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Semantic-Phonemic Discrepancy and its changes over time in Alzheimer's Disease: Evidence from Clustering and Switching Analyses

Jee Eun Sung[a]

Sang Eun Lee[a]

Gayle DeDe[b]

Se Jin Oh[a]

Mi Kyung Shin[a]

Soo Eun Lee[a]

[a]Dept. of Communication Disorders, EWHA Womans University, Seoul, South Korea

[b]Dept. Of Communication Sciences & Disorders, Temple University, USA

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Semantic vs. Phonemic

- **Verbal fluency tasks** are frequently used to **index cognitive-linguistic decline** in neurodegenerative clinical populations such as Alzheimer's Disease (AD).

- Verbal fluency has been often measured in two domains using the semantic and phonemic fluency tasks.

Semantic Fluency	Phonemic Fluency
generate as many words as possible that belong to a certain semantic category (e.g., 'animal') in a given time constraint (e.g., '60 seconds')	produce words that start with a specific letter such as 'F', 'S', or 'A' under the same time frame.

Confrontation naming vs. Verbal fluency

The verbal fluency tasks have been regarded as imposing **greater cognitive demands than the confrontation naming tasks** (e.g., Crawford & Henry, 2004; Huff et al., 1986).

Confrontation naming task	Verbal fluency task
visual stimuli → aid easier access to the semantic memory	to inhibit what they have already produced for searching the new items by keeping track of their behaviors

Due to the additional demands of self-directed planning procedures, the verbal fluency measures have been reported as being more sensitive to detect the presence of neurodegenerative disease

Semantic vs. Phoneme
Differences in processing mechanisms

Semantic Fluency

- **successful activation of semantic memory**
- **general semantic knowledge from the long-term memory**
- (Butters , Granholm, Salmon, & Grant, 1987; Hodges, Salmon, & Butters , 1992)

Phonemic Fluency

- **access to the orthographic and phonemic relatedness** (Brin al., 2010; Weakley et al., 2014).
- **Inhibition of the automatic activation of word meanings** by primarily relying on phoneme representations.

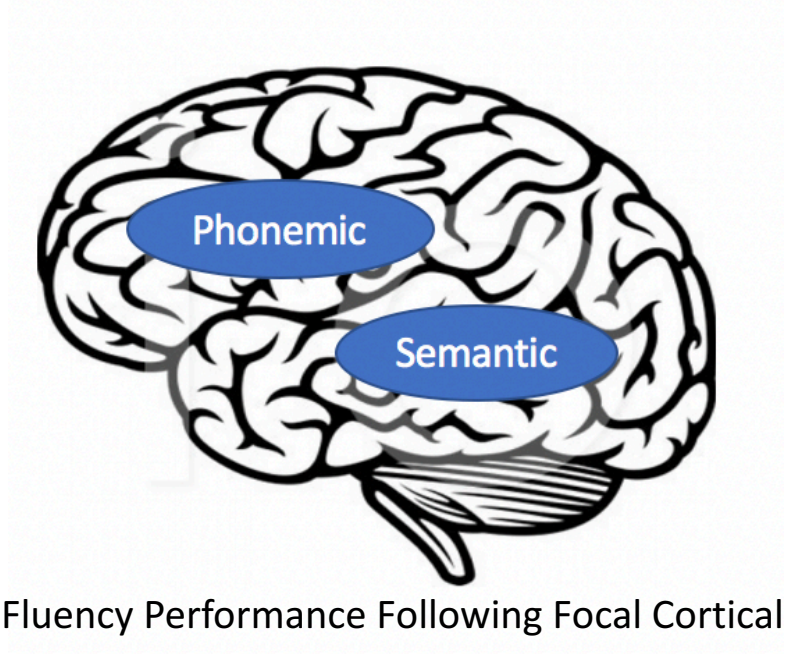
Semantic vs. Phoneme
Differences in neural substrates

Phonemic Disadvantage

- **Frontal lobe**: inhibitory control, self-directed planning
- **Phonemic < semantic** : Participants with focal frontal lesions

Semantic Disadvantage

- **Temporal lobe**: related to semantic memory
- **Semantic < Phonemic**: AD patients with temporal atrophy



Henry & Crawford (2004)
A Meta-Analytic Review of Verbal Fluency Performance Following Focal Cortical Lesions, Neuropsychology, 18(2), 284-295

Clustering vs. Switching

Clustering and Switching Analyses

- To quantify performance on the verbal fluency tasks, the total of number generated is the most commonly used metric.
- However, only the correct numbers of items retrieved **does not provide enough information on underlying cognitive mechanisms** involved in the verbal fluency tasks (Troyer, 2000).
- In order to better understand the behavioral process associated with the verbal fluency measures, researchers developed **additional methods to quantify performance using clustering and switching analyses** (Troyer, Moscovitch, & Winocur, 1997).

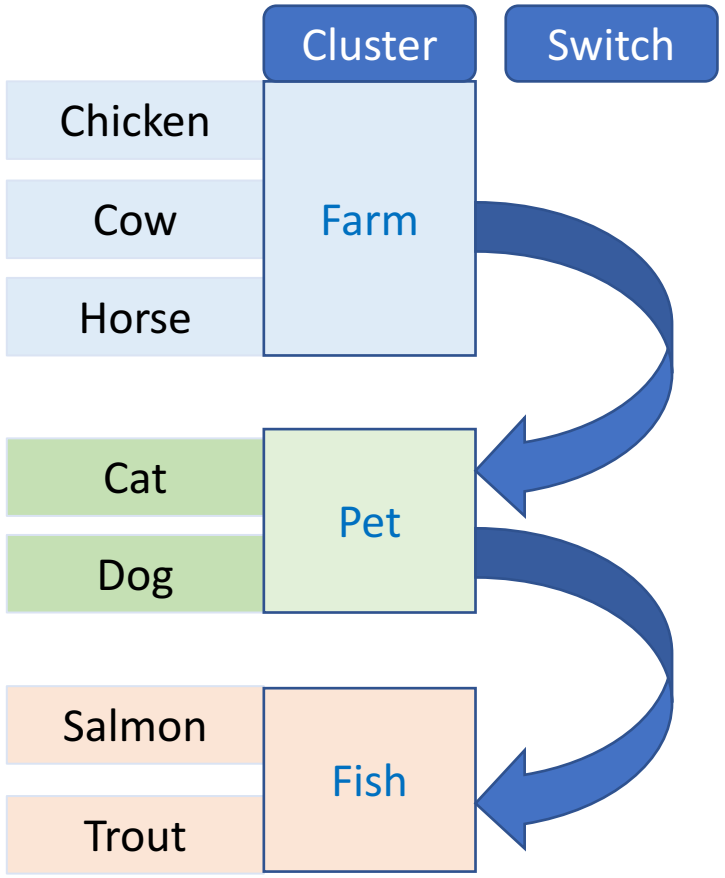
Clustering vs. Switching

Clustering

- **subcategorization** of the items that participants generated within a specific category
- clustering relies on **relatively automatic processing** by activating the semantic relatedness within a certain subcategory.

Switching

- Once items within a subcategory are exhausted, they **switch to another subcategory.** This shifting behavior was called as switching (Troyer et al., 1998)
- **more actively engage cognitive process** in order to switch the subcategory to another



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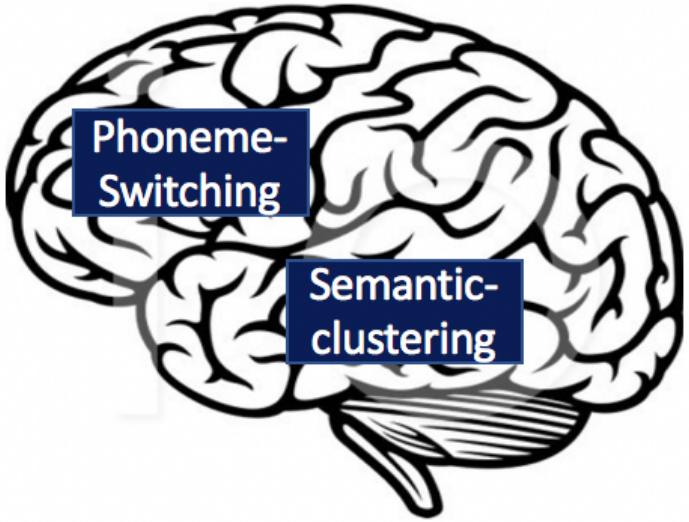
Clustering vs. Switching
Differences in neural substrates

Switching Disadvantage

- Participants with focal frontal lobe lesions
- Less switching than controls, but normal clustering performance

Clustering Disadvantage

- Patients with temporal lobe lesions
- Phonemic: not impaired in both switching and clustering
- Semantic: smaller cluster



Best predictors

- Phonemic switching
  - for frontal lesions
- Semantic clustering
  - for temporal lobe lesions

Troyer et al. (1998). Clustering and switching on verbal fluency: the effects of focal frontal- and temporal-lobe lesions. Neuropsychologia, 36 (6)

Purpose of the Study

The current study examined differences between phonemic and semantic fluency in AD by analyzing clustering and switching in age- and education-adjusted normative data (Troyer, 2000).

Furthermore, we examined how verbal fluency changes over time and explored what factors predict these changes.

Participants

Participants were 58 individuals with probable Alzheimer's Disease (prAD) from the dementia bank project, Pitt Corpus (Becker et al., 1994).

15 participants were followed up for a second visit (mean days between visits: 391.4, SD=47.2, Range= 337-486)

	1st Visit(n=58)	2nd Visit(n=15)
Gender (male:female)	16:42	3:12
Age(yrs)	72.2 (±8.8) (56-88)	1st Visit: 69.8 (±9.5) (56-88)
		2nd Visit: 70.5 (±9.5) (57-89)
MMSE	19.07 (±4.04) (10-27)	1st Visit: 21.5 (±3.0) (16-27)
		2nd Visit: 18.9 (±4.6) (11-27)
Education(yrs)	11.7 (±2.7) (6-20)	12.5 (±2.6) (8-18)

Materials

For semantic fluency, participants generated animal names (1st visit) and supermarket items (2nd visit) for 60 seconds.

For phonemic fluency, participants generated words beginning with f (1st visit) and s (2nd visit).

	Semantic Fluency	Phonemic Fluency
1st Visit	Animal names	Words beginning with F
2nd Visit	Supermarket items	Words beginning with S

Outcome measures

Dependent measures included

1) **total number of correct words**
2) **mean cluster size**
3) **number of switches**

Semantic Fluency Analyses: Cluster (Troyer, 2000)

- **Clusters on semantic fluency trials consist of successfully generated words belonging to the same subcategories.**

Animals

African animals: aardvark, antelope, buffalo, camel, chameleon, cheetah, chimpanzee, cobra, eland, elephant, gazelle, giraffe, gnu, gorilla, hippopotamus, hyena, impala, jackal, lemur, leopard, lion, manatee, mongoose, monkey, ostrich, panther, rhinoceros, tiger, wildebeest, warthog, zebra

Australian animals: emu, kangaroo, kiwi, opossum, platypus, Tasmanian devil, wallaby, wombat

Arctic/Far North animals: auk, caribou, musk ox, penguin, polar bear, reindeer, seal

Farm animals: chicken, cow, donkey, ferret, goat, horse, mule, pig, sheep, turkey

North America animals: badger, bear, beaver, bobcat, caribou, chipmunk, cougar, deer, elk, fox, moose, mountain lion, puma, rabbit, raccoon, skunk, squirrel, wolf

Water animals: alligator, auk, beaver, crocodile, dolphin, fish, frog, lobster, manatee, muskrat, newt, octopus, otter, oyster, penguin, platypus, salamander, sea lion, seal, shark, toad, turtle, whale

Beasts of burden: camel, donkey, horse, llama, ox

Animals used for their fur: beaver, chinchilla, fox, mink, rabbit

Pets: budgie, canary, cat, dog, gerbil, golden retriever, guinea pig, hamster, parrot, rabbit

Birds: budgie, condor, eagle, finch, kiwi, macaw, parrot, parakeet, pelican, penguin, robin, toucan, woodpecker

Bovine: bison, buffalo, cow, musk ox, yak

Canine: coyote, dog, fox, hyena, jackal, wolf

Deers: antelope, caribou, eland, elk, gazelle, gnu, impala, moose, reindeer, wildebeest

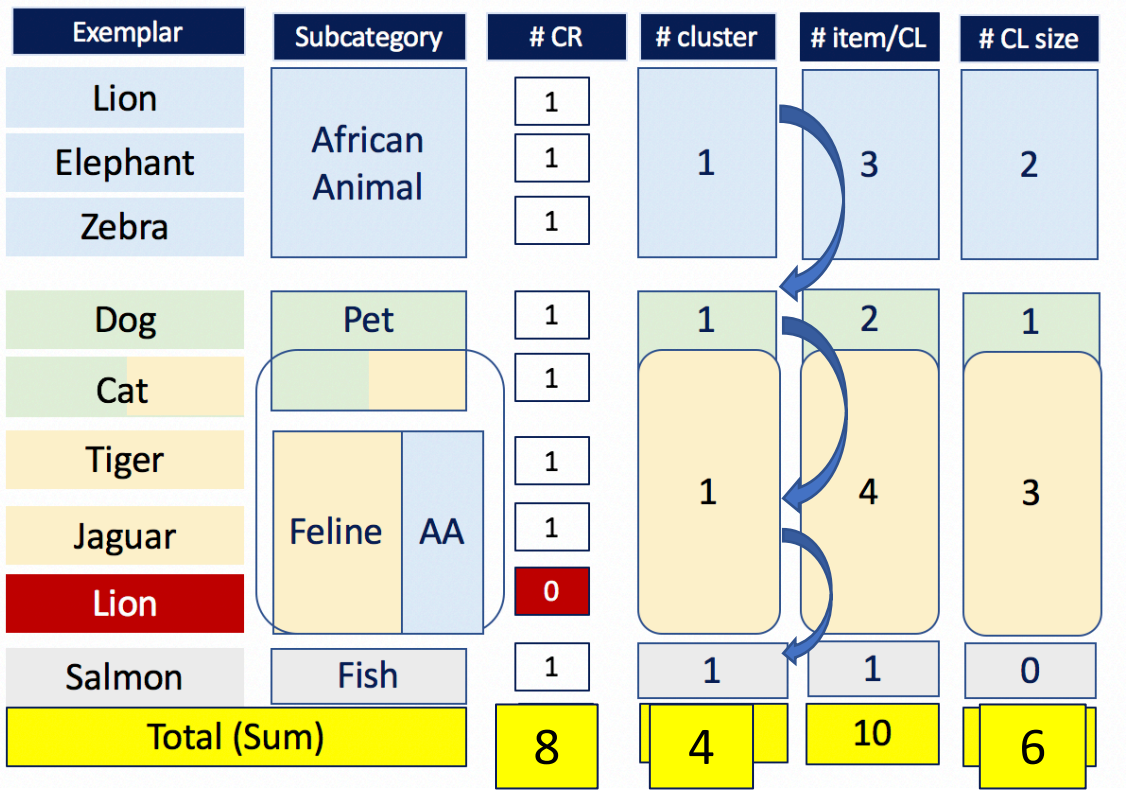
Feline: bobcat, cat, cheetah, cougar, jaguar, leopard, lion, lynx, mountain lion, ocelot, panther, puma, tiger

Semantic fluency analyses (Troyer, 2000)

Exemplar	Subcategory	# CR	# cluster	# item/CL	Cluster size
Lion	African Animal	1	1	3	2
Elephant		1			
Zebra		1			
Dog	Pet	1	1	2	1
Cat		1			
Tiger	Feline	1	1	4	3
Jaguar		1			
Lion		0			
Salmon	Fish	1	1	1	0
Total (Sum)		8	4	10	6

AA

Semantic fluency analyses (Troyer, 2000)



Dependent measures

Total number of correct words =

Mean cluster size = / = 1.5

Number of switches = 3

Phonemic fluency analyses (Troyer, 2000)

Phonemic Fluency Analyses: Cluster (Troyer, 2000)

- **Clusters on phonemic fluency trials consist of successfully generated words that shared any of the following phoneme characteristics**

First Letters	**Words beginning with same two letters**	**Arm, art**
Rhymes	**Words that rhyme**	**Sand, stand**
First and last sounds	**Words differing only by a vowel sound, regardless of the actual spelling**	**Sat, seat, soot, sight, sought**

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Phonemic fluency analyses (Troyer, 2000)

Exemplar	Subcategory	# CR	# cluster	# item/CL	# CL size
Flake	Words beginning with same two letters	1	1	2	1
Floss		1			
Fun	* Error! Words with different suffixes	1	1	2	1
Funny		0			
Father	Words that rhyme	1	1	2	1
Feather		1			
Ford	* Error! Proper names	0	1	1	0
Fill	Words with differing only by a vowel sound	1	1	2	1
Fall		1			
Total (Sum)		7	5	9	4

Normalization

The raw scores were normalized based on the age- and education-adjusted coefficients (Troyer, 2000)

The raw scores for # CR (semantic) = 35 (age=50, Edu=13)
Corrected score = 35 + 50*(0.23) + 13*(-0.74) = 36.8

Table 1. Corrections, Demographically Corrected Descriptive Data, and Percentiles for Fluency Scores.

	Phonemic			Semantic			Animals		
	Cluster	Switches	Total	Cluster	Switches	Total	Cluster	Switches	Total
Age (years)	–0.001	+0.05	+0.04	–0.001	+0.11	+0.23	–0.002	+0.05	+0.09
Education (years)	–0.015	–0.38	–1.06	–0.012	–0.25	–0.74	–0.023	–0.17	–0.51
Form (FAS)	+0.094	–2.67	–2.18	NA	NA	NA	NA	NA	NA
Mean	0.24	23.9	28.6	0.94	23.4	46.9	0.75	9.8	18.1
SD	0.23	8.2	11.1	0.47	4.4	7.9	0.57	2.7	4.6
1st percentile	–0.16	6.6	4.3	0.24	13.4	28.3	–0.24	3.9	8.3
5th percentile	–0.06	10.2	11.4	0.40	16.2	34.4	0.01	5.8	10.9
16th percentile	0.01	15.6	17.0	0.60	18.9	39.4	0.23	7.3	13.5
25th percentile	0.08	18.7	20.6	0.66	20.5	40.7	0.40	7.9	14.9
50th percentile	0.19	23.3	28.7	0.91	22.7	46.3	0.64	9.6	17.9
75th percentile	0.35	29.7	36.6	1.18	26.5	52.5	1.12	11.6	21.2
84th percentile	0.44	32.3	39.3	1.44	27.5	56.6	1.39	12.4	22.8
95th percentile	0.73	37.6	47.6	2.02	31.3	60.7	1.89	14.7	26.7
99th percentile	0.97	43.2	57.4	2.37	34.0	62.4	2.43	16.7	29.3

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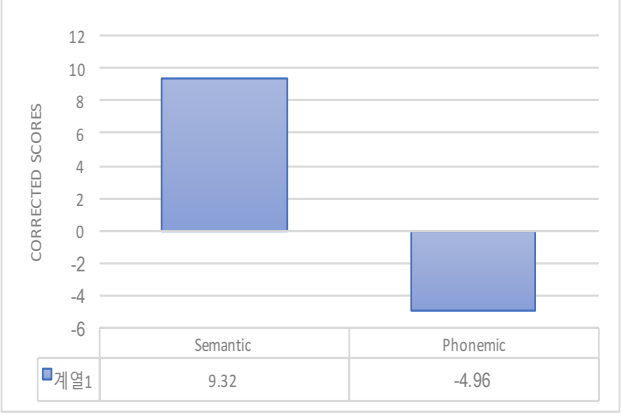
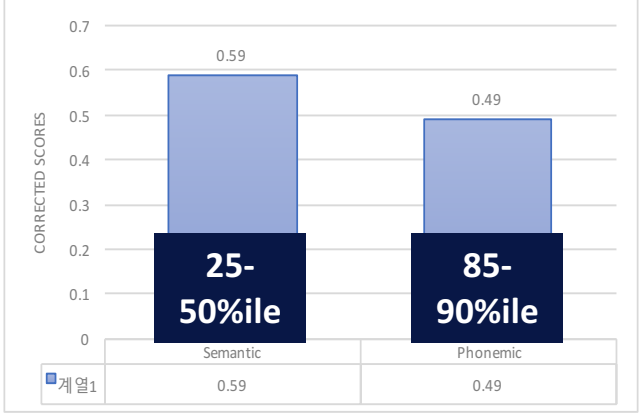
Results - Semantic vs. Phonemic comparisons (n=58)

One-way Repeated ANOVA between the semantic and phonemic fluency measures with corrected scores per each DV

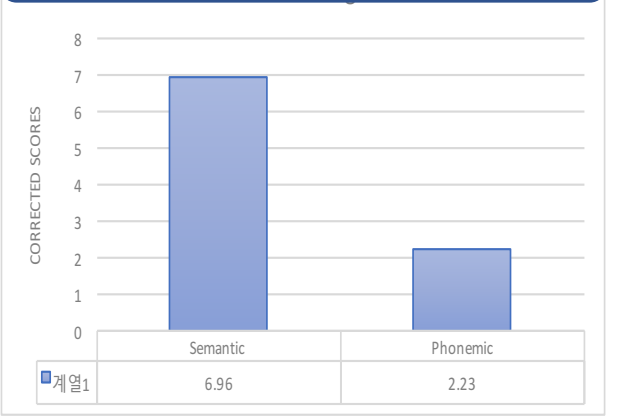
Correct Words



Mean Cluster Size



Switching



Less words in phonemic than semantic fluency task, $F\ (1,\ 57)=483.6$, $p<.001$, $\eta^2_p\ =\ .90$

Not Significant

Less switching in phonemic than semantic fluency task, $F\ (1,\ 57)=69.5$, $p<.001$, $\eta^2_p\ =.55$

Results (Sem. Vs. Phon. N=58)

Correlations & Stepwise Regression Analyses

		MMSE	Age	Education	Regression
#Correct Words	Semantic	0.45**	.096	-.264*	**MMSE & Education p=.001**
	Phonemic	0.05	.095	-.643**	
Mean Cluster Size	Semantic	0.02	-.027	-.205	NONE
	Phonemic	0.26*	.173	.101	
#Switch	Semantic	0.32*	.138	.017	**Education p=.044**
	Phonemic	0.13	.067	-.299*	

Results: Changes over time

Research Q2:

we examined how verbal fluency changes over time and explored what factors predict these changes.

	Mean	SD	One-way ANOVA
MMSE (1st visit)	21.47	3.04	**Sig.** **F(1, 14)=14.078, p=0.002**
MMSE (2nd visit)	18.93	4.62	

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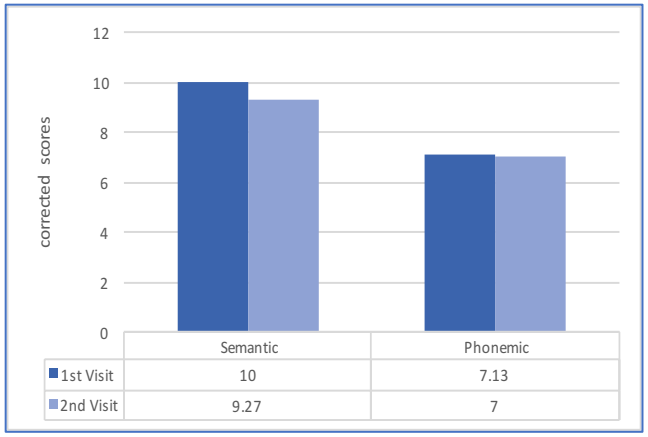
Results – Modality x Time-point

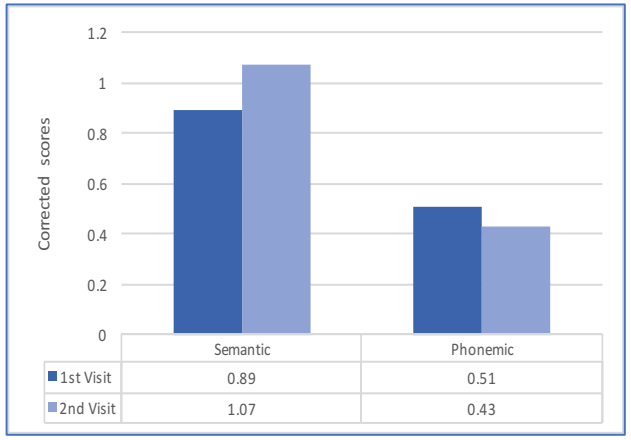
Two-way Repeated ANOVA between Modality (Sem. Vs. Phon.) and Time-point (1st vs. 2nd Visit)

Correct Words



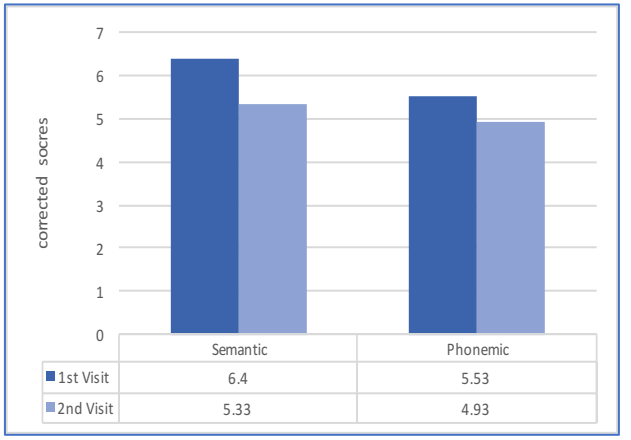
	Semantic	Phonemic
1st Visit	10	7.13
2nd Visit	9.27	7

Mean Cluster Size



	Semantic	Phonemic
1st Visit	0.89	0.51
2nd Visit	1.07	0.43

Switching



	Semantic	Phonemic
1st Visit	6.4	5.53
2nd Visit	5.33	4.93

Significant Main Effects for Modality : Phonemic < Semantic
for # correct words, $F(1, 14)=2611.0$, $p<.0001$
mean cluster size, $F(1, 14)=8.7$, $p<.05$
number of switches, $F(1, 14)=1063.0$, $p<.0001$

No other effects were significant.

Results: Predictor for change over time

To examine changes over time, **first to second visit difference scores** were calculated for each dependent measure.

DV = Difference scores between 1st and 2nd visit in #CR, Mean cluster size, and #Switch for semantic and phonemic fluency task

IVs= MMSE (1st visit), MMSE (2nd visit), Age, Education

MMSE (1st visit) scores significantly predicted discrepancy scores in number of switches for the phonemic fluency task, $F(1, 13)=7.57$, $p=.016$, $R^2=.368$.

No other results were significant.

Discussion

Semantic-Clustering Disadvantage

Participants with AD demonstrated **lower percentile scores in the semantic than phonemic clustering** behaviors, consistently with the previous studies that suggested AD patients with temporal atrophy presented semantic disadvantage.

Phonemic-Switching Disadvantage

Individuals with AD presented **less switching behaviors in phonemic** than semantic fluency task.

→ **Phonemic-switching** behaviors have been argued as being associated with the **frontal lobe functions**.

→ We speculate that AD participants may have **deficits in frontal lobe** function as well.

Discussion

Education as cognitive reserve

People with **lower education demonstrated greater discrepancy** between phonemic and semantic fluency tasks, given that the years of education was the significant predictor to account for the phonemic-semantic discrepancy.

Education has been reported as one of the critical factors associated with **cognitive reserve** in aging and AD literature.

Cognitive reserve is defined as the abilities to **optimize or maximize performance through differential recruitment of brain network**

Reduced cognitive reserve seems to be responsible for greater discrepancy between the modalities.

Discussion

MMSE (1st Visit) & changes over time in phonemic-switching

MMSE from the 1st visit predicted performance on changes over time in phonemic-switching behaviors, which is the most frontal-lobe demanding condition.

→ It suggested that **cognitive reserve from the time of enrollment may be sensitive to detect changes over time especially in the most frontal-lobe demanding behaviors** .

Clinical Implications:
Phoneme-Switching Task: may serve as an index of cognitive reserve, which is important for compensating progressive deficits

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이화여자대학교
EWHA WOMANS UNIVERSITY