty pairs of verb stimuli, including 20 pairs of verbal lures, 100 pairs of verbal associates, and 30 pairs of verbal unrelated words, were judged from highest 5 to lowest 1 based on their own intuition of the semantic relatedness of word pairs. The rating results revealed

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significantly different values of semantic relatedness in verbs: 4.31 (SD = 0.67) for lures, 3.87 (SD = 0.61) for associates, and 1.38 (SD = 0.64) for unrelated words [lures vs. associates, $t(199) = 9.56$, $p < 0.001$; lures vs. unrelated words, $t(199) = 43.19$, $p < 0.001$; associates vs. unrelated words, $t(199) = 41.00$, $p < 0.001$].

The noun stimuli were recorded by a male (CA = 26.9) at 44.1 kHz the *Praat* sound-editing software. The average auditory length was 0.88 s (SD = 0.22 s, range = 0.60-1.54; mean length of characters = 2.50, SD = 0.63) for lures, 0.84 s (SD = 0.15 s, range = 0.58-1.27; mean length of characters = 2.22, SD = 0.44) for associates, and 0.81 s (SD = 0.08 s, range = 0.70-1.05; mean length of characters = 2.00, SD = 0.00) for unrelated words. One-way ANOVA analyses with the same auditory length as the within-participants factor and the same word type as the between-participants factor yielded no differences in auditory length across word types. However, the auditory length based on topics in word lists, including lures, associates, and unrelated words, yielded significant difference [$F(9,150) = 2.818$, $p = 0.004$, $\eta^2 = 0.145$]. The results revealed that some word lists (e.g., breakfast store [0.784, SD = 0.082], public dancing [0.802, SD = 0.100], bathroom [0.744, SD = 0.093], hospital [0.804, SD = 0.131) were responded less accurately than others (e.g., amusement park [0.933, SD = 0.234], road [0.915, SD = 0.150], Christmas [0.905, SD = 0.215]). Character lengths of the word types were significant [$F(2,157) = 9.688$, $p < 0.001$, $\eta^2 = 0.110$], suggesting all three types of words were different from one another (lures, 2.5, SE = 0.81 vs. associates, 2.22, SE = 0.44, $p = 0.003$; associates vs. unrelated, 2, SE = 0.081, $p = 0.003$; lures vs. unrelated, $p < 0.001$).

The verb stimuli were recorded by a female (CA = 25.3) at 44.1 kHz the *Praat* sound-editing software. The average auditory length was 0.88 s (SD = 0.15 s, range = 0.72-1.29; mean length of characters = 2.13, SD = 0.35) for lures, 0.88 s (SD = 0.20 s, range = 0.63-1.40; mean length of characters = 2.18, SD = 0.39) for associates, and 0.85 s (SD = 0.12 s, range = 0.66-1.38; mean length of characters = 2.03, SD = 0.18) for unrelated words. The analyses of ANOVA with repeated measures of the auditory length of word types as a within-participants factor revealed that no difference was observed across the types of words or word lists on verbs. Auditory length based on verb topics yielded no differences. The character lengths of the verb word types were not significant.

### *2.5. Procedures*

In the study phase, a fixation point was displayed on a computer screen for 1000 ms. Word lists were then presented aurally via computer speakers, with an average presentation rate of 2000 ms for each word with a clear voice. The volume was adjusted to ensure comfort for each participant. The inter-stimulus interval was 100 ms.

In the recognition phase, a 500 ms fixation point was followed aurally by a test word. The presentation rates were the same throughout the study period. The participants were asked to pay attention to the spoken voice and make a yes/no judgment as to whether the word had been heard previously on the study list by pressing the corresponding button. Buttons *d* and *k* were counterbalanced to indicate positive or negative responses to green or red stickers. Two green and red squares were displayed simultaneously on the screen to serve as reminders for the corresponding buttons on the keyboard. The red square, with circles and cross symbols on it, represents the *new* response to the testing words; meanwhile, the green square, with two circles on it, indicates the *old* response to the testing words. Thus, people with DS were able to respond without memory-confounding factors. Button pressing was counterbalanced across participants. Before the experiment began, an additional word list was provided to each participant to ensure they understood it. There was no time limit for decision making. Once the participants had made their decisions, the button was pressed as soon as possible. Each study lasted approximately 10 min. Reaction times and response accuracies were measured. The study was conducted in a quiet room equipped with a laptop computer.

The instruction was as follows: "Nice to meet you! You are playing a computer game now. In this game, you have to do two things. First, the computer will speak several words to you via speakers. You have to pay full attention to it. Are you ready to play the game? Let us do some practices to make sure you know how to play the game." After listening to lists of words, the experimenter gave the rest of the instructions: "Okay! Now you will do the second thing. This time, the computer will speak one word at a time via speakers. When you hear a word, press one of the buttons on the keyboard, indicating whether the word has been presented before. If you think the computer has spoken the word, that is, you have just heard this word, press the green button; if you think the computer has not spoken the word, that is, you have not heard the word just now, press the red button. You should listen to each word carefully and then press the button. Are you ready to play the game? Let's start!"

## 3. Results

### *3.1. Analyses of College Data*

To find out the typical pattern of category-related processing in false memory, twenty college students (10F/10M, CA = 23.5, SD = 2.4, range = 18.8-26.11, SD = 2.4) took part in the study. Yes responses were included in the analyses. The types of words and syntactic categories were considered within participants in repeated-measures analyses of variance. In the analysis of the yes responses, no interactions emerged ($F < 1$). The main effect of types of words was significant [$F(2,38) = 138.56$, $p < 0.001$, $\eta^2 = 0.879$], suggesting lowest yes responses to unrelated words (0.07, SE = 0.024) and highest yes responses to associative words (0.76, SE = 0.030). The proportion of yes responses to lures (0.49, SE = 0.037) was between. No difference was observed in syntactic category, although verbs (0.44, SE = 0.022) received higher yes responses than nouns (0.43, SE = 0.019). The accuracy of each type of semantic relationship is shown in Figure 1.

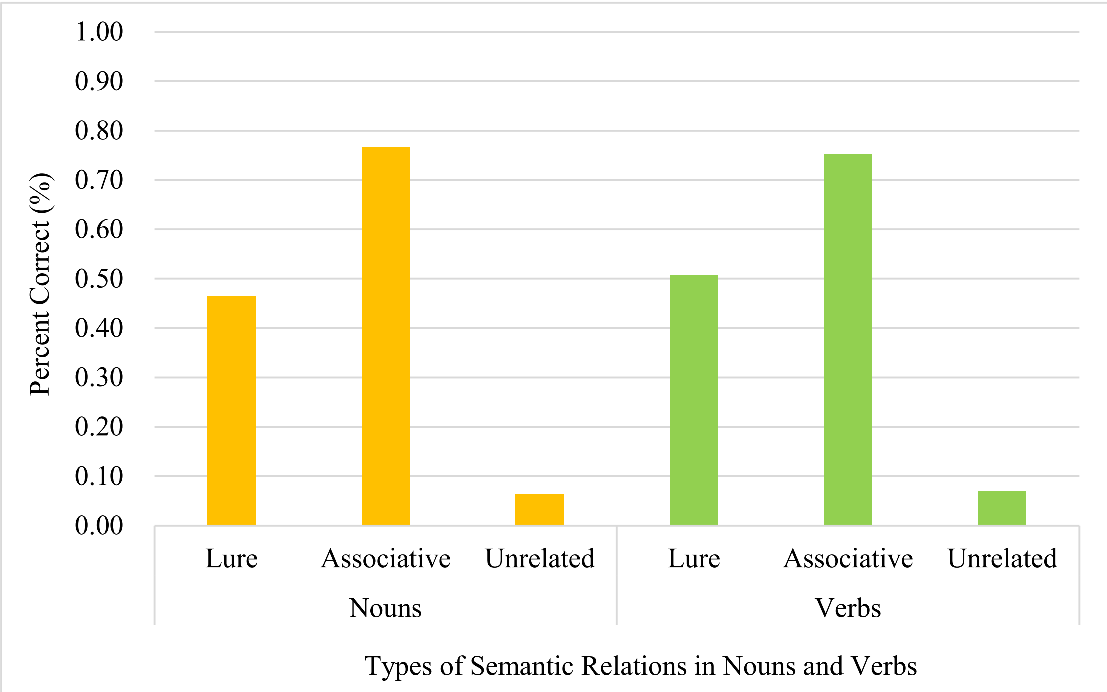


**Figure 1.** Accuracy of Types of Semantic Relations in Nouns and Verbs of College Students.

Follow-up studies on response latency, types of words, and syntactic categories were considered within the participants with repeated measures. No interaction was observed ($F < 1$). The main effect of syntactic category was significant [$F(1,9) = 6.92$, $p = 0.027$, $\eta^2 = 0.43$], suggesting nouns (1377, SE = 57.838) were responded faster than verbs (1527, SE = 80.612). The main effect of types of words was also significant [$F(2,18) = 5.49$, $p = 0.014$, $\eta^2 = 0.37$], implying associative words were among the fastest responded (1352, SE = 37.731) and unrelated words were responded the longest (1542, SE = 99.829). Lures responded between (1463, SE = 65.273). The response latencies for each type of semantic relationship are shown in Figure 2.

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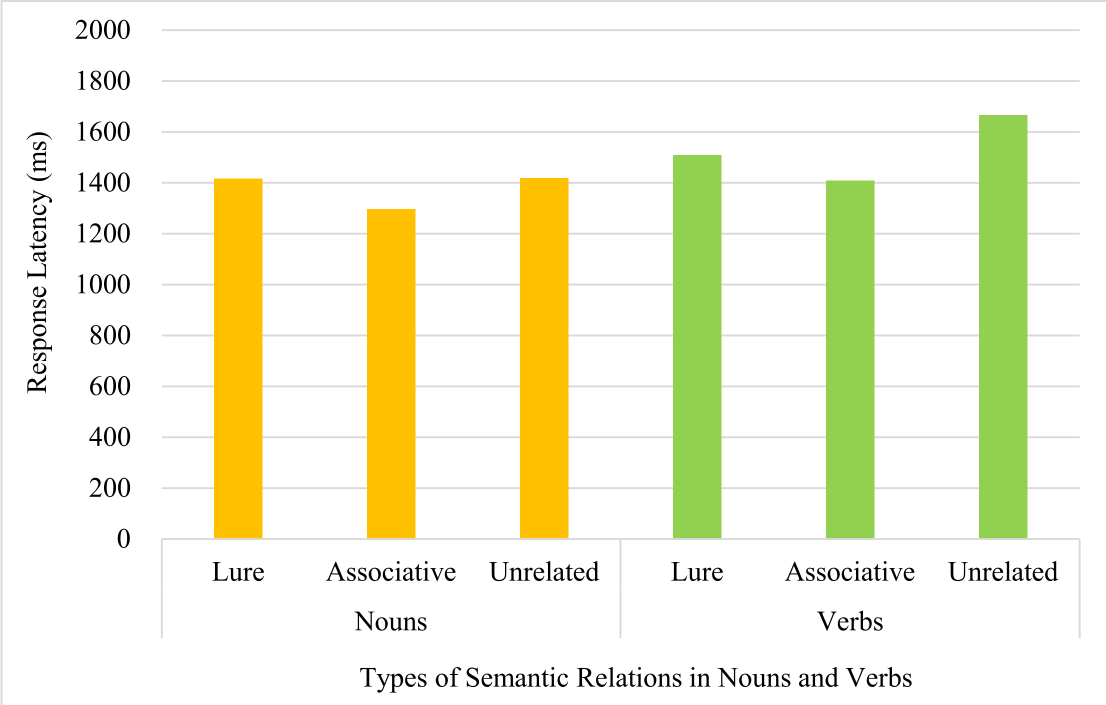


**Figure 2.** Response Latency of Types of Semantic Relations in Nouns and Verbs of College Students.

*3.2. Data Analyses of People with Down Syndrome and Typically Developing Controls*

Three-way ANOVA repeated ANOVAs with yes responses in types of words as within-participants factors and groups as between-participants factors were included in the analyses. No three-way interactions were observed ($F < 1$). Two-way interaction between types of words and groups reached significance [$F(4,114) = 12.06$, $p < 0.001$, $\eta^2 = 0.29$]. One of the simple main effects was from the difference among groups in each type of words, suggesting group difference in lures [DS, 0.518, SE = 0.040; CA, 0.441, SE = 0.040; MA, 0.359, SE = 0.040; $F(2,57) = 3.96$, $p = 0.025$, $\eta^2 = 0.122$], group difference in associates [CA, 0.709, SE = 0.031; MA, 0.592, SE = 0.031; DS, 0.588, SE = 0.031; $F(2,57) = 4.931$, $p = 0.011$, $\eta^2 = 0.147$], and group difference in unrelated words [DS, 0.355, SE = 0.032; MA, 0.157, SE = 0.032; CA, 0.101, SE = 0.032; $F(2,57) = 17.270$, $p < 0.001$, $\eta^2 = 0.377$]. The difference in lures was due to the difference between the DS and MA ($p = 0.007$). The difference in associations was due to the difference between DS and CA ($p = 0.008$) and the difference between MA and CA ($p = 0.01$). The difference in unrelated words was due to the difference between DS and CA ($p < 0.001$) and DS and MA ($p < 0.001$). Another simple main effect was the difference in the types of words used in each group. In the CA group, associates (0.709, SD = 0.157) were responded more accurately than lures (0.440, SD = 0.153) and unrelated words (0.100, SD = 0.196) at $p < 0.001$ [$F(2,38) = 91.743$, $p < 0.001$, $\eta^2 = 0.828$]. The latter two types of words differed significantly ($p < 0.001$). In the MA group, associates (0.591, SD = 0.123) were responded more accurately than lures (0.359, SD = 0.131) and unrelated words (0.156, SD = 0.132) at $p < 0.001$ [$F(2,38) = 77.022$, $p < 0.001$, $\eta^2 = 0.802$]. The latter two types of words differed significantly ($p < 0.001$). In the DS group, associates (0.588, SD = 0.132) were responded more accurately than lures (0.517, SD = 0.232) and unrelated words (0.355, SD = 0.187) at $p < 0.001$ [$F(2,38) = 22.058$, $p < 0.001$, $\eta^2 = 0.537$]. The latter two types of words differed significantly ($p < 0.001$). The difference between associates and lures was not significant.

Two-way interaction of syntactic categories and types of words reached significance [$F(2,114) = 4.718$, $p = 0.011$, $\eta^2 = 0.076$]. The simple main effect was from difference among types of nouns [$F(2,118) = 97.864$, $p < 0.001$, $\eta^2 = 0.624$] and verbs [$F(2,118) = 131.211$, $p < 0.001$, $\eta^2 = 0.690$]. For nouns, associates (0.619, SE= 0.021) received higher responses than lures (0.441, SE = 0.027) or unrelated words (0.224, SE = 0.025) [all $p < 0.001$]. For verbs, associated words (0.641, SE = 0.022) received higher responses

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than lures (0.438, SE = 0.024) or unrelated words (0.184, SE = 0.024) [all $p < 0.001$]. No differences in the syntactic categories of the word types emerged.

The main effect of types of words reached significance [$F(2,114) = 179.553$, $p < 0.001$, $\eta^2 = 0.759$], suggesting associates received higher yes responses (0.630, SE = 0.018) than lures (0.439, SE = 0.023) and unrelated words (0.204, SE = 0.019) at $p < 0.001$. Unrelated words received the least number of responses. The main effect of groups was significant [$F(2,57) = 5.114$, $p = 0.009$, $\eta^2 = 0.152$], implying that the DS group pressed highest frequency of yes responses (0.487, SE = 0.026) compared to the CA group (0.417, SE = 0.026) and the MA group (0.369, SE = 0.026). Only the difference between the DS group and MA group was significant ($p = 0.002$). The response accuracies of the types of nouns and verbs in the three groups are shown in Figure 3.

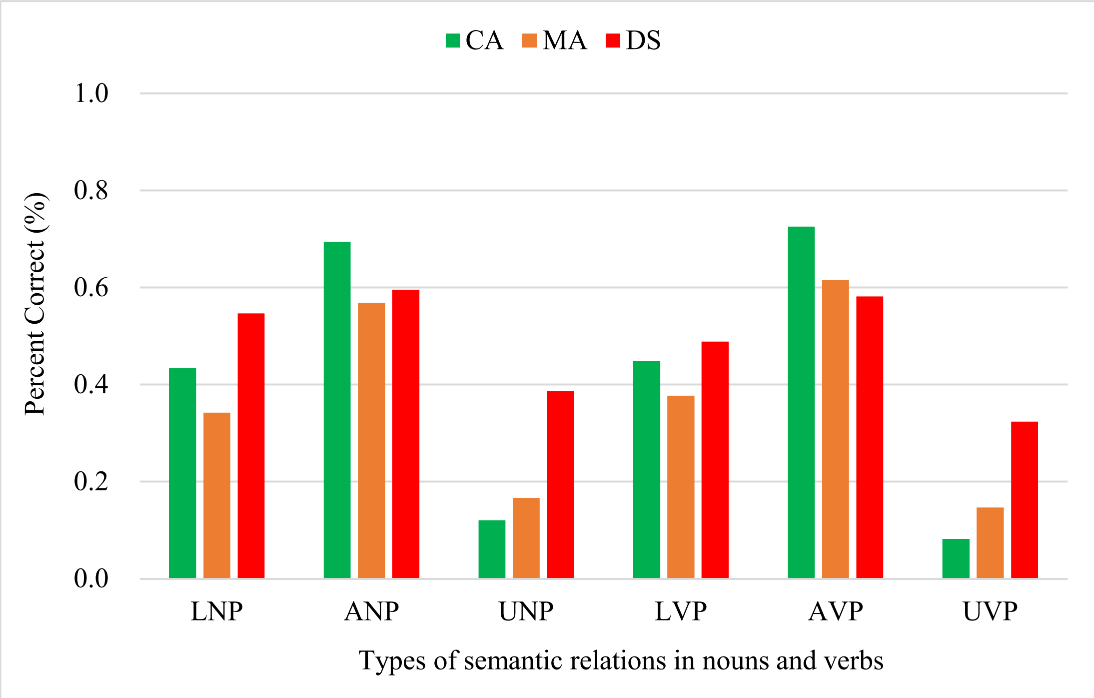


**Figure 3.** Accuracy of Types of Semantic Relations in Nouns and Verbs of the Three Groups.

In sum, people with DS had developmental delays in responding to associates as well as developmental deviance in processing lures and unrelated words.

In the analyses of reaction times, the data of one participant were removed because their reaction times were too long to respond to almost all trials. Other data were counted as missing in the analyses because of 100 percent correct responses to unrelated words (14% nouns and 17% verbs). The analyses with syntactic categories and types of words as within-participants factors and groups as between-participants factors revealed no differences in the three- and two-way interactions. The main effect of the types of words was significant [$F(2,82) = 4.500$, $p < 0.014$, $\eta^2 = 0.099$], suggesting longest responses were observed with the unrelated words (2233 ms, SE = 161) compared to the lures (2112 ms, SE = 158) [$p = .030$] and the associates (2034 ms, SE = 147) [$p = 0.026$]. The latter two values were not statistically significant. The main effect of groups was significant [$F(2,46) = 7.117$, $p = 0.002$, $\eta^2 = 0.236$]. People with DS (2956 ms, SE = 268 ms) were slowest in responding to all trials compared to the two controls (CA, 1588 ms, SE = 277 ms, $p = 0.001$; MA, 1857 ms, SE = 277 ms, $p = 0.007$). No significant differences were observed between the CA and MA groups. The reaction times for the types of nouns and verbs in the three groups are shown in Figure 4.

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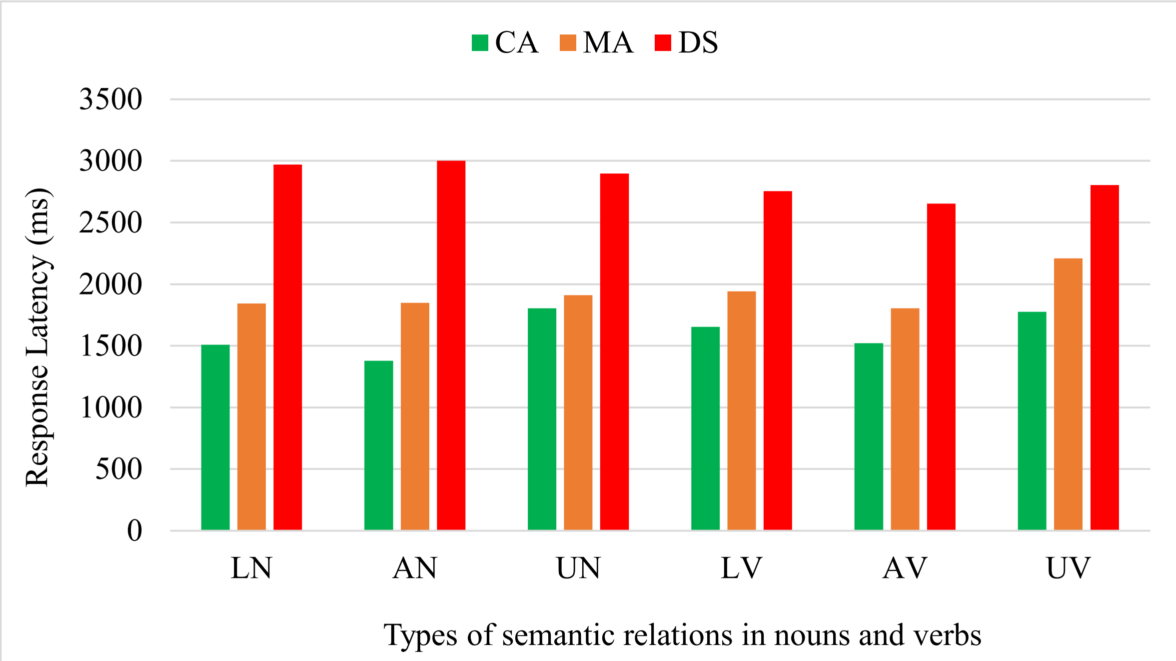


**Figure 4.** Reaction Times of Types of Semantic Relations in Nouns and Verbs of the Three Groups.

*3.3. Analyses of Stimuli Discrimination in Noun-Eliciting False Memory Task and Verb-Eliciting False Memory Task*

To determine whether there was a positivity bias in response to nouns in the three groups, the discrimination sensitivity of *the d* prime between associates (hits) from lures (false alarms) and between associates (hits) from unrelated words (false alarms) was analyzed. A one-way ANOVA with univariate analysis was performed with *d* prime values of associates and lures as the within-participants factor and groups as the between-participants factor. The results revealed no differences in the differentiation of associates from lures among groups. Another one-way ANOVA with univariate analysis was performed with *d* prime values of associated and unrelated words as the within-participants factor, and groups as the between-participants factor. Significant difference among groups was observed [$F(2,48) = 7.501$, $p = 0.001$, $\eta^2 = 0.238$], suggesting the CA group (9.83, SD = 9.37) showed high differentiation of associates from unrelated words compared to the MA group (4.80, SD = 5.78) and the DS group (1.58, SD = 0.713). The latter two groups did not show significant differences. Further analyses of the correlation between participants' age and the two-*d* prime sensitivity values revealed no significant difference.

The sensitivity of the positivity bias of participants' responses to verbs was entered into a one-way ANOVA with *the d* prime value as a within-participants factor and groups as a between-participants factor. No significant differences were observed between the groups ($F < 1$). The positivity bias differentiating associates from unrelated words yielded significance [$F(2,46) = 7.710$, $p = 0.001$, $\eta^2 = 0.251$], implying the DS group (2.18, SD = 1.36) showed the lowest sensitivity value than the CA group (9.98, SD = 6.75) and the MA group (8.13, SD = 8.18). There were no significant differences between the two groups. Only the MA group showed a significant correlation between age and sensitivity for differentiating associated from unrelated words [$r = 0.581$, $p = 0.018$]. No significant correlation was observed between the CA and DS groups. This finding suggests that MA-matched controls were sensitive to the differences between associated and unrelated words related to the verb-eliciting false memory task with age.

Taken together, compared to controls, people with DS were delayed in differentiating associates from unrelated words in the noun-eliciting false memory task. People with DS deviate in differentiating associates from unrelated words in verb-eliciting false memory tasks.

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*3.4. Analyses of Error Patterns in Noun-Eliciting False Memory Task*

To determine which semantic concepts of nouns were more fragile in people with DS compared to controls, the error patterns of the topics in each group were analyzed. The nominal topics and types of words were taken as the within-participants factors, and groups as the between-participants factor in a three-way analysis of variance. The results revealed significant three-way interaction [$F(36,1026) = 1.571$, $p = 0.018$, $\eta^2 = 0.052$]. One of the simple main effects was from the two-way interaction of topics and groups to lures [$F(18,513) = 2.273$, $p = 0.002$, $\eta^2 = 0.074$]. The simple simple main effect was from group effect on topics of "public square dancing" [DS, 0.500, SD = 0.296; MA, 0.133, SD = 0.199; CA, 0.116, SD = 0.163; $F(2,57) = 18.279$, $p < 0.001$, $\eta^2 = 0.391$], "amusement park" [DS, 0.516, SD = 0.314; MA, 0.266, SD = 0.231; CA, 0.283, SD = 0.311; $F(2,57) = 4.694$, $p = 0.013$, $\eta^2 = 0.141$], and "summer" [DS, 0.433, SD = 0.326; MA, 0.250, SD = 0.238; CA, 0.216, SD = 0.291; $F(2,57) = 3.286$, $p = 0.045$, $\eta^2 = 0.103$]. With respect to these topics, people with DS made more errors than the two control groups with least significance difference among post-hoc analyses at $p < 0.001$ on the top of "public square dancing" to both CA group and MA group at $p = 0.013$ (DS vs. CA) and $p = 0.008$ (DS vs. MA) on the topic of "amusement park," and at $p = 0.021$ (DS vs. CA) and $p = 0.049$ (DS vs. MA) on the topic of "summer." Other group effect was observed on the topics of "breakfast store" [DS, 0.650, SD = 0.366; MA, 0.300, SD = 0.303; CA, 0.500, SD = 0.315; $F(2,57) = 5.674$, $p = 0.006$, $\eta^2 = 0.166$] and "road" [DS, 0.616, SD = 0.363; MA, 0.300, SD = 0.303; CA, 0.483, SD = 0.295; $F(2,57) = 4.866$, $p = 0.011$, $\eta^2 = 0.146$], suggesting higher errors of people with DS than the controls in MA to the topics of "breakfast store" and "road." On these topics, people with DS made more errors than the MA control groups with least significance difference post-hoc analyses on the topic of "breakfast store" ($p = 0.001$) and on the topic of "road" ($p = 0.003$).

Another simple simple main effect was from topic effect on groups [CA, $F(9,171) = 9.735$, $p < 0.001$, $\eta^2 = 0.339$; MA, $F(9,171) = 7.431$, $p < 0.001$, $\eta^2 = 0.281$; DS, $F(9,171) = 2.145$, $p = 0.028$, $\eta^2 = 0.101$]. All the groups erred highest to the topic of "hospital" (CA, 0.700, SE = 0.064; MA, 0.733, SE = 0.052; DS, 0.667, SE = 0.084); however, the patterns of lowest errors were different in people with DS from the two healthy control groups. The CA group and the MA group erred least to "public square dancing" (CA, 0.117, SE = 0.036; MA, 0.133, SE = 0.045); the DS group erred least to "barber shop" (0.433, SE = 0.091) and to "summer" (0.433, SE = 0.073). The main effect of the group reached significance [$F(2,57) = 5.558$, $p = 0.006$, $\eta^2 = 0.163$], suggesting the DS group erred most (0.547, SE = 0.044) than the CA group (0.433, SE = 0.044) and the MA group (0.342, SE = 0.044). The difference between the DS group and MA group was statistically significant ($p = 0.002$).

The interactions between topics and groups in the processing of associated and unrelated words were not significant. The main effect of groups in processing associates was significant [$F(2,57) = 3.631$, $p = 0.033$, $\eta^2 = 0.113$], suggesting the CA group erred least (0.307, SE = 0.035) than the MA group (0.432, SE = 0.035, $p = 0.013$) and the DS group (0.405, SE = 0.035, $p = 0.049$). The lowest errors was observed to "hospital" (0.217, SE = 0.039) and the highest errors was to "summer" (0.472, SE = 0.038). Moreover, the main effect of the group in processing the unrelated words was significant [$F(2,57) = 16.733$, $p < 0.001$, $\eta^2 = 0.370$], suggesting the DS group erred most (0.387, SE = 0.035) than the CA group (0.120, SE = 0.035) and the MA group (0.167, SE = 0.035) at $p < 0.001$. In sum, people with DS made errors in association as the MA controls (i.e., delay), but they made errors in unrelated words the most (i.e., deviance). The error patterns of people with DS differed from those of the two control groups.

Another simple main effect was the two-way interaction between the type and group for each topic. The results showed the topics of "the Dragon Boat Festival," "public square dancing," "bathroom," "road," and "summer" reached significance. Table 2 presents the statistical results.

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**Table 2.** Error Analyses of Types of Words under Each Nominal Topic of the Three Groups.

| Topic | Topic Chinese name | Topic English name | Topic x group interaction[a] | Main effect of type under topic[b] | Main effect of group under topic[c] |
|---|---|---|---|---|---|
| 1 | 理发店 | barber shop | 2.126, $p = 0.082$ | 10.901, $p < 0.001$ | 5.029, $p = 0.01$ |
| 2 | 端午节 | the Dragon Boat Festival | 2.484, $p = 0.048$ | 21.693, $p < 0.001$ | 2.239, $p = 0.116$ |
| 3 | 早餐店 | breakfast store | 1.743, $p = 0.145$ | 5.909, $p = 0.004$ | 7.576, $p = 0.001$ |
| 4 | 广场舞 | public square dancing | 6.755, $p < 0.001$ | 9.916, $p < 0.001$ | 12.63, $p < 0.001$ |
| 5 | 游乐园 | amusement park | 0.812, $p = 0.52$ | 1.989, $p = 0.142$ | 10.32, $p < 0.001$ |
| 6 | 浴室 | bathroom | 2.731, $p = 0.032$ | 19.055, $p < 0.001$ | 4.754, $p = 0.012$ |
| 7 | 马路 | road | 2.721, $p = 0.033$ | 9.962, $p < 0.001$ | 9.401, $p < 0.001$ |
| 8 | 夏天 | summer | 5.919, $p < 0.001$ | 15.059, $p < 0.001$ | 7.848, $p < 0.001$ |
| 9 | 圣诞节 | Christmas | 1.033, $p = 0.393$ | 22.652, $p < 0.001$ | 2.313, $p = 0.108$ |
| 10 | 医院 | hospital | 1.447, $p = 0.223$ | 51.097, $p < 0.001$ | 2.443, $p = 0.096$ |

*Note.* [a]$F_{(4,114)}$ for topic x group interaction, [b]$F_{(2, 114)}$ for main effect of type under topic, [c]$F_{(2, 57)}$ for main effect of group under topic.

In the topic of "the Dragon Boat Festival," the simple main effect was from group effect on associates [$F(2,57) = 3.485$, $p = 0.037$, $\eta^2 = 0.109$]. The DS group (0.533, SD = 0.199) erred in the MA group (0.500, SD = 0.253, $p = 0.017$) which, in turn, was greater than that in the CA group (0.333, SD = 0.305, $p = 0.045$). No significant differences were observed between the two groups, and no differences were observed between the groups for lures or unrelated words. The other simple main effect was from types of words on groups [CA, $F(2,38) = 7.858$, $p = 0.001$, $\eta^2 = 0.293$; MA, $F(2,38) = 8.703$, $p = 0.001$, $\eta^2 = 0.314$; DS, $F(2,38) = 10.916$, $p < 0.001$, $\eta^2 = 0.365$]. People with DS responded less to unrelated words (0.217, SE = 0.065) than to lures (0.517, SE = 0.074) and associates (0.533, SE = 0.045) at $p = 0.001$. The patterns observed in the CA group were similar to those in people with DS (unrelated words, 0.117, SE = 0.050; associates, 0.333, SE = 0.068; lures, 0.517, SE = 0.085). The difference between unrelated words and lures was significant ($p = 0.001$), as was the difference between unrelated words and associates ($p = 0.008$). However, the MA group had more associated words (0.500, SE = 0.057) than lures (0.300, SE = 0.072) and unrelated words (0.150, SE = 0.051). The difference between associates and lures was $p = 0.019$ and the difference between associates and unrelated words was $p < 0.001$. The results revealed different patterns in the MA group compared to those in the CA and DS groups. A graph showing yes responses as the semantic distance between the topic of "the Dragon Boat Festival" and the types of words is shown in Figure 5. To display the complete picture of semantic relatedness among all groups, the results for college students are included in the graph for comparison.

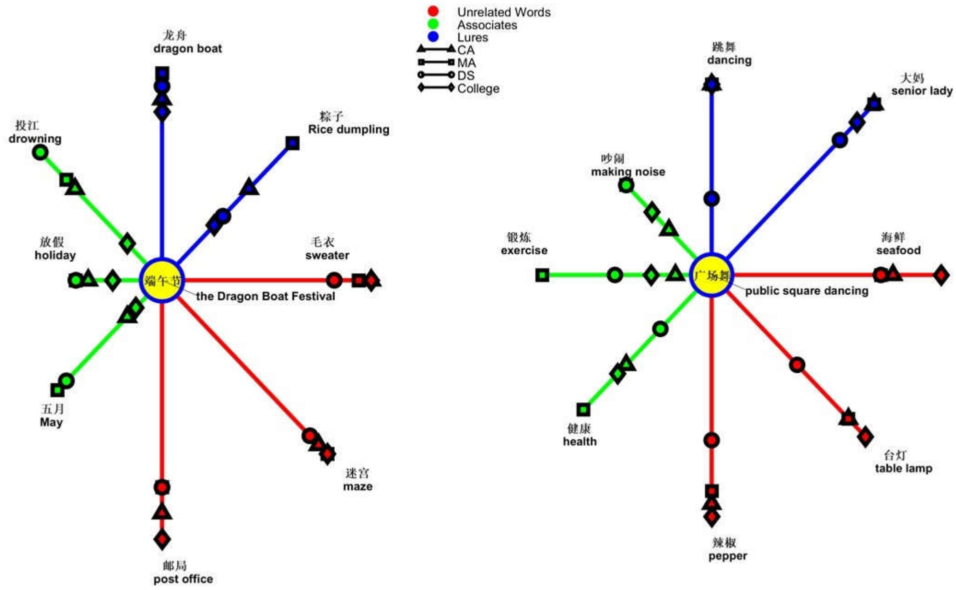


**Figure 5.** Semantic Relatedness of the Four Groups in the Nominal Lure of "Dragon Boat Festival" and "Public Square Dancing".

In the topic of "public square dancing," interaction of types of words and groups reached significance [$F(4,114) = 6.755$, $p < 0.001$, $\eta^2 = 0.192$]. The simple main effect was from group effect on lures [$F(2,57) = 5.674$, $p = 0.006$, $\eta^2 = 0.116$] and unrelated words [$F(2,57) = 3.572$, $p = 0.035$, $\eta^2 = 0.111$]. People with DS made more errors (0.650, SE = 0.074) in lures than did the CA (0.500, SE = 0.074) and MA groups (0.300, SE = 0.074). Only the difference of people with DS and MA group was significant ($p = 0.001$). People with DS (0.450, SE = 0.066) erred more than the two control groups (0.233, SE = 0.066) for unrelated words, suggesting deviant processing in people with DS. Another main effect was from effect of types of words in control groups [CA, $F(2,38) = 4.815$, $p = 0.014$, $\eta^2 = 0.202$; MA, $F(2,38) = 19.046$, $p < 0.001$, $\eta^2 = 0.501$; DS, $F < 1$]. In the CA group and MA group, associates erred significantly more than lures (CA, $p = 0.012$; MA, $p < 0.001$) and unrelated words (CA, $p = 0.049$; MA, $p = 0.001$)[CA, associates, 0.300, SD = 0.239; lures, 0.116, SD = 0.163; unrelated words, 0.183, SD = 0.253; MA, associates, 0.650, SD = 0.275; lures, 0.133, SD = 0.199; unrelated words, 0.216, SD = 0.311]. However, people with DS did not observe in pattern. Instead, people with DS erred more toward lures (0.500, SE = 0.066) than toward associates (0.400, SE = 0.071) or unrelated words (0.383, SE = 0.070). No significant differences were observed between the word types. This finding suggests that people with DS were deviant in making the highest proportion of yes responses to unrelated words and showed a distinct pattern of higher errors in lures than the control groups. A graph showing yes responses as the semantic distance between the topic of "public square dancing" and the types of words is shown in Figure 5.

In the topic of "bathroom," interaction of types of words and groups reached significance [$F(4,114) = 2.731$, $p = 0.032$, $\eta^2 = 0.087$]. The simple main effect was from group effect on unrelated words [$F(2,57) = 7.320$, $p = 0.001$, $\eta^2 = 0.204$], suggesting people with DS made more errors than the CA group ($p < 0.001$) and the MA group ($p = 0.017$). Another simple main effect was from types of words in groups [CA, $F(2,38) = 23.413$, $p < 0.001$, $\eta^2 = 0.552$; MA, $F(2,38) = 3.973$, $p = 0.027$, $\eta^2 = 0.173$]. However, this difference was not significant in the DS group. In the CA and MA groups, lures erred more often than associates or unrelated words (CA, lures, 0.600, SD = 0.255; associates, 0.333, SD = 0.305; unrelated words, 0.050, SD = 0.122; MA, lures, 0.416, SD = 0.322; associates, 0.400, SD = 0.298; unrelated words, 0.166, SD = 0.315). The CA group showed a difference between unrelated words and lures at $p < 0.001$ and a difference between unrelated words and associates at $p = 0.001$. The difference between lures and associates was $p = 0.012$. The MA group showed a difference between

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unrelated words and lures at $p = 0.010$ and a difference between unrelated words and associates at $p = 0.019$. Lures and their associates were not statistically significant. The graph showing yes responses as semantic distance between "bathroom" and types of words is depicted in Figure 6.

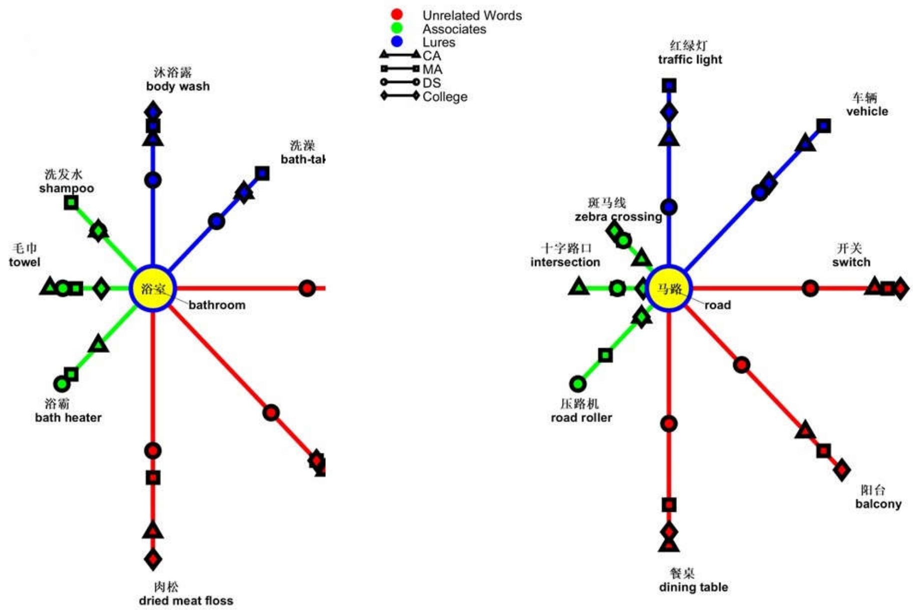


**Figure 6.** Semantic Relatedness of the Four Groups in the Nominal Lure of "Bathroom" and "Road".

In the topic of "road," interaction of types of words and groups was significant [$F(4,114) = 2.721$, $p = 0.033$, $\eta^2 = 0.087$]. The simple main effect was from group effect on lures [$F(2,57) = 4.866$, $p = 0.011$, $\eta^2 = 0.146$] and unrelated words [$F(2,57) = 10.756$, $p < 0.001$, $\eta^2 = 0.274$]. People with DS made more errors in lures than those in the MA group ($p = 0.003$). People with DS erred more unrelated words than those in the MA group and CA group, both at $p < 0.001$. Another simple main effect was from effect of types of words in the CA group [$F(2,38) = 8.412$, $p = 0.001$, $\eta^2 = 0.307$] and in the DS group [$F(2,38) = 5.159$, $p = 0.010$, $\eta^2 = 0.214$]. In the CA group, lures (0.483, SD = 0.295) erred more frequently than associates (0.216, SD = 0.223, $p = 0.014$) and unrelated words (0.166, SD = 0.299, $p = 0.001$). In the DS group, lures (0.616, SD = 0.363) erred more than unrelated words (0.516, SD = 0.350) or associates (0.316, SD = 0.275), both at $p = 0.012$. The graph showing yes responses as semantic distance between "road" and types of words is depicted in Figure 6.

In the topic of "summer," interaction of types of words and groups was significant [$F(4,114) = 5.919$, $p < 0.001$, $\eta^2 = 0.172$]. The simple main effect was from group effect on types of words [lures, $F(2,57) = 3.286$, $p = 0.045$, $\eta^2 = 0.103$; associates, $F(2,57) = 3.643$, $p = 0.032$, $\eta^2 = 0.113$; unrelated words, $F(2,57) = 17.401$, $p < 0.001$, $\eta^2 = 0.379$]. Regarding the error patterns of lures and unrelated words, the DS group made more errors than the CA and MA groups (DS, lures, 0.433, SE = 0.064; CA, 0.217, SE = 0.064; MA, 0.250, SE = 0.064; unrelated words, DS, 0.433, SE = 0.049; CA, 0.033, SE = 0.049; MA, 0.150, SE = 0.049). For lures, the difference between the DS group vs. the MA group was $p = 0.049$ and the difference between the DS group and CA group was at $p = 0.021$. In unrelated words, the difference between the DS group and two control groups was $p < 0.001$. However, in the error pattern of associates, the MA group (0.617, SE = 0.066) erred the most compared to the CA group (0.417, SE = 0.066, $p = 0.037$) and DS group (0.383, SE = 0.066, $p = 0.015$). Another simple main effect was from effect of types of words in the CA group [$F(2,38) = 12.938$, $p < 0.001$, $\eta^2 = 0.405$] and the MA group [$F(2,38) = 15.721$, $p < 0.001$, $\eta^2 = 0.453$]. Both the CA and MA groups erred more to associates (CA: 0.417, SE = 0.063; MA: 0.617, SE = 0.078) than to lures (CA: 0.217, SE = 0.065; MA: 0.250, SE = 0.053) or unrelated words (CA: 0.033, SE = 0.023; MA: 0.150, SE = 0.045). No significant differences were observed between the two groups. Taken together, these results suggest that people with DS show

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deviations in processing summer-related semantic words. The graph showing yes responses as semantic distance between the topic of "summer" and types of words is depicted in Figure 7.

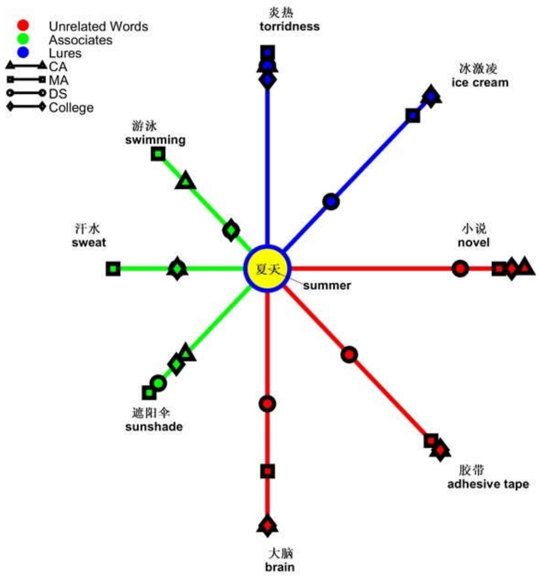


**Figure 7.** Semantic Relatedness of the Four Groups in the Nominal Lure of "Summer".

No interaction was observed between processing "barber shops" and "breakfast stores," "amusement park," "Christmas," and "hospital." People with DS erred the most compared with the CA and MA controls. Significant differences among the groups were observed in processing "barber shops," "breakfast stores," "public square dancing," "amusement parks," "bathrooms," "roads," and "summer." The effects of word type in each group differed for each topic. In the CA group, all the effects of the types of words were significant (except for the topic of "amusement park"). In the MA group, almost all effects of the types of words were significant (except for "breakfast store," "amusement park," and "road"). In the DS group, almost all the effects of types of words were not significant (except for "the Dragon Boat Festival," "road," and "hospital"). These findings suggest that people with DS deviate from forming concepts through lexical semantics.

### *3.5. Analyses of Error Patterns in Verb-Eliciting False Memory Task*

To determine which semantic concepts of verbs were more fragile in people with DS compared to controls, the error patterns of topics in each group were analyzed. Verbal topics and types of words were taken as the within-participants factors and groups as the between-participants factor in a three-way analysis of variance. The results revealed significant three-way interaction [$F(36,1026) = 2.083$, $p < 0.001$, $\eta^2 = 0.068$]. One of the simple main effects was from the two-way interaction of topics and groups in processing lures [$F(18,513) = 2.566$, $p < 0.001$, $\eta^2 = 0.083$]. The simple simple main effect was from group effect on "do housework" [$F(2,57) = 3.243$, $p = 0.046$, $\eta^2 = 0.102$], "transport during Spring Festival" [$F(2,57) = 3.917$, $p = 0.025$, $\eta^2 = 0.121$], "get married" [$F(2,57) = 3.966$, $p = 0.024$, $\eta^2 = 0.122$], and "shop online." In processing of the former two topics and the last one, the DS group erred more than the two control groups ["do housework," DS, 0.583, SD = 0.402; CA, 0.533, SD = 0.380; MA, 0.300, SD = 0.340; "transport during Spring Festival," DS, 0.466, SD = 0.294; CA, 0.283, SD = 0.311; MA, 0.216, SD = 0.270; "shop online," DS, 0.650, SD = 0.350; CA, 0.500, SD = 0.275; MA, 0.350, SD = 0.253]. Only the differences between the DS group and MA group were significant ("do housework," $p = 0.020$; "transport during the Spring Festival," $p = 0.009$; "shop online," $p = 0.002$). When processing "get married," the DS group (0.466, SD = 0.313) produced fewer yes responses than the two control groups

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(0.716, SD = 0.329). The differences between the DS group and the two controls were significant ($p$ = 0.018).

Another simple simple main effect was from the effect of types of words in groups [CA, $F(9,171) = 5.018$, $p < 0.001$, $\eta^2 = 0.209$; MA, $F(9,171) = 5.373$, $p < 0.001$, $\eta^2 = 0.220$; DS, $F(9,171) = 2.996$, $p = 0.002$, $\eta^2 = 0.136$]. The error patterns differed between the DS and control groups. In the two control groups, both groups erred most to "get married" (0.716, SD = 0.329) and least to "celebrate birthday" (CA, 0.250, SD = 0.283; MA, 0.216, SD = 0.270) and "transport during Spring Festival" (CA, 0.283, SD = 0.311; MA, 0.216, SD = 0.270). However, people with DS erred most to "shop online" (0.650, SD = 0.350) and least to "celebrate birthday" (0.400, SD = 0.368) and "play piano" (0.283, SD = 0.369).

Another simple main effect was from the effect of types of words in processing associates [$F(18,513) = 2.003$, $p = 0.008$, $\eta^2 = 0.066$]. The simple simple main effect was from group effect on "get married" [$F(2,57) = 10.121$, $p < 0.001$, $\eta^2 = 0.262$], "celebrate New Year" [$F(2,57) = 5.894$, $p = 0.005$, $\eta^2 = 0.171$], and "play piano" [$F(2,57) = 4.101$, $p = 0.022$, $\eta^2 = 0.126$]. In processing of the former two topics, people with DS erred most among groups ["get married," DS, 0.550, SD = 0.329; MA, 0.283, SD = 0.291; CA, 0.150, SD = 0.228; "celebrate New Year," DS, 0.366, SD = 0.284; MA, 0.250, SD = 0.303; CA, 0.083, SD = 0.183]. In the process of "playing piano," people with DS (0.416, SD = 0.322) made errors similar to those in the CA group (0.383, SD = 0.311), which were fewer than those in the MA group (0.633, SD = 0.262). Another simple simple main effect was from the effect of topics in groups [CA, $F(9,171) = 4.400$, $p < 0.001$, $\eta^2 = 0.188$; MA, $F(9.171) = 4.812$, $p < 0.001$, $\eta^2 = 0.202$]. No significant differences were observed between the DS and DS groups. Moreover, the error patterns differed between the CA and MA groups. In the CA group, the errors to "transport during Spring Festival" were the highest (0.400, SD = 0.352) and the errors to "celebrate the New Year" (0.083, SD = 0.183) and "get married" (0.150, SD = 0.228). In the MA group, the errors to "play piano" were the highest (0.633, SD = 0.262) and the errors to "celebrate New Year" (0.250, SD = 0.303) and "watch movies" (0.250, SD = 0.262). The interaction between topics and groups in processing unrelated words was not significant. People with DS erred most among groups to the unrelated words [main effect of group, $F(2,57) = 13.132$, $p < 0.001$, $\eta^2 = 0.315$; DS, 0.323, SE = 0.035; MA, 0.147, SE = 0.035; CA, 0.082, SE = 0.035].

In sum, people with DS were deviant in responding to lures of the verb-eliciting topics of "do housework," "transport during Spring Festival," "get married," and "shop online." Peoples with DS showed deviant error patterns in processing lures that differed from the control groups. People with DS were deviant in responding to associates of the verb-eliciting topics "get married," "celebrate New Year," and "play piano" Unlike the two control groups, people with DS showed similar yes responses to all topics, without significant differences for any specific topic in the processing associates. To clarify the nature of processing verb-eliciting topics in false memory tasks across groups, topic-based statistical results are listed in Table 3.

**Table 3.** Error Analyses of Types of Words under Each Verbal Topic of the Three Groups.

| Topic | Topic Chinese name | Topic English name | Topic x group interaction[a] | Main effect of type under topic[b] | Main effect of group under topic[c] |
|---|---|---|---|---|---|
| 1 | 庆生 | celebrate birthday | 1.3, $p = 0.274$ | 8.988, $p < 0.001$ | 2.663, $p = 0.078$ |
| 2 | 做家务 | do housework | 2.778, $p = 0.03$ | 14.086, $p < 0.001$ | 3.888, $p = 0.026$ |
| 3 | 春运 | transport during Spring Festival | 0.332, $p = 0.856$ | 19.087, $p < 0.001$ | 5.78, $p = 0.005$ |
| 4 | 结婚 | get married | 7.658, $p < 0.001$ | 31.469, $p < 0.001$ | 5.279, $p = 0.008$ |
| 5 | 升旗 | raise a flag | 2.256, $p = 0.067$ | 16.978, $p < 0.001$ | 0.8, $p = 0.454$ |
| 6 | 过年 | celebrate New Year | 2.21, $p = 0.072$ | 28.045, $p < 0.001$ | 6.559, $p = 0.003$ |
| 7 | 迷路 | get lost | 1.266, $p = 0.288$ | 6.505, $p = 0.002$ | 2.302, $p = 0.109$ |
| 8 | 看电影 | watch movies | 0.274, $p = 0.894$ | 16.719, $p < 0.001$ | 11.807, $p < 0.001$ |
| 9 | 弹琴 | play piano | 2.563, $p = 0.042$ | 14.641, $p < 0.001$ | 3.214, $p = 0.048$ |
| 10 | 网购 | shop online | 2.179, $p = 0.076$ | 16.834, $p < 0.001$ | 11.522, $p < 0.001$ |

*Note.* [a]$F_{(4,114)}$ for topic x group interaction, [b]$F_{(2,114)}$ for main effect of type under topic, [c]$F_{(2,57)}$ for main effect of group under topic.

In processing of “do housework,” interaction of types and groups reached significance [$F(4,114) = 2.778$, $p = 0.030$, $\eta^2 = 0.089$]. The simple main effect was from group effect on types [lures, $F(2,57) = 3.243$, $p = 0.046$, $\eta^2 = 0.102$; unrelated words, $F(2,57) = 5.778$, $p = 0.005$, $\eta^2 = 0.169$]. In processing lures, people with DS (0.583, SD = 0.402) erred more than those with CA (0.533, SD = 0.380) or MA (0.300, SD = 0.340). The difference between the DS group and MA group was $p = 0.020$. In processing unrelated words, people with DS (0.250, SD = 0.283) erred more than those with CA (0.016, SD = 0.074) or MA (0.183, SD = 0.253). The difference between the DS group and CA group was $p = 0.002$; the difference between the CA group and MA group was $p = 0.022$. Another simple main effect was from the effect of types of words in groups [CA, $F(2,38) = 13.103$, $p < 0.001$, $\eta^2 = 0.408$; MA, $F(2,38) = 4.217$, $p = 0.022$, $\eta^2 = 0.182$; CA, $F(2,38) = 3.690$, $p = 0.034$, $\eta^2 = 0.163$]. People with DS responded more to lures than to associated or unrelated words (CA, lures, 0.533, SE = 0.085; associates, 0.367, SE = 0.068; unrelated words, 0.017, SE = 0.017; DS, lures, 0.583, SE = 0.090; associates, 0.367, SE = 0.072; unrelated words, 0.250, SE = 0.063). The differences between lures and associates, or lures and unrelated words, in the CA group were both $p < 0.001$. The difference between lures and unrelated words in the DS group was $p = 0.003$. However, the MA group responded more strongly to associated words (0.483, SD = 0.295) than to lures (0.300, SD = 0.340) or unrelated words (0.183, SD = 0.253). A graph showing yes responses as the semantic distance between “do housework” and the types of words is shown in Figure 8.

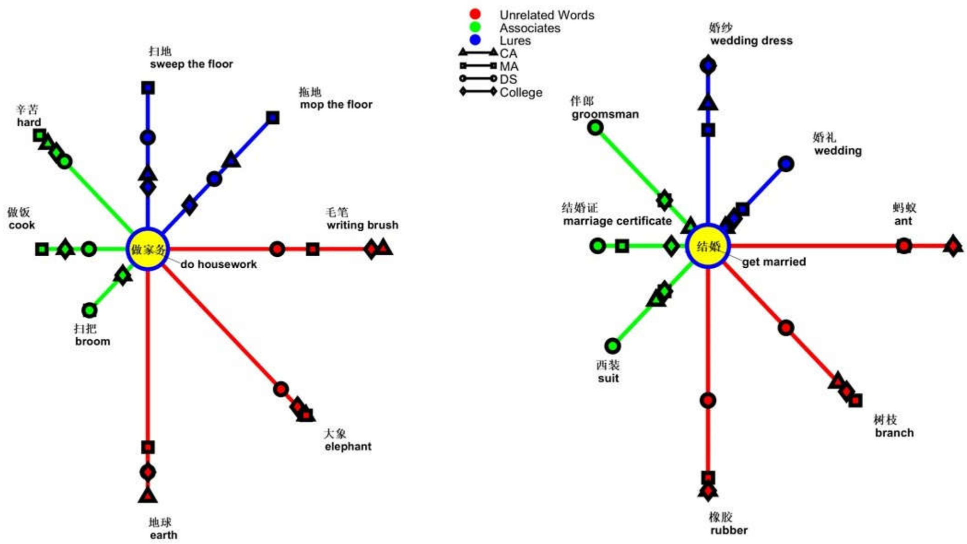


**Figure 8.** Semantic Relatedness of the Four Groups in the Verbal Lure of “Doing Housework” and “Getting married”.

In processing of “get married,” interaction of types and groups reached significance [$F(4,114) = 7.658$, $p < 0.001$, $\eta^2 = 0.212$]. The simple main effect was from group effect on types [lures, $F(2,57) = 3.966$, $p = 0.024$, $\eta^2 = 0.122$; associates, $F(2,57) = 10.121$, $p < 0.001$, $\eta^2 = 0.262$; unrelated words, $F(2,57) = 8.471$, $p = .001$, $\eta^2 = 0.229$]. People with DS deviate in processing topics. When processing associate and unrelated words, most people with DS erred the most significantly among groups (associates, DS: 0.550, SD = 0.329; MA: 0.283, SD = 0.291; CA: 0.150, SD = 0.228; unrelated words: DS, 0.383, SD = 0.291; MA, 0.150, SD = 0.228; CA, 0.100, SD = 0.156). In processing lures, people with DS had significantly fewer yes responses than those in the two control groups (DS, 0.466, SD = 0.313; MA, CA, 0.717, SD = 0.329). Another simple main effect was from effect of types of words in groups [CA, $F(2,38) = 39.271$, $p < 0.001$, $\eta^2 = 0.674$; MA, $F(2,38) = 20.193$, $p < 0.001$, $\eta^2 = 0.515$]. No differences were observed among patients with DS. Both the CA and MA groups erred more in lures than in associate and unrelated words. The graph showing yes responses as semantic distance between "get married" and types of words is depicted in Figure 8.

In processing of "play piano," interaction of types and groups reached significance [$F(4,114) = 2.563$, $p = 0.042$, $\eta^2 = 0.083$]. The simple main effect was from group effect on types of words [associates, $F(2,57) = 4.101$, $p = 0.022$, $\eta^2 = 0.126$; unrelated words, $F(2,57) = 4.682$, $p = 0.013$, $\eta^2 = 0.141$]. People with DS erred more unrelated words than those in the MA and CA groups (DS, 0.333, SD = 0.324; MA, 0.183, SD = 0.253; CA, 0.083, SD = 0.183). Only the difference between the DS group and CA group was statistically significant ($p = 0.004$). People with DS did not show significant differences in the error patterns associated with the CA group (DS, 0.416, SD = 0.322; CA, 0.383, SD = 0.311), which were significantly lower than those in the MA group (0.633, SD = 0.262). No difference was observed in lure processing among the groups, although the MA group (0.350, SD = 0.295) responded more positively than the CA (0.283, SD = 0.311) and DS (0.283, SD = 0.329) groups. Another simple main effect was from effect of types of words in groups [CA, $F(2,38) = 8.430$, $p = 0.001$, $\eta^2 = 0.307$; MA, $F(2,38) = 15.596$, $p < 0.001$, $\eta^2 = 0.451$]. Both control groups responded more to associates than to lures or unrelated words. In the CA group, the difference between unrelated words and associates was $p = 0.001$; the difference between unrelated words and lures was $p = 0.010$. In the MA group, the difference between unrelated words and associates was $p < 0.001$; the difference between unrelated words and lures was $p = 0.029$. The difference between the associates and lures was $p = 0.009$. No differences in word type were observed in the DS group. The graph showing yes responses as semantic distance between "play piano" and types of words is depicted in Figure 9.

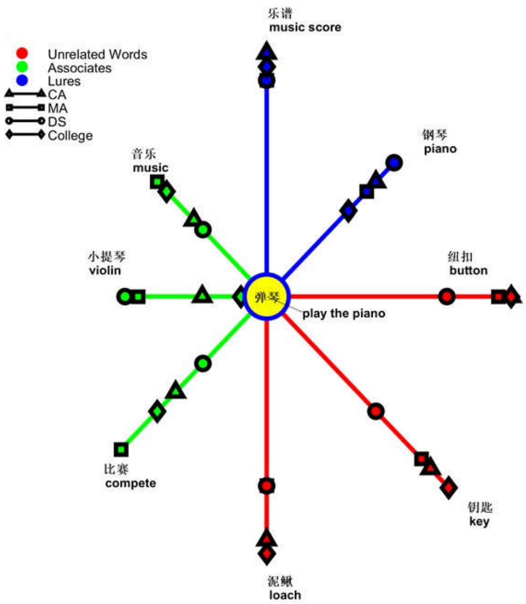


**Figure 9.** Semantic Relatedness of the Four Groups in the Verbal Lure of "Playing Piano".

Taken together, people with DS deviated in the processing of "do housework," "get married," and "play piano." Moreover, people with DS erred most among groups in processing "transport during Spring Festival," "celebrate New Year," "watch movies," and "shop online" [main effect of group, "transport during Spring Festival," $F(2,57) = 5.780$, $p = 0.005$, $\eta^2 = 0.169$; "celebrate New Year," $F(2,57) = 6.559$, $p = 0.003$, $\eta^2 = 0.187$; "watch movies," $F(2,57) = 11.807$, $p < 0.001$, $\eta^2 = 0.293$; "shop online," $F(2,57) = 11.522$, $p < 0.001$, $\eta^2 = 0.288$]. Hence, people with DS did not show group difference in processing of "celebrate birthday," "raise flag," and "get lost."

Another simple main effect was from interaction of topics and types in groups [CA, $F(18,380) = 4.303$, $p < 0.001$, $\eta^2 = 0.169$; MA, $F(18,380) = 3.909$, $p < 0.001$, $\eta^2 = 0.156$]. No interactions were observed among people with DS. The main effect of types of words in the three groups reached significance [CA, $F(2,380) = 100.056$, $p < 0.001$, $\eta^2 = 0.345$; MA, $F(2,380) = 45.850$, $p < 0.001$, $\eta^2 = 0.194$; DS, $F(2,380) =$

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12.568, $p < 0.001$, $\eta^2 = 0.062$]. People with the DS and the CA group responded more to lures (CA: 0.448, SE = 0.023; DS: 0.488, SE = 0.025) than to associates (CA: 0.275, SE = 0.020; DS: 0.418, SE = 0.021) or unrelated words (CA: 0.082, SE = 0.012; DS: 0.323, SE = 0.022). The MA group responded more strongly to associated words (0.385, SE = 0.021) than to lures (0.377, SE = 0.022) or unrelated words (0.147, SE = 0.016). In the CA group and the MA group, the main effect of topics was significant [CA, $F(9,190) = 2.155$, $p = 0.027$, $\eta^2 = 0.093$; MA, $F(9,190) = 2.279$, $p = 0.019$, $\eta^2 = 0.097$]. Error patterns in the CA and MA groups were similar. Over half of the topics received the highest errors for lures, and three of the topics received the highest errors for associates. The topic "get lost" was not significant. People with DS show deviant error patterns in verb-eliciting false memory tasks.

Regression analyses of the working memory factors obtained from the WSIC standardized tests with the accuracy and reaction times of the three groups were conducted, including working memory forward digit span length and score, working memory backward digit span length and score, and total memory length and score. The results revealed that total memory length negatively predicted the yes/response proportion of unrelated words in verbs for people with DS ($r = -0.455$, adjusted $R^2 = 0.163$, $F(1,19) = 4.706$, $p = 0.04$). This finding suggests that people with DS might use a verbatim strategy to memorize the stimuli but not automatically integrate the words into semantic memory. No other predictor was observed as a predictor of accuracy or reaction time for any group of nouns or verbs.

## 4. Discussion

This study used the classical false memory paradigm to investigate the conceptual formation of semantic knowledge among people with DS. By presenting semantically related words in the study phase and mixing semantically unrelated words with conceptually integrated lures in the recognition phase, people with DS clicked more yes responses to all types of words and showed delayed processing of associates and deviant processing of lures and unrelated words. Asymmetrical processing of nouns and verbs has emerged in people with DS. In processing nouns, people with DS were delayed in differentiating associates from unrelated words to nouns, and deviant in differentiating associates from unrelated words to verbs. Further evidence of problematic semantic processing of words in people with DS compared to the control group was observed, indicating the atypical development of semantic networks in people with DS by conceptual integration from semantic relatedness. Similar to Hsu (2016, 2019), the findings in our study showed that people with DS were deviant in semantic processing using the false memory paradigm.

The false-memory task was developed by Roediger and McDermott's (1995) as the very classic paradigm in probing false memory, which was similar to a virtual sentential processing based on semantically related words that formed semantic networks. The ability of sentential processing is the foundation of social cognition. If people with DS have difficulties in sentential processing, their social cognition is impaired; if they have difficulties in comprehending lexical words, their ability to comprehend sentences is deficient. Hence, the semantic knowledge of lexical words of people with DS is the root cause to probe their semantic organization and social cognition. According to our findings, people with DS were indeed atypical in their comprehension of lexical semantics. The impairment of lexical semantics in people with DS might result from bizarre semantic features of words in their semantic network.

Based on the spreading activation model (Collins & Loftus, 1975), a word is a node with intersections with other nodes as a concept. These concepts are grouped closer together because of their shared semantic features. Our analyses of the error patterns for each topic in people with DS revealed possible bizarre semantic features embedded in lexical semantics, leading to atypical semantic knowledge. This hypothesis of bizarre semantic features of lexical semantics is consistent with the hypotheses of dosage imbalance and amplified developmental instability in people with DS related to genetic impairment in the early stage. In turn, this impairment results in neurodevelopment atypicality and neurodegeneration in people with DS (Contestabile, Benfenati, & Gasparini, 2010).

Anderson (1983) considered a node to be a cognitive unit with connected elements or semantic features. Each unit is processed in the working memory and spread to other units in the long term memory via various elements, with the impact of connection strength. Whenever a word is processed, it undergoes an encoding stage that creates a trace with different strengths that influences the speed of retrieval. The second stage involves the storage or retention of words. The trace is not lost but decays with time. The last stage is retrieval, in which spreading activation occurs, and levels of processing play a role. Based on this analysis, people with DS may be impaired at any stage, which leads to deviant recognition in false memory tasks. Furthermore, nominal and verbal lures result in distinct processing patterns in people with DS compared to typically developing controls.

The connectionist model proposed by Rumelhart, Hinton, and McClelland (1987) adopts a parallel-distributed processing perspective to account for human information processing. There are input units that carry integrated information, hidden units that are invisible but determine each type of representation, and output units that perform computations to realize connectivity among the units. For people with DS, impairments can occur at the inputs, hidden units, or outputs. Any impairment results in a breakdown of connectivity within the representation system. This may account for deficits in semantic processing and atypical semantic organization in people with DS.

Impaired processing of lexical semantics might be distinct at behavioral and neurological levels. A study using the false memory paradigm to investigate the integration ability of people with WS showed this asymmetry (Hsu, Karmiloff-Smith, Tzeng, Chin, & Wang, 2007). While people with WS showed typical behavior, they showed atypical neurological processing. They processed semantic-related but non-presented lures as the displayed words. Further, they simultaneously showed delayed and deviant semantic organization at the processing stage. It was unclear whether people with DS would show brain and behavioral asymmetry while integrating semantically-related words. Further studies should be conducted using neuroimaging techniques to investigate lexical semantics in people with DS. Future interventions for people with DS should focus on the concept of semantic knowledge, which could potentially enhance their social cognition.

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**Conflicts of Interest:** The authors report no conflicts of interest.

**Data is Available Upon Request:** This study has been approved by the Institutional Review Board in the School of Foreign Languages in Hunan University.

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