

# The Influence of Associative Interference on Cued Recall of Word Pairs

**Mayank Rehani (rehani@ualberta.ca)**

Department of Psychology, University of Alberta  
Edmonton, AB T6G 2E9 Canada

**Jeremy. B. Caplan, Ph.D. (jcaplan@ualberta.ca)**

Department of Psychology & Centre for Neuroscience, University of Alberta  
Edmonton, AB T6G 2E9 Canada

## Abstract

Recent evidence suggests that paired associates learning (PAL) relies on the same cognitive processes as serial list learning (SL). However, Murdock and Franklin (1984) suggested that PAL and SL represent distinct modes of learning. We asked whether a robust property of PAL, holistic-like learning (observed as a high correlation between forward and backward probes of a pair) sets pairs apart from lists. Using the double-function paradigm, a PAL paradigm which includes a substantial level of associative interference, we tested whether interference can influence the apparent holistic character of pairs in the same way as has been argued for lists. Our results suggest that, far from being distinct forms of learning, interference has a comparable effect on PAL as on SL, lending further support to the unified framework.

**Keywords:** Paired associate learning; Associative symmetry; Double function lists; Interference; Verbal memory.

## Introduction

Many activities in daily life require us to make association between items. There are two competing theories as to the nature of the learned associations in paired associates learning (PAL). According to the Independent Associations Hypothesis (Wolford, 1971), when participants are presented with a pair (A-B), they learn two distinct associations, first from A to B and then from B to A. Therefore, learning of a pair according to this model involves two presumably independent learning steps. This hypothesis leads to the prediction that forward (A-?) and backward (?-B) probes should be independent since they tap statistically independent learning events.

The competing theory is the Associative Symmetry Hypothesis (ASH) (Asch & Ebenholtz, 1962). According to this theory, when participants are presented with items of a pair (A-B), the items lose their individual identity and become a holistic unit. In this view, learning the association between the two items of a pair is a one-step process. One can look at AB as a holistic unit or, in a less theoretically loaded view, as a single bidirectional association. In either case the forward (A-?) and backward (?-B) probes have to

be correlated because they test the same underlying learning process.

Asch and Ebenholtz (1962) suggested that the ASH predicts symmetric mean performance in forward and backward directions. This is a robust finding and has been replicated in various studies (see Kahana, 2002 for a review). But this may not be a direct test of Associative Symmetry. For instance, consider a participant that was presented with the pair RATION-COUSIN and responded correctly on the forward probe (RATION-?) but incorrectly on the backward probe (?-COUSIN). The same participant when presented with another pair REVOLT-VIRTUE, responded incorrectly on the forward probe (REVOLT-?) but correctly on the backward probe (?-VIRTUE). For this participant, mean accuracy in the forward and backward direction equal, however learning the association is clearly not holistic. For this reason, Kahana (2002) suggested that associative symmetry requires specifically that there be evidence for a high *correlation* between forward and backward performance of a single pair over successive testing (i.e. testing the same pair in two tests, whether in same or different directions). This high correlation has been observed in verbal PAL by Rizzuto and Kahana (2000), Caplan (2004, 2005) and in object-location pairs by Sommer, Rose and Buchel (2007).

An important question in understanding associations is whether memory for ordered lists and memory for pairs could be modeled using the same cognitive processes. Some modelers, including Murdock and Franklin (1984), have suggested that PAL and SL represent completely distinct modes of learning and therefore need to be explained using separate models. Caplan (2004, 2005) and Caplan, Glaholt, and McIntosh (2006) demonstrated that it is possible to model PAL and SL together and nonetheless obtain empirically observable dissociations in performance measures. Critically, this explanation relied on a careful analysis of the sources of interference in cued recall probes of a list. To understand this, consider the following cued

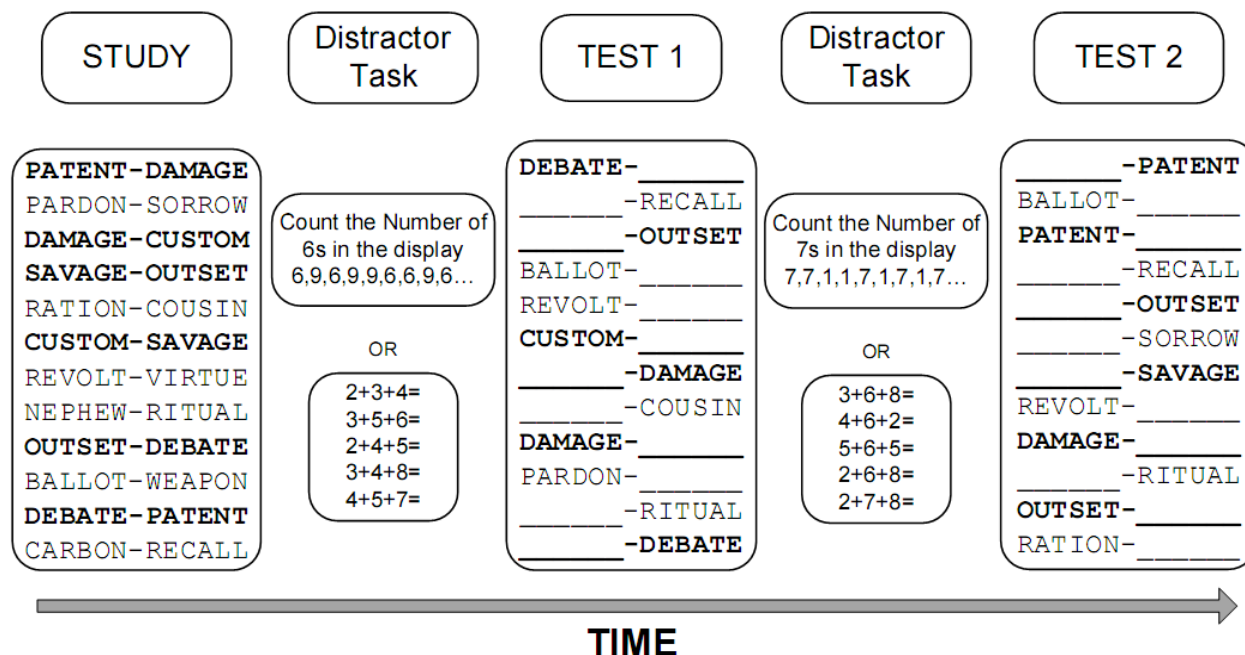


Figure 1. A single round of the task. In the study/test phases, the order of presentation of Single Function and Double Function(bolded) pairs/probes were randomised. In the test phases the order of forward and backward probes were also randomised.

recall examples. Suppose a participant is presented with the following list of pairs, A-B, C-D, E-F. The A-B association could be tested in either the forward direction (A-?) or the backward direction (?-B). Performance on both of these probes depends solely on the strength of the A-B association. Since there is little interference from other items in the list, the correlation between the forward and backward association will be very high, as forward and backward probes measure the strength of the unitary association between A and B. However, if the participant is presented with the following triples (short serial lists), A-B-C, D-E-F, G-H-I, performance on the forward probe of A-B depends on the strength of the A-B association but performance on backward probe (?-B) depends upon the strength of the A-B association and the interference that the B item receives from its association with C. Therefore, one observes a reduced correlation due to interference that depends on probe direction (Caplan, 2004, 2005; and Caplan et al. 2006).

We asked whether this mechanism would apply to a PAL paradigm that has high levels of interference, namely, the double function paradigm. As Murdock and Franklin (1984) argued, pairs may represent a special mode of learning; from this view, one might predict that the pair is learned as a strong enough unit that it is unbreakable (and therefore, the forward-backward correlation would not reduce) even in

the presence of interference. Instead, we propose that, a set of pairs can exhibit a reduced correlation similar in character to that observed in lists, simply by the presence of interference. Thus, if interference reduces the correlation in an interference-heavy PAL paradigm, this would lend further support to the notion that PAL and SL can be modeled within the same theoretical framework. Consider the following pure paired associate task with interference (aka Double Function lists), I-J, J-K, K-L, L-I (Primoff, 1938). In this situation, all probes are subject to significant interference from other associations that depends on the probe direction. Therefore, we should also observe a reduced correlation due to interference depending on probe direction. However, if memory for pairs operates differently than memory for serial lists, interference may not disrupt the high forward-backward correlation.

## Methods

### Materials

Study sets were constructed using Toronto Word Pool and MRC Psycholinguistic Database. All stimuli were nouns that were two syllables in length and composed of six letters. Other properties, such as, Kucera-Francis frequency, imageability and concreteness were maintained in an intermediate range. As experiment 1 was conducted in a

Experiment	Setting	Number of Subjects	Mode of Response	Number of Rounds	Number of pairs per round	Number of SF/DF pairs	Presentation rate of stimuli
1	In-Class	79	Written	3	8	4/4	4 seconds
2	Individual	70	Typed	7	12	6/6	4 seconds
3	Individual	55	Typed	7	12	6/6	2 seconds

*Table 1.* Three experiments with slight modifications were conducted with this paradigm. In experiment 1 each of the distractor task was 20 seconds long and in Experiments 2 and 3 it was 5 seconds per question. In all tasks, subjects were given 10 seconds per probe to respond.

classroom setting, the same study set was used for all subjects. For experiments 2 and 3, words were drawn at random. In all three experiments equal numbers of pairs in Single Function (SF) and Double Function (DF) were presented. Pairs in an SF list do not share items with other pairs in the list (i.e. A-B, C-D, E-F, G-H). Pairs in a DF list share items with other pairs in the list (i.e. I-J, J-K, K-L, L-I).

### Participants

All participants were undergraduate university students. Subjects in experiments 2 and 3 participated for partial fulfillment of course requirements of introductory psychology courses.

### Procedure

Table 1 compares the design of the three experiments. Participants in all three experiments participated in a practice round (excluded from analyses) followed by experimental sets (Figure 1). Each round in the task consisted of the several phases: study phase, a distractor task, a cued recall (Test 1), another distractor task, and finally another cued recall (Test 2).

All participants were presented with SF or DF pairs in a randomized order followed by a distractor task that involved simple arithmetic questions. Distractor tasks were as follows. In experiment 1, participants had to count the total number of a given digit in an 8-by-6 matrix made up of two digits. They were given 20 seconds to count and record their responses. In experiments 2 and 3, participants had 5 addition questions involving addition of 3 digits (from 2 to 8). They were given 5 seconds to type their responses.

Cued recall consisted of a probe word and a blank line, either to the left or right of the word. In this way the participants were tested in either forward or backward direction for the pairs just studied. In all three experiments,

participants were given 10 seconds to recall and record their responses.

Cued recall was followed by a second distractor task. Participants were then successively tested for the pairs just studied in the same or different direction as the first test (Table 2). Participants were probed in the forward direction in both tests (Forward-Forward), in the backward direction in both tests (Backward-Backward), forward in the first test but backward in the second (Forward-Backward) or vice-versa (Backward-Forward).

### Data Analysis

We used MATLAB 7.1 for Windows for all analyses except ANOVAs which were carried out using SPSS 15.0.

**Mean Accuracy** The ANOVA was performed with the Greenhouse-Geisser correction where appropriate. Effects are considered significant based on an alpha level of 0.05 and post-hoc pair-wise comparisons are always Bonferroni-corrected. Only effects reaching significance are reported.

**Correlation for accuracy on successive tests** We used Yule's Q as our measure of correlation between Test 1 and Test 2 probes. Yule's Q is appropriate for dichotomous data. 'Same' estimates the correlation due to test-retest reliability alone and will be the highest correlation when successive testing is done in the same direction (Forward-Forward and Backward-Backward). 'Different' is based on the correlation between forward and backward directions, when test 1 and test 2 were in different directions (Forward-Backward and Backward-Forward). Therefore is our measure of interest. The 'Control' is the lowest possible expected correlation and is designed to account for the correlation between unrelated pairs within the same round, one pair from test 1 and a different pair from test 2 (bootstrapping), in order to control for subject, and round variability. Due to the nature of these measures, 'Same' and 'Control' demonstrate the effective range of the 'Different' correlation. Yule's Q was evaluated using the log-odds ratio

transform (Bishop, Fienberg, and Holland, 1975; and Hayman and Tulving, 1989).

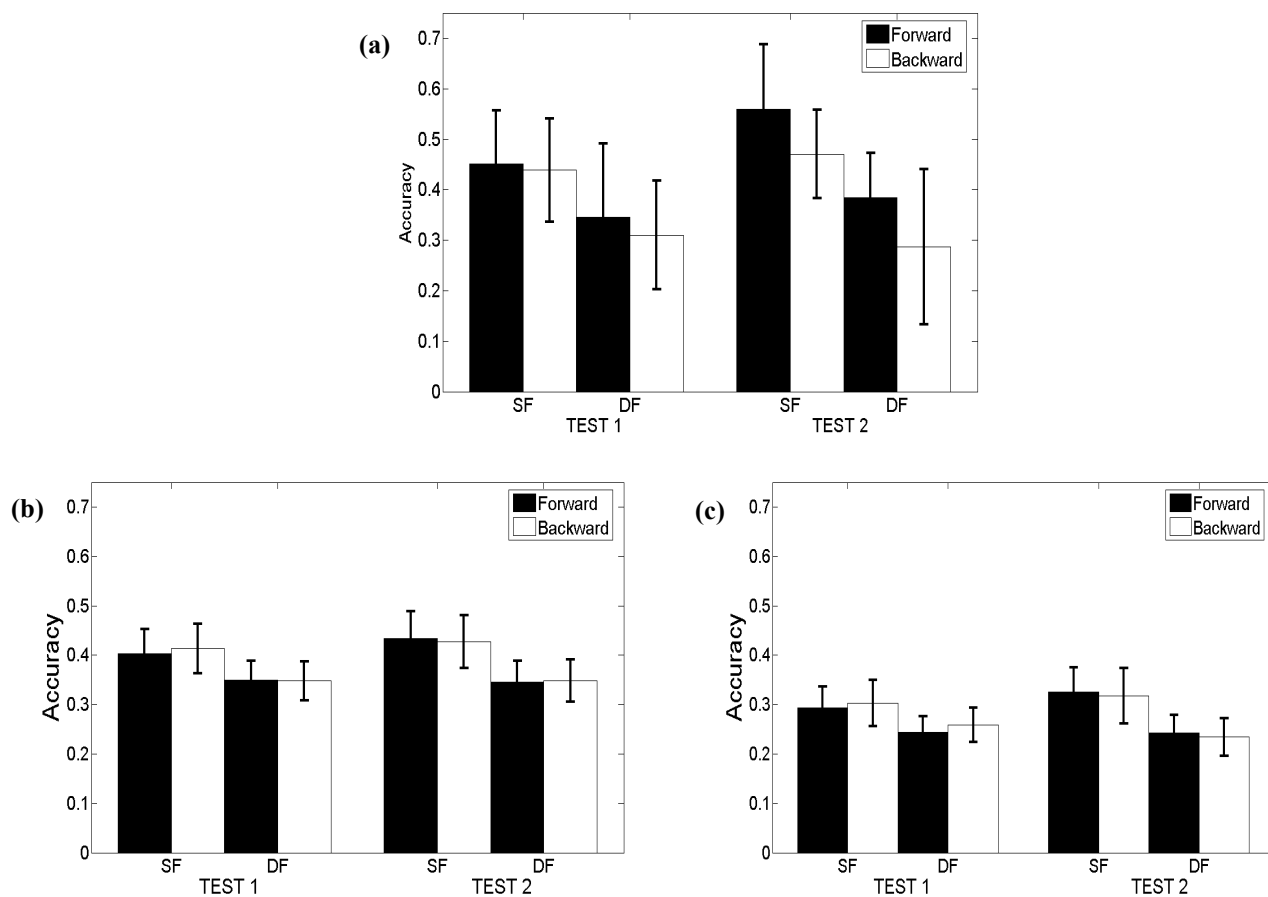
Condition	Test 1 Probe	Test 2 Probe	Nature of Testing
Forward-Forward	REVOLT-?	REVOLT-?	Same
Backward-Backward	?-VIRTUE	?-VIRTUE	Same
Forward-Backward	REVOLT-?	?-VIRTUE	Different
Backward-Forward	?-VIRTUE	REVOLT-?	Different

*Table 2.* Conditions of successive testing. Participants can be tested in 4 possible conditions over two tests. Two of the conditions comprise of the same probe in both tests and two comprise of different probes in both tests.

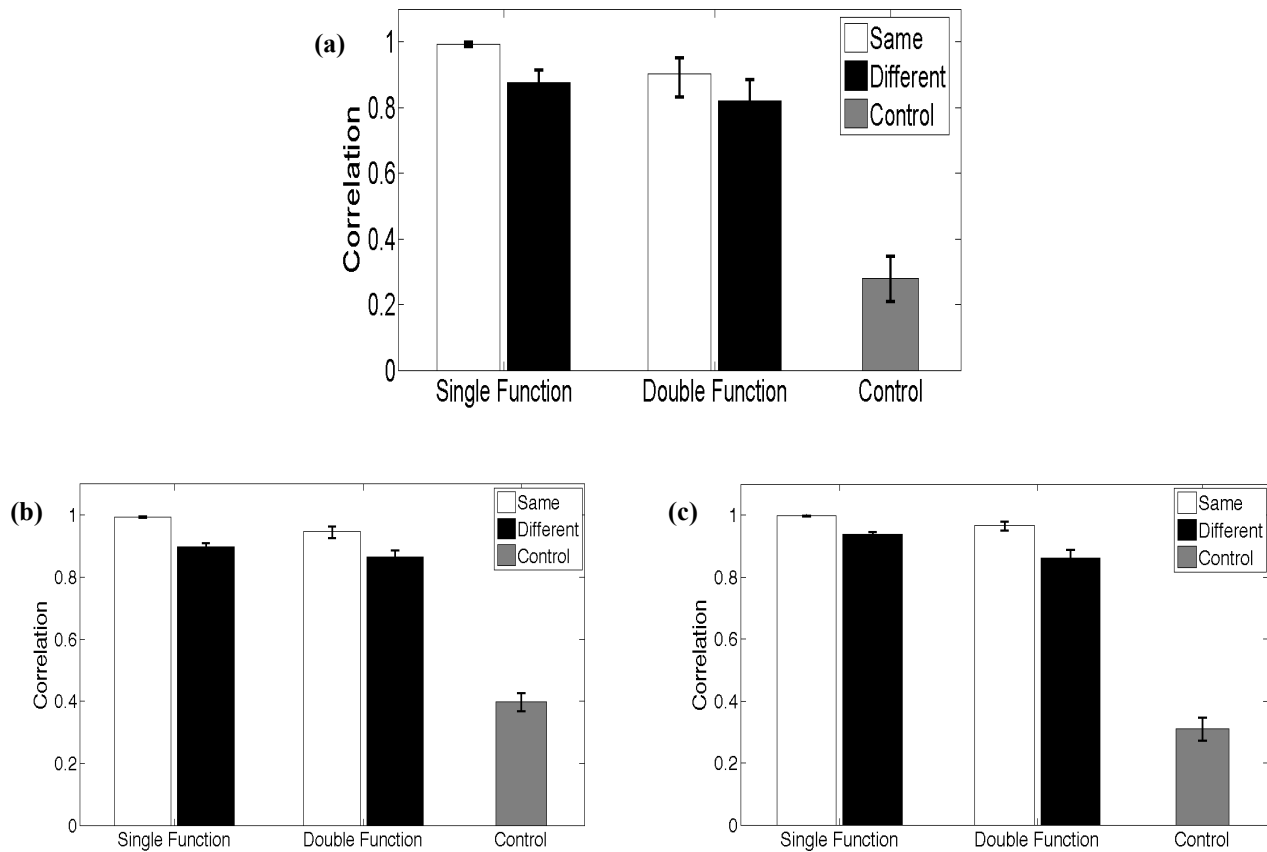
## Results

### Mean Accuracy

We performed a 3 factor Repeated Measures ANOVA on TEST[2] X FUNCTION[2] X DIRECTION[2]. As illustrated by Figure 2(a), there is a significant main effect of FUNCTION [ $F(1,78)=63.72$ ,  $MSe=0.33$ ,  $p<0.0001$ ], TEST [ $F(1,78)=17.11$ ,  $MSe=0.082$ ,  $p<0.0001$ ] and DIRECTION [ $F(1,78)=13.78$ ,  $MSe=0.40$ ,  $p<0.0001$ ] and an interaction between TEST X FUNCTION [ $F(1,78)=12.69$ ,  $MSe=0.072$ ,  $p<0.001$ ] in experiment 1. Post hoc pair-wise comparisons revealed that performance on SF probes were significantly different than DF probes [ $p<0.05$ ] and that performance on test 2 was significantly different from test 1 [ $p<0.05$ ]. To study interactions, simple effects were calculated and revealed that in both tests 1 and 2, SF probes were significantly different from DF probes.



*Figure 2.* Mean accuracy in experiment 1 (a), experiment 2 (b) and experiment 3 (c) for Single Function (SF) and Double Function (DF) probes in Forward and Backward directions. Error bars are 95% Confidence Intervals.



**Figure 3.** Correlation for accuracy on successive tests for experiment 1 (a), experiment 2 (b) and experiment 3 (c). For a description of ‘Same’, ‘Different’ and ‘Control’ refer to Table 2. Error bars are 95% Confidence Intervals.

In experiment 2, (Figure 2b), the main effect of **FUNCTION** does prove to be significant [ $F(1,69)=24.00$ ,  $MSe=0.030$ ,  $p<0.0001$ ], as well as the interaction between **TEST X FUNCTION** [ $F(1,69)=7.759$ ,  $MSe=0.003$ ,  $p<0.01$ ]. Post hoc pair-wise comparisons reveal that SF probes were significantly different from DF probes. Simple effects revealed that in both tests 1 and 2, SF pairs were significantly better than DF pairs. This pattern was also seen in experiment 3 (Figure 2c).

### Correlation for accuracy on successive tests

We calculated the correlation between accuracy on test 1 and on test 2 of the same pair. As illustrated in Figure 3, the correlation of ‘Different’ DF probes was lower than that of the ‘Different’ SF probes due to interference in DF pairs from other items in the list. Pair-wise comparisons revealed that the difference between ‘Same’ and ‘Different’ within SF and DF probes were significant and that the difference between ‘Same’ and ‘Different’ between SF and DF was significant in all three experiments [ $p<0.01$ ]. All Q values

were significantly different from the control Qs in all three experiments [ $p<0.01$ ].

## Discussion

### Mean Accuracy

SF probes are significantly better recalled than DF probes (Figure 2). This finding has been replicated in many studies since Primoff (1938). The difference between tests 1 and test 2 is not significant in any of the experiments, which suggests that there was not substantial output encoding or forgetting between successive tests. Effects of direction are also not significant. Performance on forward and backward probes are similar, therefore, neither of the directions hold an advantage over the other.

### Correlation for accuracy on successive tests

All the “Different” correlations are quite high, replicating prior findings that lend support to the associative symmetry hypothesis. As predicted the correlation of ‘Different’ DF probes was lower than that of the ‘Different’ SF probes. This indicates that DF probes faced interference from other

items in the study set which may be lowering the correlation. However, a finding we had not anticipated is that the correlation of the 'Same' DF probes is also significantly lower than the 'Same' SF pairs. This suggests a probabilistic response selection rule (not winner-take-all) operating at test.

Therefore, paired associates can appear non-holistic due to interference from different sources, dependent on probe directions. This reduced correlation in a PAL paradigm which suggests that interference may operate in PAL in a qualitatively similar way as it does in SL. This further buttresses prior evidence (Caplan 2004, 2005; and Caplan et al. 2006) suggesting that PAL and SL should be explained in a single, more parsimonious model rather than two separate models.

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### References

- Asch, S. E., & Ebenholtz, S. M. (1962). The principle of Associative symmetry. *Proceedings of the American Philosophical Society*, 106(2), 135-163.
- Bishop, Y., Fienberg, S. E., & Holland, P. W. (1975). Discrete multivariate analysis: *Theory and practice*. Cambridge, MA: MIT Press.
- Caplan, J. B. (2004). Unifying models of paired associates and serial learning: insights from simulating a chaining model. *NeuroComputing*, 58-60, 739-743.
- Caplan, J. B. (2005). Associative isolation: unifying associative and order paradigms. *Journal of Mathematical Psychology*, 49(5), 383-402.
- Caplan, J. B., Glaholt, M., & McIntosh, A. R. (2006). Linking associative and list memory: pairs versus triples. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32(6), 1244-1265.
- Friendly, M., Franklin, P. E., Hoffman, D., & Rubin, D. C. (1982). Norms for the Toronto Word Pool. *Behavior Research Methods and Instrumentation*, 14, 375-399.
- Hayman, C. A. G., & Tulving, E. (1989). Contingent dissociation between recognition and fragment completion: the method of triangulation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15(2), 228-240.
- Kahana, M. J. (2002). Associative symmetry and memory theory. *Memory & Cognition*, 30(6), 823-840.
- Murdock, B. B. and Franklin P. E., Associative and serial-order information: Different modes of operation? *Memory & Cognition*, 12 (1984) (3), pp. 243-249.
- Primoff, E. (1938), Backward and forward associations as an organizing act in serial and in paired-associate learning, *Journal of Psychology* 5, pp. 375-395.
- Rizzuto, D. S. and Kahana M. J. (2000), Associative symmetry vs. independent associations, *NeuroComputing* 32-33, 973-978.
- Sommer, T., Rose, M., & Buchel, C. (2007). Associative Symmetry versus independent associations in the memory for object location associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33(1), 90-106.
- Wilson, M. D. (1988) The MRC Psycholinguistic Database: Machine Readable Dictionary, Version 2. *Behavioural Research Methods, Instruments and Computers*, 20(1), 6-11.
- Wolford, G. (1971). Function of distinct associations for paired-associate performance. *Psychological Review*, 78(4), 303-313.