Oppositional Processes in Divergent Thinking

by

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ABSTRACT

In this study, the oppositional processes theory was proposed to suggest that reliance on semantic and episodic memory systems hinder originality during idea generation for divergent thinking tasks that are generally used to assess creative potential. In order to investigate the proposed oppositional processes theory, three experiments that manipulated the memory accessibility in participants during the alternative uses tasks were conducted. Experiment 1 directly instructed participants to either generate usages based on memory or not from memory; Experiment 2 provided participants with object cues that were either very common or very rare in daily life (i.e., bottle vs. canteen); Experiment 3 replicated the same manipulation from Experiment 2 with much longer generation time (10 minutes in Experiment 2 vs. 30 minutes in Experiment 3). The oppositional processes theory predicted that participants who had less access to direct and unaltered usages (i.e., told to not use memory, were given rare cues, or were outputting items later in the generation period) during the task would be more creative. Results generally supported the predictions in Experiments 1 and 2 where participants from conditions which limited their access to memory generated more novel usages that were considered more creative by independent coders. Such effects were less prominent in Experiment 3 with extended generation time but the trends remained the same.

ACKNOWLEDGMENTS

I am very grateful to my advisor Dr. Gene Brewer for being an amazingly inspirational and supportive mentor, whose guidance made this entire dissertation process extremely educational and enjoyable for me. I also want to thank my committee members: Dr. Arthur Glenberg, Dr. Stephen Goldinger and Dr. Donald Homa, Memory and Attention Control Lab members: Dr. Chris Blais, Dr. Hunter Ball, Kimberly Wingert, Derek Ellis, Margarida Pitães and Blake Elliott who provided vital intellectual input and support through this entire process. Many thanks to the brilliant undergraduate research assistants who helped me collect and code the data: Kenzie Harrison, Courtney McNeill, Alexandra Inmon, Katrina Dickson, Allison Coulson, Stephan Gallegos and Brian Clarke. And finally, I want to thank my parents and grandparents for their unconditional love, without which I can never have the strength to do all this.

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INTRODUCTION

Creativity and Divergent Thinking Tasks

Creativity is a topic that has captured people's fascination for much of known human history. Creativity is an important quality of the human experience because it involves how people develop original ideas that have not previously existed. Originality is therefore a key component for judging people's creative behavior. Wilson, Guilford and Christensen (1953) defined originality with three separate aspects: uncommonness, remoteness and cleverness. Uncommonness refers to the statistical infrequency of the ideas within a population; remoteness refers to a greater distance in making associations to generate the ideas; and cleverness often refers the ideas being striking, insightful or smart at a glance. Based on these definitions, to be truly creative people must generate ideas that surpass both what they know themselves and what is known in general by the population.

A relatively understudied theoretical question is how people can suppress what they know from their personal past, and what is known by the general population, to generate novel ideas. Our proposed theory is that in order to be truly creative, people have to abandon a certain amount of reliance on their episodic and semantic memory systems during creative generation experiences. Specifically, they should suppress the more common and readily accessible information emerging from their memory to search for and combine remote and uncommon ideas. Our primary goal is to develop a theory of oppositional processes that support creative idea generation and develop a series of experimental studies that test predictions from this theory. Furthermore, we examine whether creativity can be improved in idea generation if we limit access to more common and accessible information from people's memory.

One prominent way of studying creative potential is through divergent thinking tasks (Runco & Acar, 2012). Divergent thinking tasks are different from more common convergent thinking tasks where only one correct solution exists for each particular problem. In contrast, divergent thinking tasks allow people to come up with multiple original responses that are not predefined. Guilford (1950) first noted that convergent thinking tasks may not pick up original creations from individuals; he and his colleagues later (Wilson et al., 1953) developed divergent thinking tasks such as the alternative uses task to capture originality. The alternative uses task gives participants common objects and their common uses, then asks participants to think of unusual uses for these objects. In earlier versions of this task, participants generate a finite amount of alternative uses for each object and later versions instruct participants to generate as many uses as they can in a set amount of time (Christensen, Guilford & Wilson, 1957). Through the alternative uses task both the quantity and quality of creative production can be assessed.

With divergent thinking tasks such as the alternative uses task, one important consideration is how to score the responses so they truly reflect an individual's originality. A traditional method to score originality was entirely based on statistical frequency of each response in the population of responses across participants. So called "uniqueness scoring" essentially assigns scores of "1" to responses that are not repeated in all responses being collected, and "0" to those which are repeated. Each individual receives a score on how many unique responses they can generate during an alternative uses task (Silvia et al. 2008). One limitation of uniqueness scoring is that it is confounded with the total number of responses generated by the sample. That is, uniqueness scores tend to be higher when the sample size is smaller because each response is less likely to be repeated. Another limitation of uniqueness scores is that they only address the aspect of uncommonness, but not remoteness and cleverness. Silvia et al. (2008) suggested that uniqueness scoring should be replaced with subjective scoring methods where multiple coders rate the creativity of the output for each participant. This method also takes into consideration all three aspects of originality from Wilson et al. (1953) by providing training and a rubric to the independent coders. The subjective scoring method assigns a creativity score after reviewing each response on uncommonness, remoteness and cleverness; then each participant has an average score computed that reflects how creative their responses were in the divergent thinking task. Silvia et al. (2008) found that this average score does not correlate with total amount of responses outputted like the uniqueness scores. In another assessment of creativity, top subjective scores from each individual also correlated with personality traits such as openness to experience, which has been linked with creativity in past research (McCrae, 1987). In summary, divergent thinking tasks combined with subjective scoring provide reliable measures to assess originality that may reflect creative potential at an individual differences level.

Memory Reliance and the Serial Order Effect

The oppositional processes theory can be studied by examining the creativity level of usages generated during the alternative uses task. One particular finding labeled the "serial order effect" (Beaty & Silvia, 2012; Christensen et al., 1957; Ward, 1969) connects creative usage generation to memory retrieval processes. The serial order effect in the alternative uses task reflects the fact that usages generated later during the generation process tend to be more creative than ideas generated earlier during a task. Christensen et al. (1957) first reported this effect when they compared the alternative uses task to various semantic fluency tasks. Structurally, the alternative uses task and semantic fluency tasks are similar because they both involve a cue and generating responses based on the cue. In fluency tasks, participants are usually given a certain type of cue (e.g., ungulate mammals) and try to come up with as many words associated with that cue as possible in a given amount of time. Fluency tasks tap into the structural integrity of long-term memory and also display a similar serial order effect in that high frequency items are recalled earlier in sequence compared to low frequency items (Bousfield & Barclay, 1950). The serial order effect in fluency tasks indicates that recall position is influenced by accessibility of information in memory that is associated to the cue. Research by Gilhooly, Fioratou, Anthony and Wynn (2007) provided evidence that a similar mechanism may be at work for the alternative uses task as well. In their study, participants self-reported their strategy use during the alternative uses task. Participants were more likely to generate usages based on long-term memory at earlier stages of the tasks, and novel usages (usages associated with the object participants claim they did not think of prior to the experiment) were generated in later stages of the tasks. Not too surprisingly, novel usages tend to be judged as more creative by raters than ideas retrieved from memory (Benedek et al., 2014; Gilhooly et al., 2007). Therefore, as found in the serial order effect, creativity level goes up as time goes on during the alternative uses task because more novel usages are generated later in time during the usage generation process.

The similarity between fluency tasks and the alternative uses task provides the foundation for the oppositional processes theory on creative idea generation. Oppositional processes theory is based on these empirical results and aims to further define the dynamic relation between memory retrieval and novel idea generation in divergent thinking tasks such as the alternative uses tasks. The oppositional processes theory suggests that cue-usage accessibility in divergent thinking tasks hinders novel idea generation. This dynamic occurs because people engaging in divergent thinking are less likely to be original when generating novel ideas if old ideas in memory interfere with this process. During a divergent thinking task, such as the alternative uses task, accessible uses from both semantic and episodic memory will dominate at the beginning of the generation phase and gradually lessen when their options in memory starts to deplete. The oppositional processes theory can explain the serial order effect observed in divergent thinking tasks (Christensen et al., 1957; Beaty & Silvia, 2012) because truly original idea generation are hindered at the beginning, when less original memory based ideas are still available. Logically, when people are engaged in divergent thinking during the alternative uses task, any unaltered direct usage associated with the object cue in memory must inherently be less creative.

Generation Pattern in Divergent Thinking Tasks

One function that may be useful for differentiating memory retrieval and novel idea generation processes is the cumulative recall / production function over time. Specifically, cumulative recall curves for fluency tasks display a curvilinear relation between number of items recalled and time (Bousfield & Sedgewick, 1944; Wixted & Rohrer, 1994); while the number of ideas generated in divergent thinking tasks should have a more linear relation with time if the generated ideas are truly novel (Christensen et al., 1957). In fluency tasks, because more frequent and common items are recalled before less frequent items, items are recalled more rapidly at the start of the task and slows down as time progresses. Bousfield and Sedgewick (1944) proposed the following exponential equation to study the relation between number of items recalled and time:

$$F(\mathrm{t}) = N(1 - e^{-\lambda \mathrm{t}}) \quad (1)$$

In Equation 1, F(t) is the number of items accumulated over time t, N is the estimated asymptote (maximum number) of items one can recall if given unlimited time, and λ is the rate in which the cumulative recall curve approaches the asymptote N. Wixted and Rohrer (1994) reviewed studies that reported cumulative recall over time and concluded that the negative acceleration of recall over time was well captured by the exponential function. The rate to approach asymptote (λ) was negatively related to the estimated asymptote (N); λ also reflected the breadth of search during memory retrieval (smaller λ indicates a greater search set size; Wixted & Rohrer, 1994).

It should not be surprising that the relation between idea generation in divergent thinking and time can produce very different N and λ estimates. For N, the main difference between divergent thinking and fluency tasks is that there is no theoretical upper limit for the number of original ideas one can generate, compared to number of items defined by a cue (i.e., ungulate mammals). Therefore, N estimates for divergent thinking tasks can be much higher than N estimates from fluency tasks. For λ, estimates should be much lower for divergent thinking tasks compared with fluency tasks because the estimated N is much larger for divergent thinking and it will slow down the rate to approach asymptote. This result would indicate that the breadth of search should be higher for divergent thinking tasks. Oppositional processes theory can make this prediction as well because it assumes participants in divergent thinking tasks exhaust memory options specifically tied to the cue first before they can be truly creative and generate novel ideas; therefore they may have to search through a wide range of ideas and suppress them in order to generate creative usages. Another argument is that participants have to make more remote associations during divergent thinking tasks, so they need to have a wider breadth of search beyond usages normally associated with the object from this perspective as well. It should be noted that while there is no theoretical upper limit for number of original ideas, there could be a functional limit for generating alternative uses for any given cue. In a limited amount of time (common for most experimental settings), participants may not generate as many responses for the alternative uses task compared to the fluency task.

N and λ estimates derived from fitting the cumulative recall function provide a means to investigate whether a process involves more memory-based versus more novelty-based generation. When N is relatively large and λ is relatively small, and the cumulative generation over time displays a more linear trend, generation in the task should be more novelty-based. When N is relatively small and λ is relatively large, and the cumulative generation over time displays a more curved line (increasing more rapidly at the beginning), generation in the task should be more memory-based. Figure 0.1 below demonstrates how fluency and divergent thinking tasks (i.e., more memory based versus more novelty based, respectively) can display different trends in cumulative output. It is important to note that while divergent thinking tasks should be less memory-dependent than a fluency task, a participant can still rely heavily on memory directly associated with the cues and not be creative during divergent thinking tasks. This is why instructions such as “being creative” have been shown to improve creativity in responses for divergent thinking tasks (Harrington, 1975). The oppositional processes theory also predicts that memory-based interference should happen at earlier stages of divergent thinking. Using the cumulative recall function (Equation 1) to estimate N and λ can shed light on the types of processes one utilizes during divergent thinking.

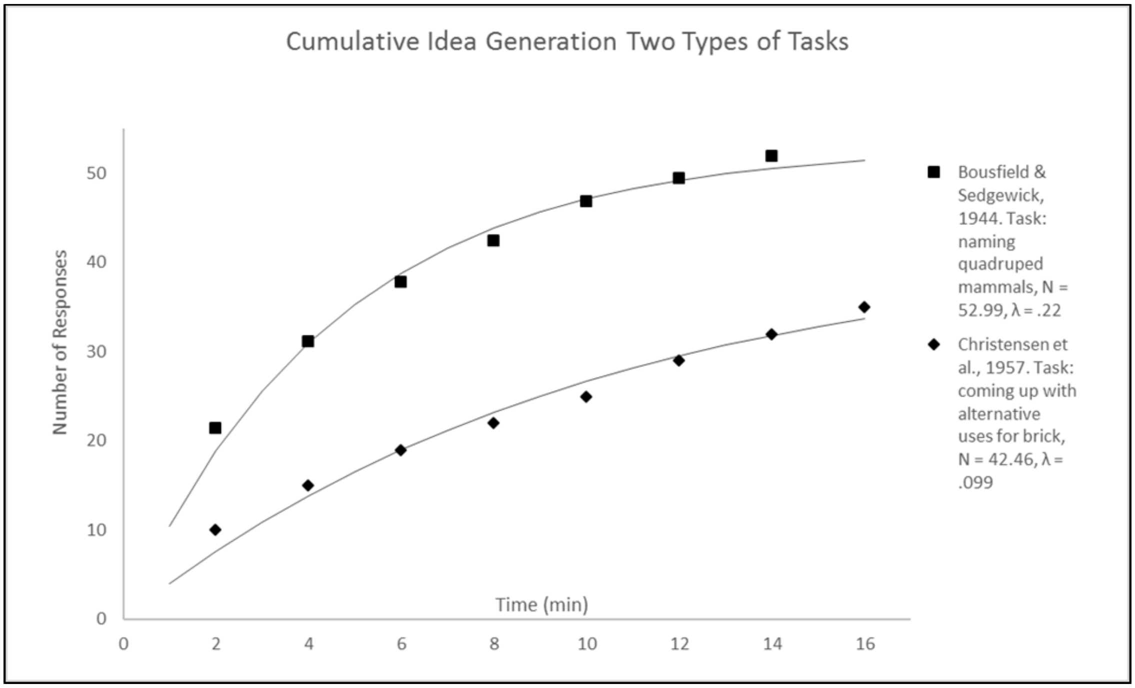

Figure 0.1. Cumulative Idea Generation Curves from Two Types of Tasks.

In summary, the oppositional processes theory proposes that novel idea generation is opposed by accessible information from semantic and episodic memory systems. The theory predicts that ideas based on memory that are less creative are generated faster and tend to appear earlier; truly novel ideas that are more creative are generated slower and tend to appear later. On the one hand, there must be a finite amount of memory-based ideas that interfere with divergent thinking and when participants in alternative uses tasks can bypass the most obvious and common ideas based on memory (meaning they move on to novel generation earlier), cumulative generation will display a more linear trend over time. On the other hand, if participants get stuck on memory based ideas and cannot move on to generate novel ones, then more (and less creative) output should be produced in earlier stages leading to a more curvilinear trend over time.

Experiment 1 was designed to test these predictions made by oppositional processes theory. In Experiment 1, memory reliance during the alternative uses task was directly manipulated between subjects: participants in the old-usage condition were told to generate usages only from what they can remember; participants in the new-usage condition were told to only generate usages they have never seen/heard/experienced before. The oppositional processes theory predicts that participants from the new-usage condition should display the following outcomes in comparison with participants from the old-usage condition; more total amount of usages, less generation time, lower proportion of usages from semantic and episodic memory, higher proportion of novel usages, higher creativity scores, higher N and lower λ estimates.

Furthermore, Experiment 1 also examined several interactions between memory reliance and time spent during the generation process. Specifically, participants in the old-usage condition should display a greater decrease in number of usages generated and greater increase in generation time as they spent more time to generate usages, compared to participants in the new-usage condition. The serial order effect should manifest in the new-usage condition rather than the old-usage condition, because the new-usage condition had greater resemblance to a real alternative uses task. Therefore, participants in the new-usage condition should display a greater increase in novel usage proportions and creativity as they spent more time to generate usages, compared to participants in the old-usage condition.

CHAPTER 2

EXPERIMENT 1: MATERIALS AND METHODS

Participants

Experiment 1 had 68 participants in total. 34 participants were randomized to the new-usage condition (*M* age = 19.84, 16 females) and 34 were randomized to the old-usage condition (*M* age = 19.88, 14 females). All participants were undergraduates recruited from the introductory psychology research participation pool at Arizona State University.

Procedures

A mixed-factorial experimental design was implemented with two factors: memory reliance during generation of usages was manipulated between-subjects (old-usage vs. new-usage); and the generation process can be divided and treated as a within-subjects factor (first 10 minutes of usage generation vs. last 10 minutes of usage generation). Two conditions were created based on memory reliance: old-usage condition had participants generate usages of an item based entirely on usages they have known/experienced in the past; new-usage condition had participants generate usages of an item based entirely on usages they have never know/experienced before.

After giving consent, participants were instructed to generate as many uses as they could think about for a cue (Brick) in 20 minutes. Participants from old-usage condition were instructed to generate usages based on memory whereas participants from novel-usage condition were instructed to generate usages not from their memory. Importantly, participants were not asked to be creative nor were they told that the task measured creativity. This was done to keep the manipulation purely memory based and not confounded by instructions of creativity. Once participants finished the usage generation task, their responses were copied to a spreadsheet and they gave creativity ratings for all their responses. Participants then finished a short survey regarding demographic information, personality and creative behavior.

Usage generation tasks. Usage generation tasks were programmed and conducted with E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Participants first went through a short practice step typing 5 generic sentences to familiarize themselves with the method of response entry and keyboard. After that, they read instructions on the screen explaining the nature of the usage generation tasks.

In the new-usage condition, participants were told not to generate any usages they have read/seen/experienced before. In the old-usage condition, participants were told to generate all usages based on what they have read/see/experienced before. The experimenter re-emphasized the instructions based on the conditions and then presented the participants their object cue (Brick). Participants typed usages of brick for the next 20 minutes. The screen where participants typed their usages also displayed text reminders based on conditions. For participants in the old-usage condition, the reminder was "uses of a brick from your memory"; for participants in the new-usage condition the reminder was "uses of a brick NOT from your memory".

Rating the responses. Once participant generated all their responses, experimenters copied the responses to a spreadsheet and participants rated their own responses along the following dimensions: creativity score, top 2 most creative uses, uses that were knowledge-based, uses that were event-based, and novel uses. The self-rated creativity score ranged from 1 to 5 with 5 being the most creative and 1 being the least. The top 2 choices were the 2 most creative responses participant felt they generated for the cue. If a response came from general knowledge (i.e., semantic memory), the participant would classify it as a knowledge-based usage. If a response came from personal experience (i.e., episodic memory), the participant would classify it as an event-based usage. If a response was new and first thought of during the experiment, the participant would classify it as a novel usage.

Short survey. Following the rating phase, participants completed a short survey distributed through Google Form. The first part of the survey asked participants general demographic questions such as age, gender and ethnicity. The second part of the survey contained the Ten Item Personality measure developed by Gosling, Rentfrow & Swann (2003). The last survey contained 50 questions from Kaufman Domains of Creativity Scale (2012). This scale measures participants' creative behavior from a variety of domains in real life (e.g. art, music, literature, etc.). Each question in this part displayed a certain behavior (e.g. "drawing something I've never actually seen"), and participants provided a score from 1 to 5 comparing themselves to general public (1 being much less creative; 3 was average: 5 being much more creative than average). [1]

Creative Score Coding

Once we collected all responses, three coders (all were undergraduate assistants) reviewed all the usages and assigned a creativity score to each of them. The coders followed scoring protocol provided by Silvia, et al. (2008). Before coding started, all responses sorted alphabetically to remove any potential bias that may arise from an individual set of

1 The short survey data was used as a pilot data for a future large scale individual differences study and will not be discussed further in the current manuscript.

responses (e.g., set size, impression of personality, etc.). Then, each coder read all the responses *before* they started coding.

The coders gave creativity scores based on three criteria first proposed by Wilson, et al. (1953) and later adopted by Silvia, et al. (2008) in their subjective scoring methods. The three criteria to consider were uncommonness, remoteness and cleverness. In this study, coders considered uncommonness as statistical infrequency within all usages pertaining to the specific cue. Rare usages that appeared only once or twice in the set were more uncommon. For remoteness, the coders considered the distances required to associate ideas that made up the usages. The more far-fetched or exotic usages were more remote. For cleverness, coders picked out usages that were more insightful and interesting / humorous that left a lasting impression with the coder. After considering all three criteria, the coders gave a creativity score for each usage ranging from 1 to 5 (5 being the most creative ones). In general, a high creativity score should also be rated high on all three dimensions. However, coders could also give a high creativity rating if only one of the three criteria fell short.

CHAPTER 3

EXPERIMENT 1: RESULTS

The results are categorized under "usage generation based results" and "usage rating based results". Usage generation based results refers to average number of usages, generation time, N and λ estimates. Usage rating based results refers to proportions of knowledge / event / novel usages, self-rated and coder-rated creativity scores.

Mixed-model ANOVAs were conducted to test between-subject differences in generation based upon memory reliance (i.e., old-usage versus new-usage conditions) as well as within-subject differences in the generation process change over time (i.e., first half vs. second half of the task). Most usage generation based results and usage rating based results from the ANOVAs support predictions from the oppositional processes theory.

For coder-rated creativity scores, sufficient reliability was found among the three coders. The average measure of Intraclass Correlation Coefficient (ICC) was .89 with 95% confidence interval from .70 to .95.

Usage Generation Based Results

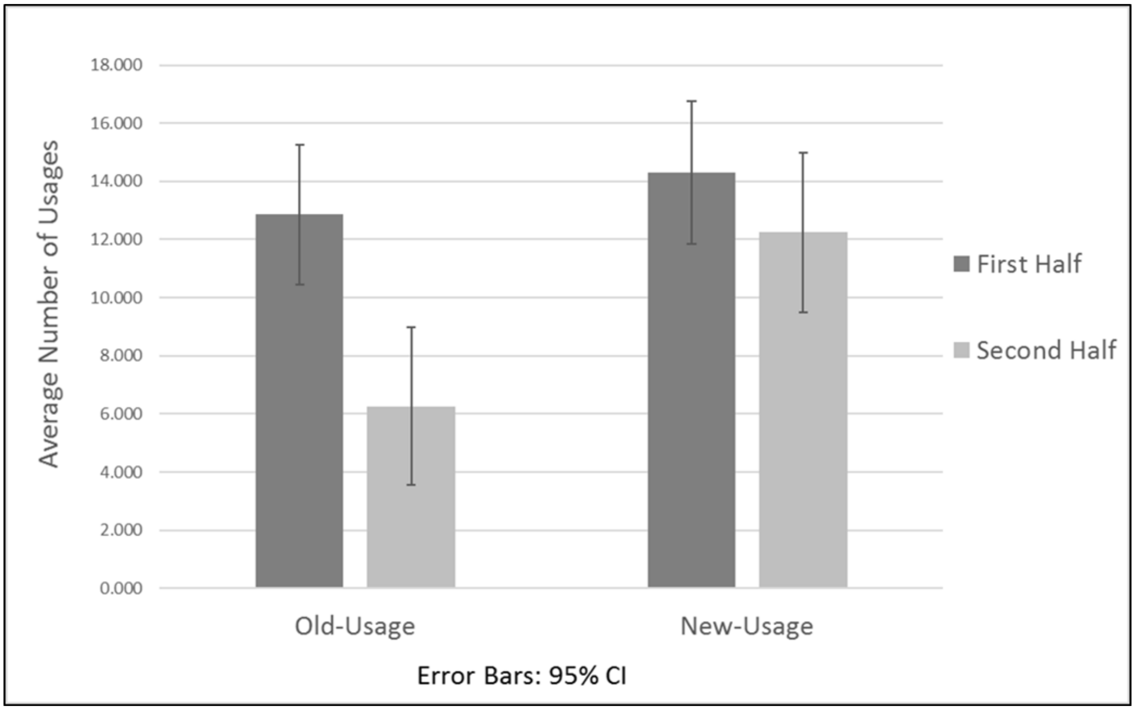

Figure 1.1. Number of Usages from Old/New Usages Conditions

The hypothesis that number of usages would differ as a function of memory reliance was supported. As seen in Figure 1.1, the mixed-model ANOVA found that the old-usage condition displayed lower amount of usages than the new-usage condition, $F(1,65) = 4.94$, $p = .030$, $\eta_p^2 =.07$. The hypothesis that number of usages would differ as a function of generation process was also supported. The mixed-model ANOVA found that participants generated more responses during the first half of the generation process, $F(1,65) = 34.07$, $p < .001$, $\eta_p^2 =.34$. In addition, there was the significant interaction between memory reliance and the generation process suggesting that participants exhausted usages from memory during the first half of the generation task, $F(1,65) = 9.33$, $p = .003$, $\eta_p^2 =.13$. Participants in the old-usage condition produced much less usages in the second half of the generation phase, $t(33) = 5.32$, $p < .001$, $d =.91$; in comparison to participants in the new-usage condition, who also produced less usages in the second half of the generation phase, but to a lesser degree, $t(32) = 2.59$, $p = .014$, d =.47

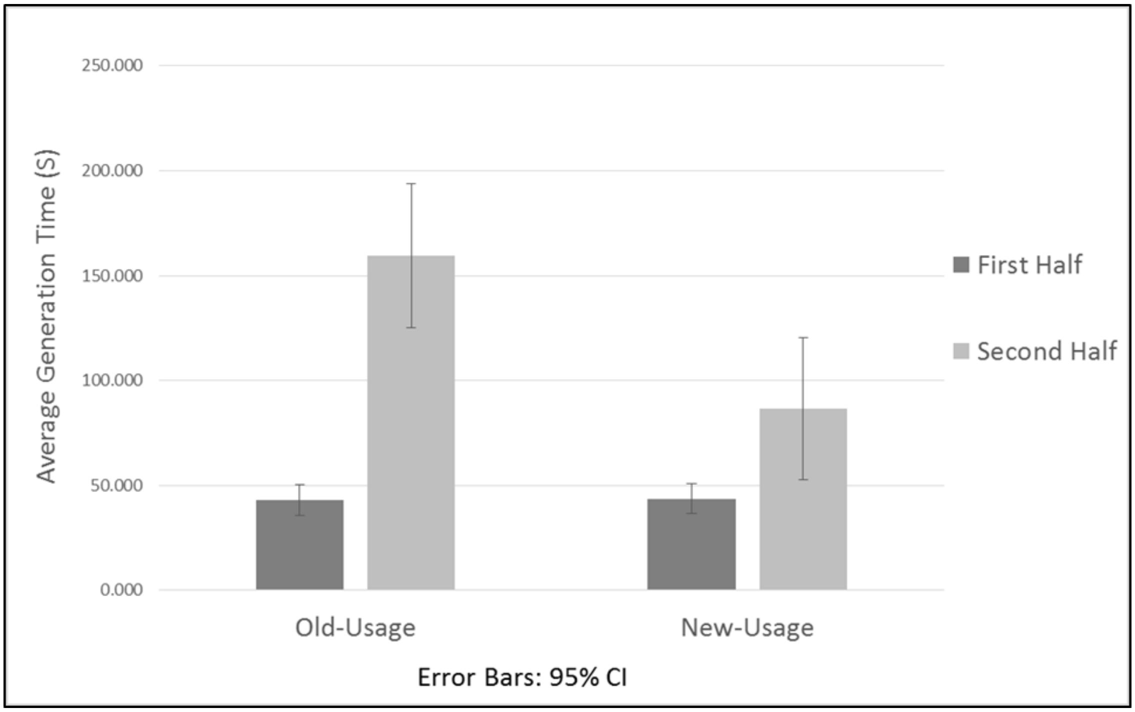

Figure 1.2. Generation Time from Old/New Usages Conditions

The hypothesis that generation time would differ as a function of memory reliance was supported. As seen in Figure 1.2, the mixed-model ANOVA found that the old-usage condition displayed greater generation time than the new-usage condition, $F(1,63) = 7.63$, $p = .008$, η_p^2 =.11. The hypothesis that generation time would differ as a function of generation process was also supported. The mixed-model ANOVA found that participants spent more time generating usages during the second half of the generation process, $F(1,63) = 47.79$, $p < .001$, η_p^2 =.43. In addition, there was the hypothesized significant interaction between memory reliance and the generation process, $F(1,63)$ =

10.14, p = .002, η_p^2 =.14. Participants in the old-usage condition spent much more time generating usages in the second half of the generation phase, $t(31) = -5.40$, $p < .001$, d = -1.27; in comparison to participants in the new-usage condition, who also spent more time generating usages in the second half of the generation phase, but to a lesser degree, $t(32) = -4.85$, $p < .001$, $d = -1.15$

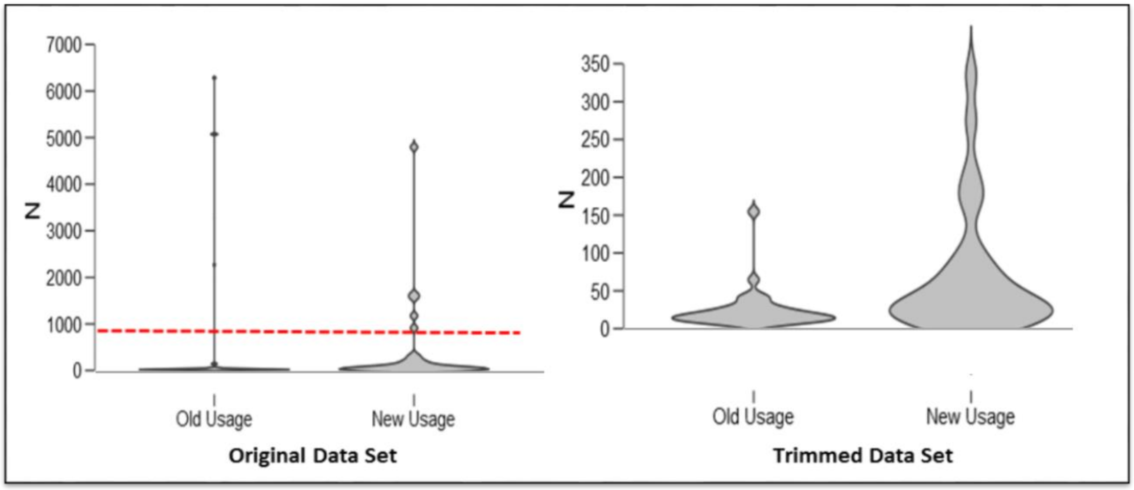

Figure 1.3. Probability Density Distribution of *N* estimates. Graph on the left displays probability distribution of all *N* estimates; graph on the right displays probability distribution of *N* estimates under 900. Red dash line marks the cut-off point for trimmed data.

The hypothesis that *N* estimates would differ as a function of memory reliance was not supported in the complete dataset. The independent-samples t-test recovered no significant difference in *N* estimates between the old-usage and new-usage conditions, $t(65) = .04$, $p = .843$, d =.05. This null finding likely arises from the large variance and a few extreme values found in *N* estimates (see Table 1 notes and Figure 1.3). Based on data distribution layout from Figure 1.3, most extreme values outside main distribution occurs above 900. In order to capture the between-subject difference of *N* estimates free from the influence of extreme values, the data set for N estimates was trimmed so any value above 900 were disgarded. The independent-samples t-test found that the trimmed *N* estimates from new-usage condition was significantly higher than the trimmed *N* estimates from old-usage, $t(57) = -17.43$, $p = .005$, $d = .74$.

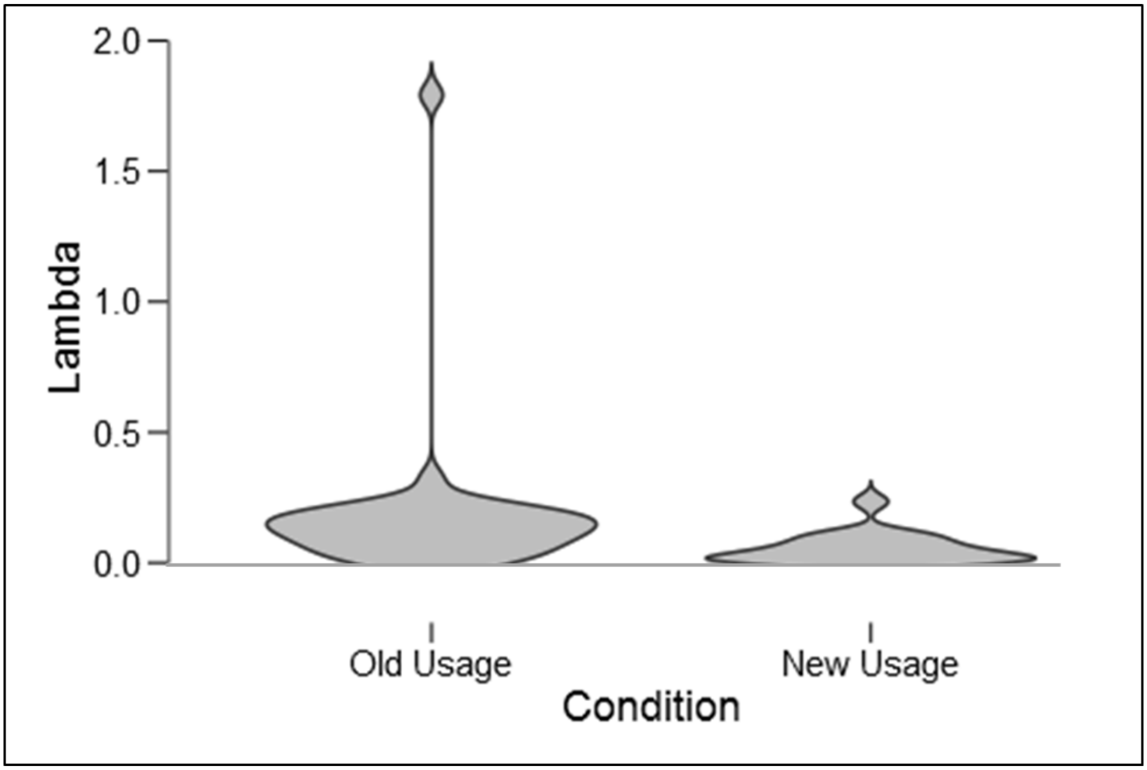

Figure 1.4. Probability Density Distribution of λ estimates

The hypothesis that λ estimates would differ as a function of memory reliance was supported (see Figure 1.4). The independent-samples t-test found that participants had greater λ estimates in old-usage condition compared with participants from the new-usage condition, $t(65) = 2.23$, $p = .029$, $d = .55$. There was an outlier λ estimate value from the old-usage condition that was close to 2. After removal of the outlier, the independent-samples t-test still found the significant difference between the conditions, $t(64) = 3.98$, $p < .001$, $d = .98$.

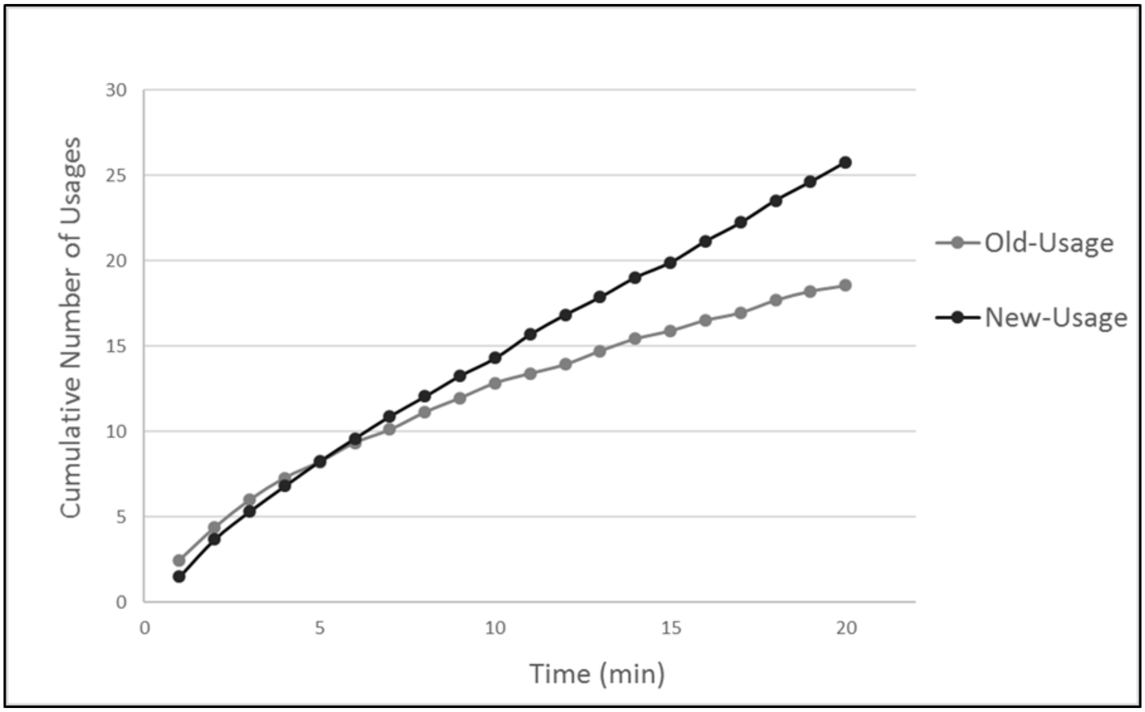

Figure 1.5. Cumulative Generation Curve from Experiment 1

Overall, usage generation based results revealed that when instructed to generate usages only based on memory, participants output less usages with much longer generation time during the second half of the generation process. On the other hand, when instructed to generate usages not based on memory, usage generation was distributed more evenly over time. Between-subjects differences in λ estimates also supported this interpretation that participants in the new-condition generated usages with a more evenly distributed pattern over time, compared with participants in the old-usage condition (see Figure 1.5).

Usage Rating Based Results

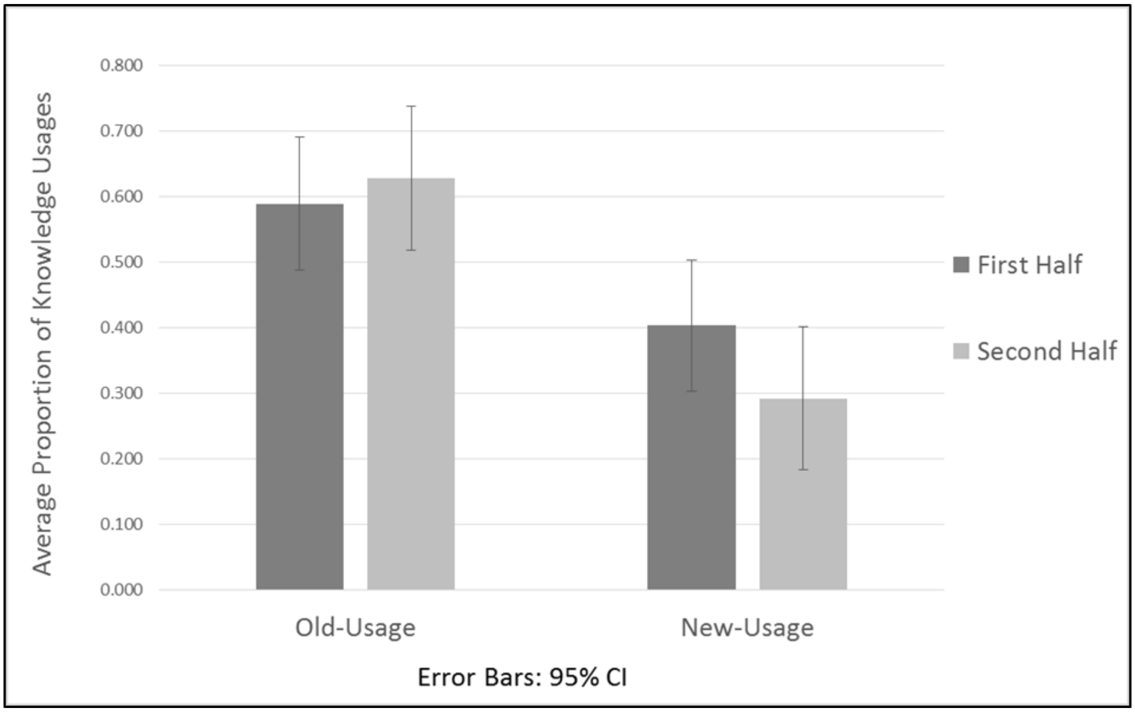

Figure 1.6. Proportion of Knowledge Usages from Old/New Usages Conditions

The hypothesis that proportion of knowledge usages would differ as a function of memory reliance was supported. As seen in Figure 1.6, the mixed-model ANOVA found that the participants in the old-usage condition indicated that a greater proportion of their generated usages were from knowledge than the participants in the new-usage condition, $F(1,63) = 14.94$, $p < .001$, $\eta_p^2 = .19$. The mixed-model ANOVA revealed no within-subject difference on proportion of knowledge usages between first and second halves of the generation process, $F(1,63) = 1.30$, $p = .259$, $\eta_p^2 = .02$. There was, however, the hypothesized significant interaction between memory reliance and the generation process, $F(1,63) = 5.69$, $p = .020$, $\eta_p^2 = .08$. Participants in the new-usage condition rated a lower percentage of their usages as coming from prior knowledge in the second half of the generation phase, $t(32) = 2.69$, $p = .011$, $d = .47$ relative to participants in the old-usage condition, their rating of their usages as coming from prior knowledge did not change during the generation phases, $t(31) = -.82$, $p = .417$, $d = -.15$

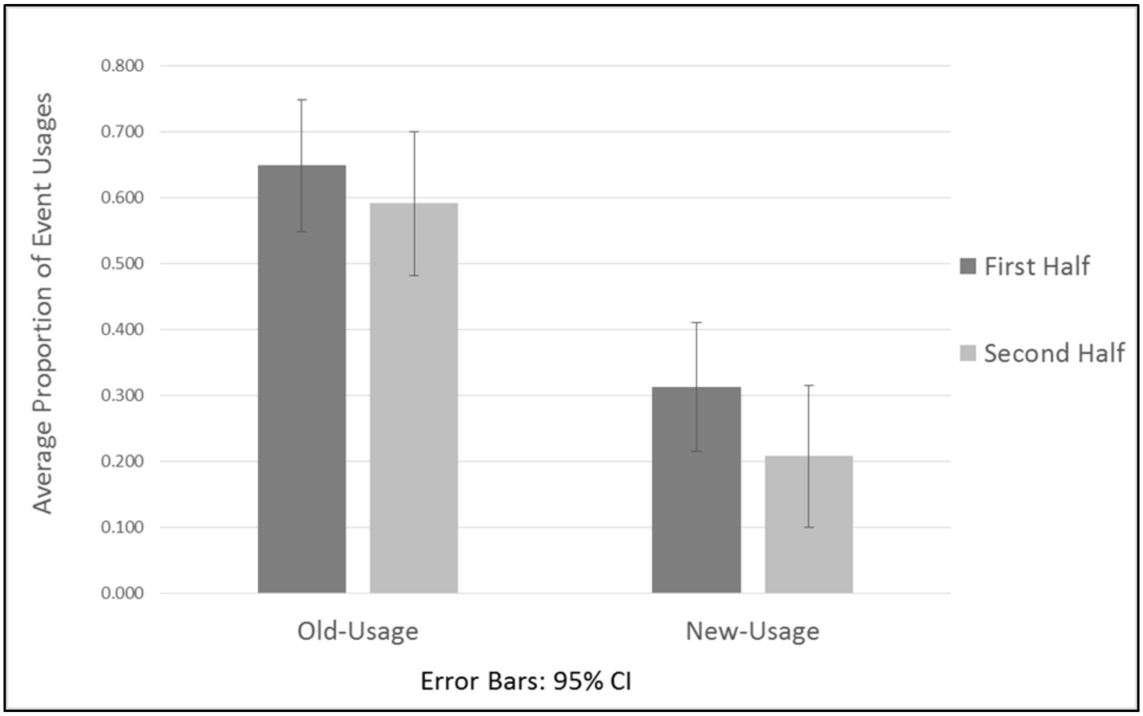

Figure 1.7. Proportion of Event Usages from Old/New Usages Conditions

The hypothesis that proportion of event usages would differ as a function of memory reliance was supported. As seen in Figure 1.7, the mixed-model ANOVA found that participants in the old-usage condition indicated a greater proportion of their generated usages were from past events than participants in the new-usage condition, $F(1,63) = 32.11$, $p < .001$, $\eta_p^2 = .34$. Although the hypotheses did not predict within-subject difference on the rated proportion of event usages, the mixed-model ANOVA revealed that participants indicated a smaller proportion of their generated usages were from event usages during the second half of the generation process, $F(1,63) = 4.89$, p

= .031, η_p^2 =.07. There was no significant interaction between memory reliance and the generation process, *F*(1,63) = .42, *p* = .518, η_p^2 = .01.

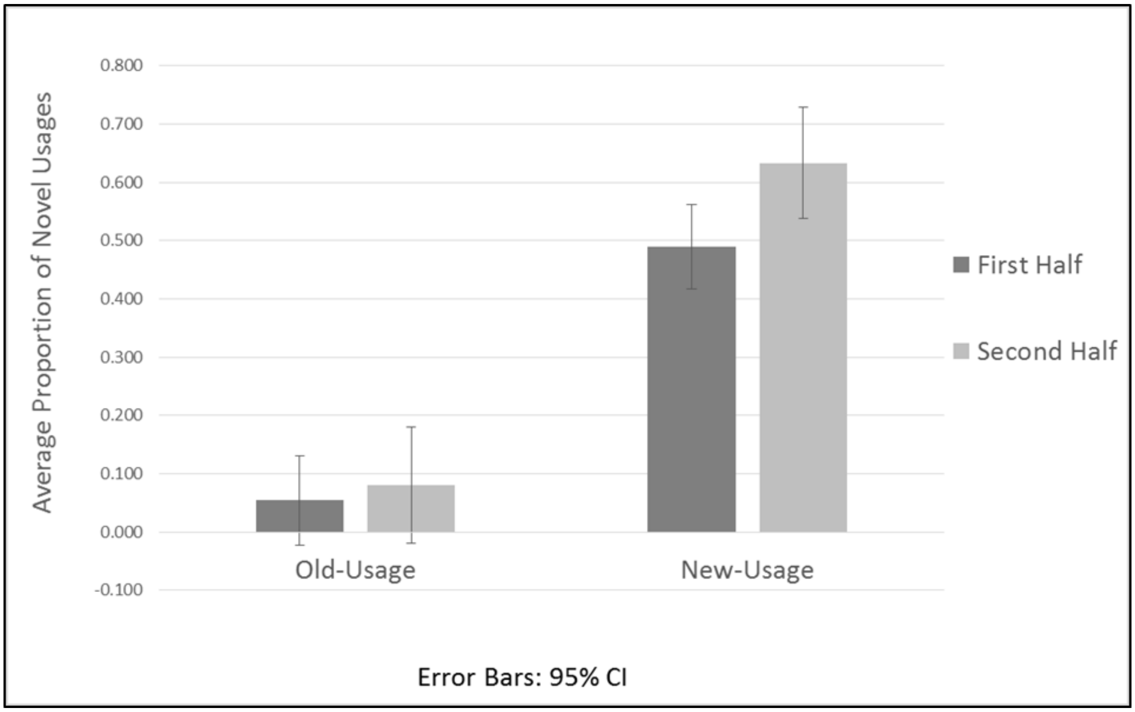

Figure 1.8. Proportion of Novel Usages from Old/New Usages Conditions

The hypothesis that proportion of novel usages would differ as a function of memory reliance was supported. As seen in Figure 1.8, the mixed-model ANOVA found that participants in the old-usage condition indicated a smaller proportion of their generated usages were novel usages than participants in the new-usage condition, *F*(1,63) = 79.09, *p* < .001, η_p^2 =.57. The hypothesis that proportion of novel usages would differ as a function of the generation process was also supported. The mixed-model ANOVA found that participants rated a higher proportion of their generated usages being novel during the second half of the generation process, *F*(1,63) = 10.79, p = .002, η_p^2 =.15. There was also the hypothesized significant interaction between memory reliance and the generation process, $F(1,63) = 5.21$, $p = .026$, $\eta_p^2 = .08$. Participants in the new-usage condition rated a higher percentage of their usages as being novel in the second half of the generation phase, $t(32) = -3.17$, $p = .003$, $d = -.57$; relative to participants in the old-usage condition, their rating of generated usages as being novel did not change during the generation phases, $t(29) = -1.24$, $p = .227$, $d = -.30$. Importantly, the paired-samples t-test for the new-usage condition showed that the proportion of self-rated novel generated items increased during the second half of the generation phase, this result helps to clarify that the interaction may not be entirely due to the obvious floor effect in the old-usage condition.

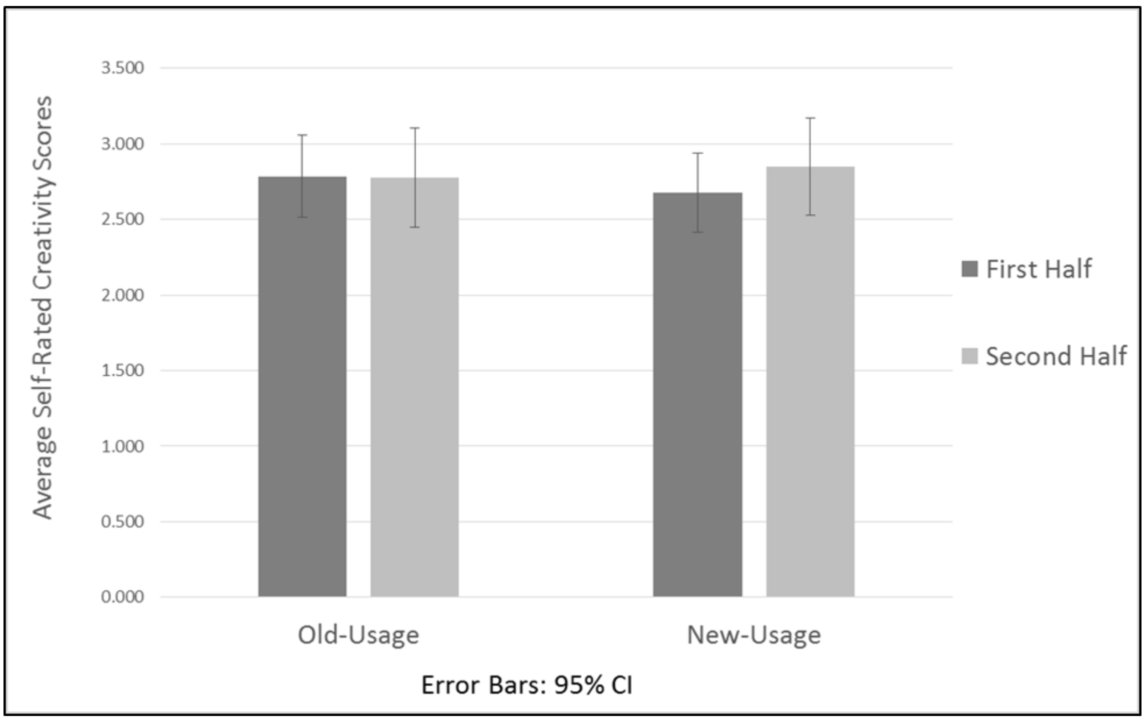

Figure 1.9. Average Self-Rated Creativity Scores from Old/New Usages Conditions

Hypotheses on self-rated creativity scores were generally not supported. The mixed-model ANOVA revealed no difference on self-rated creativity scores between old/new-usage conditions, $F(1,63) = .01$, $p = .919$, $\eta_p^2 < .001$, nor between first and second halves of the generation process, $F(1,63) = .43$, $p = .515$, $\eta_p^2 = .01$. There was no significant interaction between memory reliance and the generation process, $F(1,63) = .54$, $p = .466$, $\eta_p^2 = .01$.

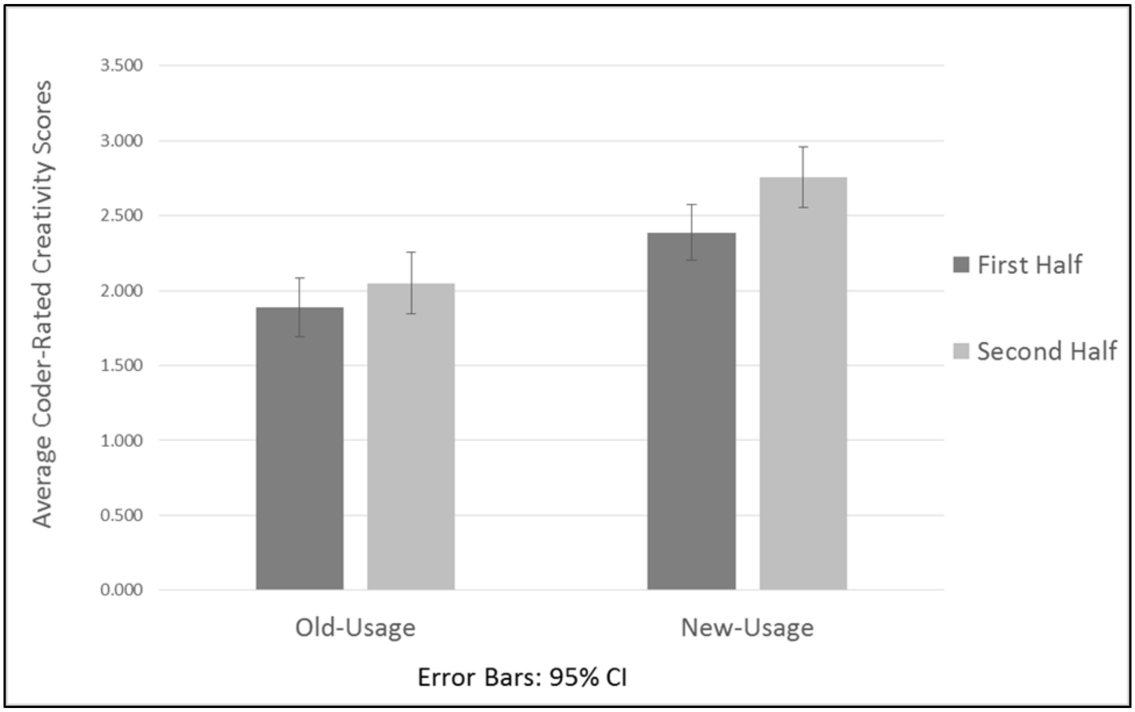

Figure 1.10. Coder-Rated Creativity Scores from Old/New Usages Conditions

Contradicting the self-rated creativity score analysis, as seen in Figure 1.10, the hypothesis that coder-rated creativity score would differ as a function of memory reliance was supported. The mixed-model ANOVA found that participants in the old-usage condition received lower coder-rated creativity scores than participants in the new-usage condition, $F(1,63) = 27.75$, $p < .001$, $\eta_p^2 =.31$. The hypothesis that coder-rated creativity scores would differ as a function of the generation process was also supported. The mixed-model ANOVA found that participants received higher creativity scores from coders during the second half of the generation process, $F(1,63) = 10.79$, $p = .002$, $\eta_p^2 =.15$. There was, however, no significant interaction between memory reliance and the generation process, $F(1,62) = 1.73$, $p = .194$, $\eta_p^2 = .03$. The failure to recover an interaction here is interesting and suggests that even in old-usage based generation conditions participants tend to report more remote, less common, and unusual responses (i.e., the dimensions independent coders used to rate creativity in these responses). However, paired-samples t-test comparing coder-rated creativity scores from the first half to the second half of the generation process with old-usage condition only did not reveal a significant difference: $t(30) = -1.20$, $p = .241$, $d = -.22$.

Summarizing the rating based results, participants in the new-usage condition generated more novel usages and fewer usages based on semantic and episodic memory than participants in the old-usage condition. Usages generated from the new-usage condition were also judged to be more creative than those from the old-usage condition. Furthermore, participants from the new-usage condition had more novel usages and were judged more creative during the second half of the generation process compared to the first half. There were also some discrepancies between self-rated and coder-rated creativity scores. They likely arose because the participants did not have access to other participants' generated usages when they made their creativity ratings. Therefore, the participants likely overestimated their own creative behavior.

CHAPTER 4

EXPERIMENT 1: DISCUSSION

Overall, direct manipulation of memory reliance during the alternative uses task significantly altered the coder-rated creativity score of the generated usages as well as the pattern of usage generation over time. These results replicate prior work and provide novel empirical support for the oppositional processes theory by showing that the memory retrieval process does indeed hinder the novel idea generation process in the old-usage condition. Inversely, by suppressing direct usage retrieval from memory in the new-usage condition, novel usage generation was promoted and participants' creative output significantly increased. This is particularly noteworthy because participants in both conditions *were not* instructed to be creative nor were they told that the alternative usages task is used to measure creativity. Therefore, these results provide clear evidence that memory interference can contaminate creative output. However, one potential issue with Experiment 1 lies in this direct method of manipulation, where the instructions in the alternative uses task was altered to either instruct participants to recall usages from past or generate ideas exclusively not from memory. Such a manipulation effectively changed the task in old-usage condition to a memory task and not a creativity task. Therefore, in Experiment 2, the main goal is to address this problem by creating a manipulation of memory accessibility while maintaining the alternative uses task in its original form wherein participants are instructed that they are completing a creativity task.

To accomplish this goal, in Experiment 2 participants focused their generation using cues that differed in the amount of memory associations between the cue and possible usages. Experiment 2 was designed such that the participants completed the alternative uses task either with cue words that had more (i.e., high context variability cues) versus less (i.e., low context variability cues) usages associated with them. The cues were conceptually similar nouns that differed in their context-variability (Steyvers & Malmberg, 2003). Context-variability (CV) is highly correlated with word frequency and measures the frequency of contexts that a word appears in in the English language. For example, a word such as “chopsticks” has really low context-variability (CV = 9) because it is limited to contexts related to Chinese food, its uses are highly specialized, and participants should not have experienced many other uses associated with “chopsticks” besides eating delicious Chinese food.

The oppositional processes theory predicts that alternative uses generated for low-CV cues should be more creative than those for high-CV cues. This prediction is based on the natural assumption that participants should have less unaltered usages associated with objects that occur in fewer contexts; they can come up with more novel ideas with low-CV objects when unaltered usages from memory are less likely to interfere. Furthermore, alternative usages for high-CV cues will be less numerous (smaller N) and the cumulative recall functions will approach asymptote faster (larger λ) when compared with alternative uses for low-CV cues because the generation process depends more on direct usages from memory.

Furthermore, Experiment 2 also examined several interactions between CV and time spent during the generation process. Specifically, participants in the high-CV condition should display a greater decrease in number of usages generated and greater increase in generation time as they spent more time to generate usages, compared to participants in the low-CV condition. The serial order effect should manifest to a greater extent in the high-CV condition compared to the low-CV condition, because the high-CV condition had greater had greater memory reliance at the beginning of the task. Therefore, participants in the high-CV condition should display a greater increase in novel usage proportions and creativity as they spent more time to generate usages, compared to participants in the low-CV condition.

CHAPTER 5

EXPERIMENT 2: MATERIALS AND METHODS

Participants

Experiment 2 had 59 participants in total. 30 participants were randomized to the low-CV condition (*M* age = 18.47, 16 females) and 29 were randomized to the high-CV condition (*M* age = 18.79, 20 females). All participants were undergraduates recruited from the introductory psychology research participation pool at Arizona State University.

Materials

A mixed-factorial experimental design was implemented with two factors: CV was manipulated between-subjects (i.e., low and high); and cue type was manipulated within-subjects (each participant received three different cues all from the same level of CV). The cues were selected in corresponding pairs of high versus low-CV to reduce the possibility that item specific factors other than context-variability may confound the results. High versus low cue pairs were chosen for this experiment to have similar common usages, but to differ substantially in their context variabilities. The first cue pair consisted of canteen (CV: 11) and bottle (CV:314); the second cue pair consisted of diaper (CV:12) and shirt (CV: 396); the third cue pair consisted of syringe (CV: 11) and tube (CV: 412).

Procedures

After giving consent, participants were instructed to generate as many uses as they could think about for three different cues that were presented one at a time. Participants from low-CV condition were presented with canteen, diaper and syringe as cues; and participants from high-CV condition were presented with bottle, shirt and tube as cues. For each of the three cues, participants generated alternative uses for 10 minutes. Therefore, participants spent 30 minutes in total on this alternative uses task. However, since the generation time for each cue is still 10 minutes, the within-subject comparison of first half versus second half of the generation process involved five-minutes time blocks. Once participants finished the alternative uses task, their responses were copied to a spreadsheet and they gave creativity ratings for all their responses. Participants then finished a short survey regarding demographic information, personality and creative behavior.

Alternative uses tasks. All tasks were programmed and conducted with E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Participants first went through a short practice step typing 5 generic sentences to familiarize themselves with the method of response entry and keyboard. After that, they read instructions on the screen explaining the nature of the alternative uses task. Participants were instructed that they would type as many novel uses for an object as they could in a fixed period of time. The instructions encouraged them to be unusual, uncommon and clever when giving their responses. Before presentation of the first cue, the experimenter asked the participants to explain the task in their own words in order to ensure that they understood the instructions. The experimenter once again encouraged participants to be creative in the task and presented the participants their first cue. Participants typed the alternative uses with the first cue (canteen/bottle) shown on the screen. After 10 minutes, the second cue (diaper/shirt) automatically appeared and stayed for another 10 minutes. Finally, the cue switched to the third one (syringe/tube) and stayed on screen for 10 minutes.

Rating the responses. Once participants generated all their responses, they rated their own responses with the same instructions from Experiment 1.

Short survey. Following the rating phase, participants completed a short survey with the same questions from Experiment 1.

Creative Score Coding

Three coders followed the same procedure from Experiment 1 to code the usages generated by participants. Coders worked on scoring usages from one cue at a time because they needed to consider the relative frequency of the usage in coding. The order of which cues should be worked on first was randomized for each coder to remove potential bias to favor earlier cues. After all usages were coded, coders compared their scores between cue pairs (i.e. canteen and bottle). They searched for similar usages between the pairs to ensure that these usages received the consistent scores.

CHAPTER 6

EXPERIMENT 2: RESULTS

The data were analyzed using a mixed-model ANOVAs with CV (high-CV versus low-CV) as a between-subject factor and the generation process (first 5 minutes versus last five minutes) as a within-subject factor to test the overall main effect of CV; in this model, cue pair type (canteen-bottle, diaper-shirt and syringe-tube) was also included as a within-subject factor. I included the cue type variable to control for item specific nuisance factors and my primary independent variable of interest was CV and its interaction with the generation process[2]. The results were categorized under "usage generation based results" and "usage rating based results". Usage generation based results refers to average number of usages, generation time, N and λ estimates. Usage rating based results refers to proportions of knowledge / event / novel usages, self-rated and coder-rated creativity scores. Overall, most usage rating based results supported the predictions made by the oppositional processes theory: participants from the low-CV condition had greater proportions of novel usages and were judged to be more creative by the coders than those from the high-CV condition; participants from the high-CV condition has had greater increase over time in their creativity, which lead to interactions between CV conditions and the generation process.

For coder-rated creativity scores, an acceptable reliability was found among the coders. The average measure of ICC was .71 with 95% confidence interval from .26 to .87.

[2] Cue-type specific differences were not reported in this manuscript, but can be made available upon contact with the author.

Usage Generation Based Results

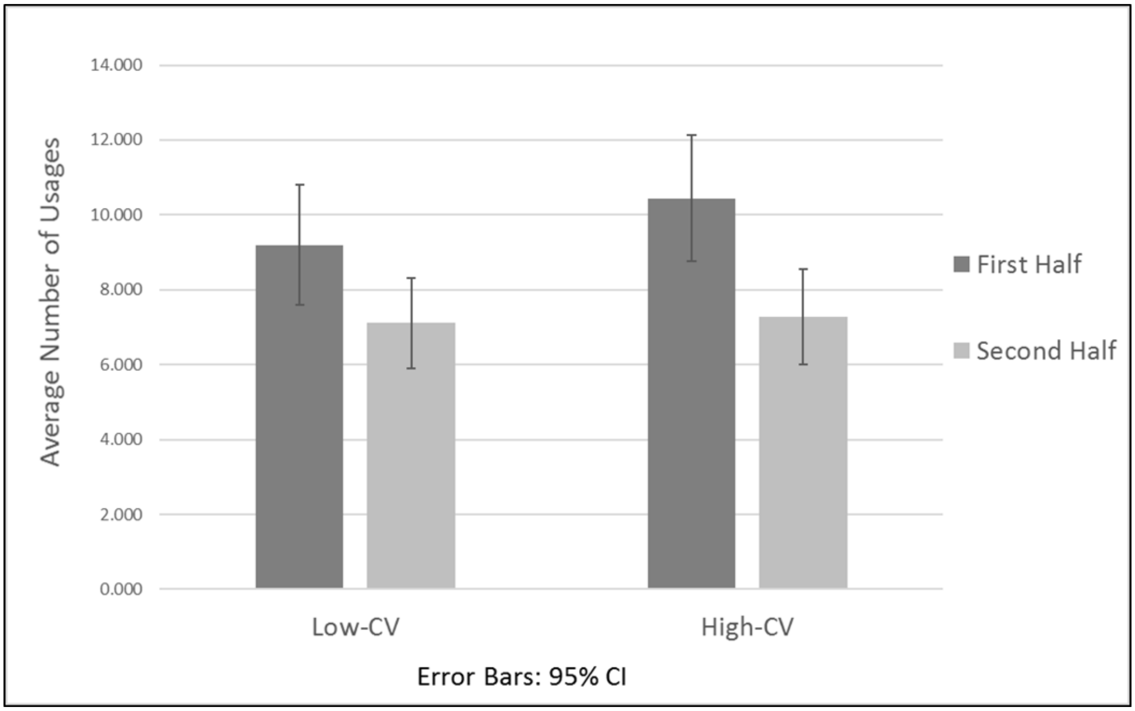

Figure 2.1. Number of Responses from CV Conditions.

The hypothesis that number of usages would differ as a function of CV was not supported. The mixed-model ANOVA failed to uncover a significant difference between high-CV and low-CV conditions on the mean number of generated usages (see Figure 2.1), $F(1,57) = .59$, $p = .446$, $\eta_p^2 = .01$. However, the mixed-model ANOVA revealed a significant decrease in number of usages from the first five minutes to the last five minutes of generation, $F(1,57) = 61.30$, $p < .001$, $\eta_p^2 = .52$. There was also an interaction between CV conditions and the generation process on number of usages, $F(1,57) = 5.24$, $p = .026$, $\eta_p^2 = .08$. As seen in Figure 2.1, this interaction most likely reflected a slightly greater decrease in number of usages over time in the high-CV condition, $t(28) = 5.96$, $p < .001$, $d = 1.16$; compared to the decrease in the low-CV condition, $t(29) = 5.11$, $p < .001$, $d = 1.12$.

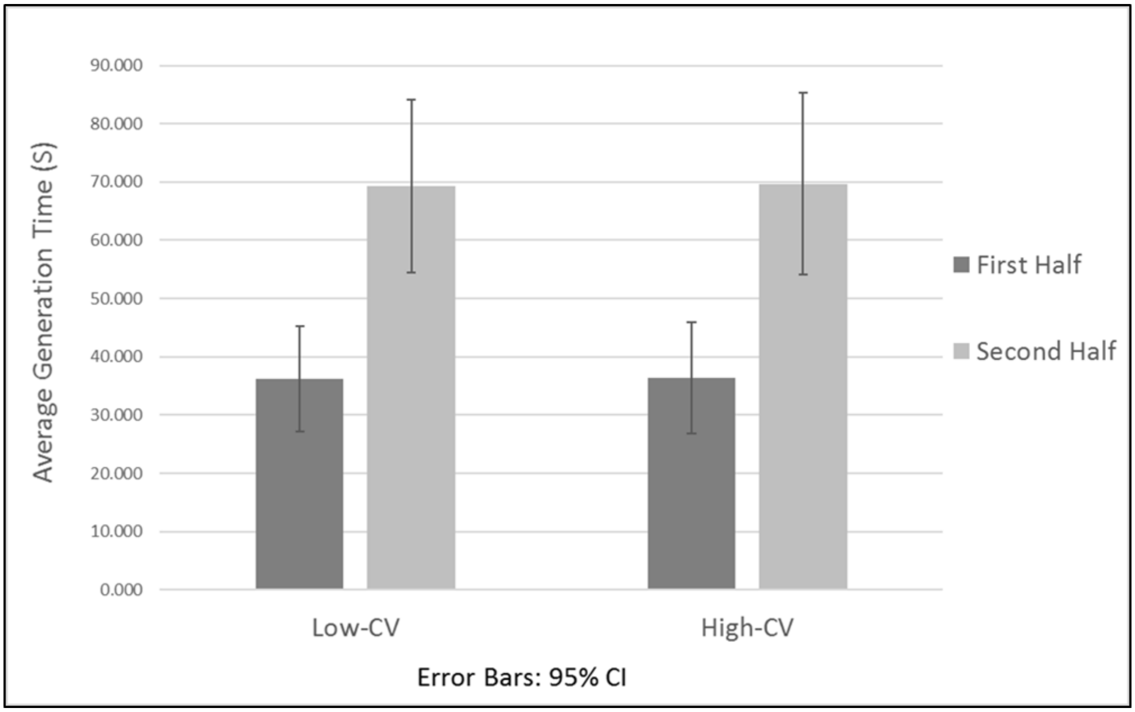

Figure 2.2. Response Time in Seconds from CV Conditions.

The hypothesis that response times would differ as a function of CV was not supported either. The mixed-model ANOVA failed to uncover a significant difference between high-CV and low-CV conditions on the mean generation time of usages (see Figure 2.2), $F(1,55) = .001$, $p = .972$, $\eta_p^2 < .001$. However, the mixed-model ANOVA revealed a significant increase in generation time from the first five minutes to the last five minutes of generation, $F(1,55) = 67.91$, $p < .001$, $\eta_p^2 = .55$. There was no significant interaction between CV conditions and the generation process on generation time, $F(1,55) = .001$, $p = .972$, $\eta_p^2 < .001$.

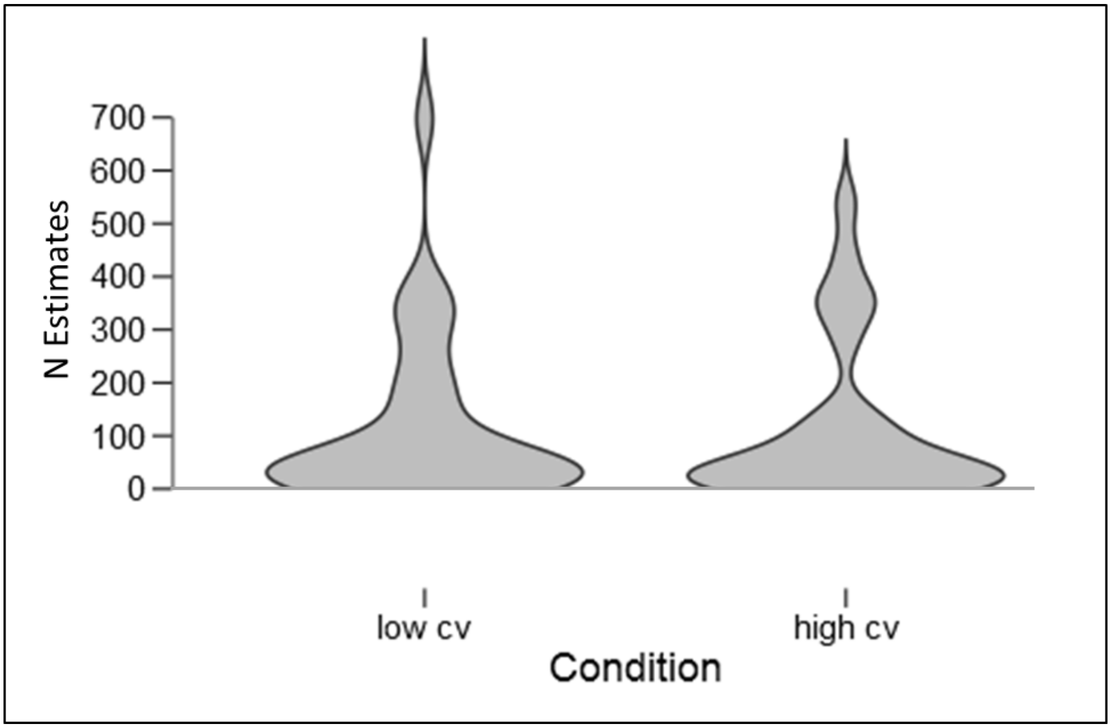

Figure 2.3. Probability Density Distribution of *N* Estimates.

The hypothesis that *N* estimates would differ as a function of CV was not supported. The mixed-model ANOVA with CV conditions as a between-subject factor and cue type as a within-subject factor[3] failed to uncover a significant difference between high-CV and low-CV conditions on *N* estimates (see Figure 2.3), $F(1,57) = .004$, $p = .950$, $\eta_p^2 < .001$.

[3] For *N* and λ estimates, generation time was not included in the model as a within-subject factor because the estimations were carried out using data across the entire generation duration.

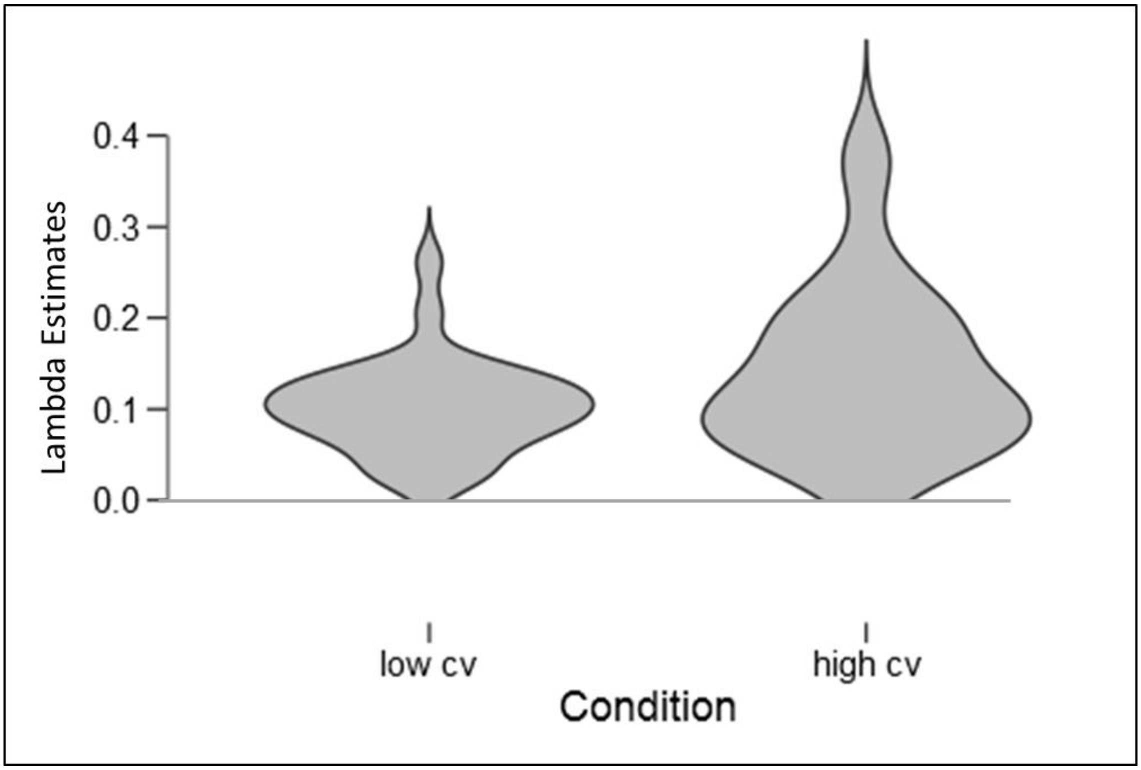

Figure 2.4. Probability Density Distribution of λ Estimates.

Unlike the evaluation of hypotheses for other usage generation based variables, the hypothesis that λ estimates would differ as a function of CV was supported. The mixed-model ANOVA found that the low-CV condition displayed lower λ estimates than the high-CV condition (see Figure 2.4), $F(1,57) = 3.95$, $p = .052$, $\eta_p^2 = .066$.

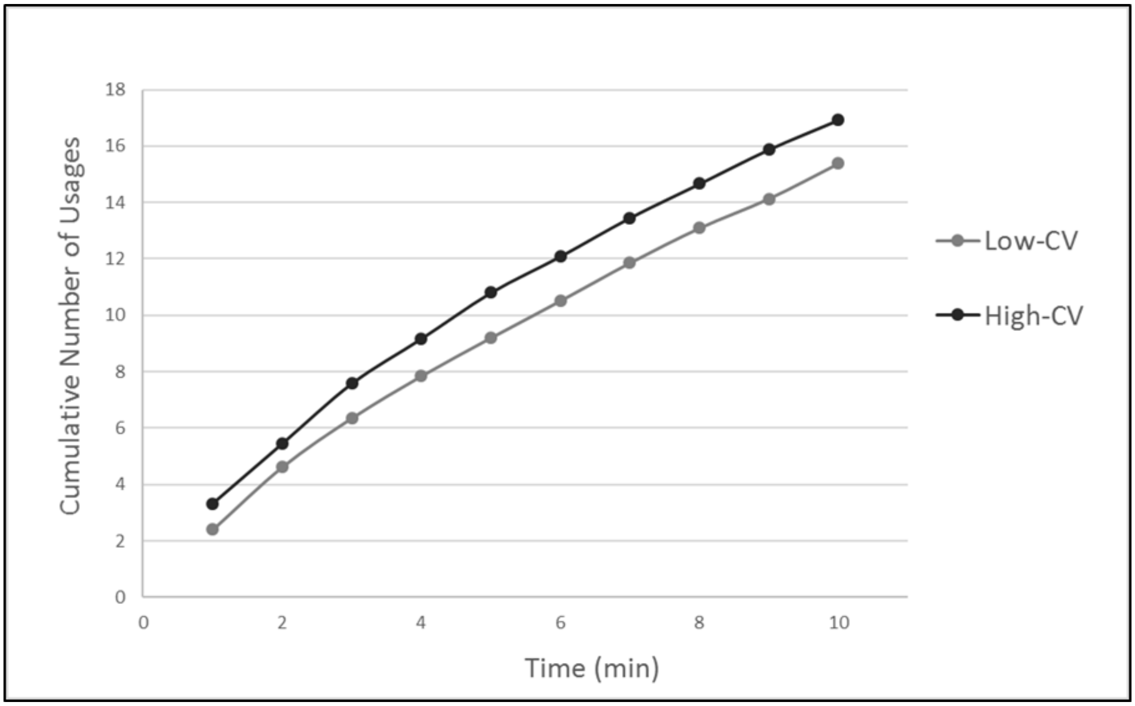

Figure 2.5. Cumulative Generation Curve from Experiment 2.

Overall, the usage generation based results demonstrated that participants from high-CV and low-CV conditions generated responses at differing rates, even when their overall number of usages and generation response times did not differ. For high-CV participants, higher λ estimates indicated that they could potentially exhaust their usages and reach theoretical asymptote faster while low-CV participants generated their usages more evenly across time. The interaction between the generation process and the CV conditions could corroborate this conclusion; participants in high-CV condition had a greater decrease in number of usages compared to participants in low-CV condition. However, this difference in λ was not very well reflected in the generation curve under the 10 minute time frame (as seen in Figure 2.5).

Usage Rating Based Results

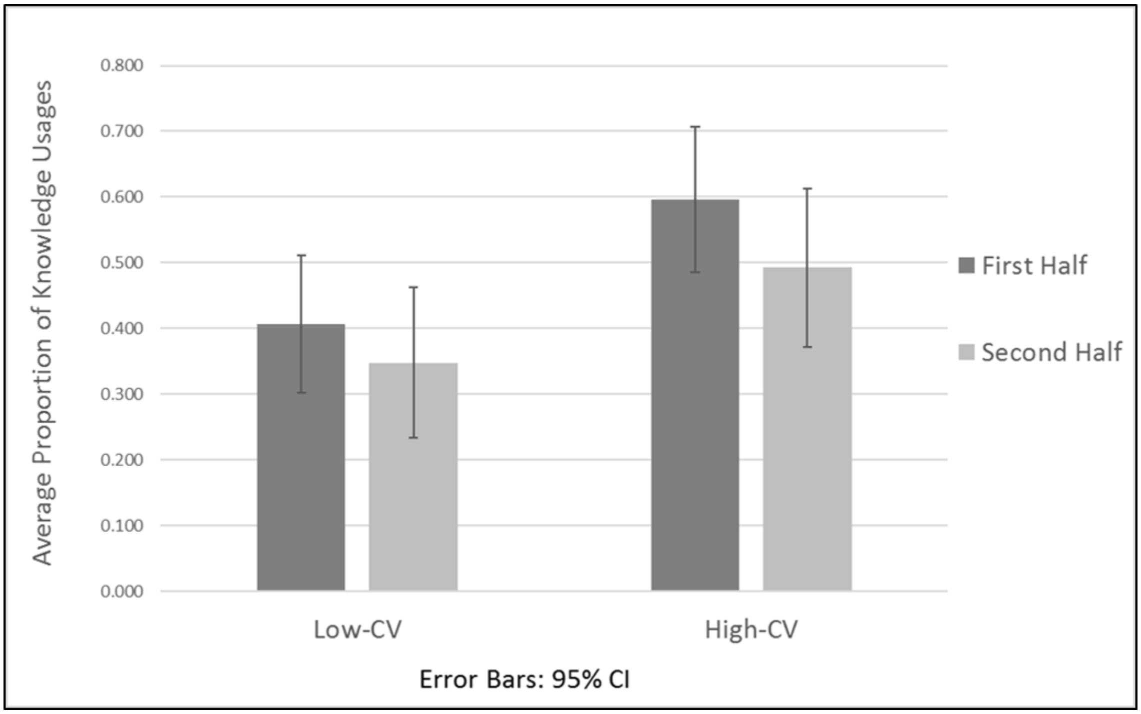

Figure 2.6. Proportion of Knowledge Usages from CV Conditions.

The hypotheses that usage distribution among the categories would differ as a function of CV were generally supported by the analyses. The mixed-model ANOVA found that the low-CV condition led to a lower proportion of usages from knowledge category than the high-CV condition (see Figure 2.6), $F(1,55) = 4.80$, $p = .033$, $\eta_p^2 = .08$. In addition, the mixed-model ANOVA revealed a significant decrease in proportion of usages judged to be in the knowledge category by participants from the first five minutes to the last five minutes of generation, $F(1,55) = 13.09$, $p = .001$, $\eta_p^2 = .19$. There was no significant interaction between CV conditions and the generation process on the proportion of knowledge usages, $F(1,55) = 1.03$, $p = .315$, $\eta_p^2 = .02$.

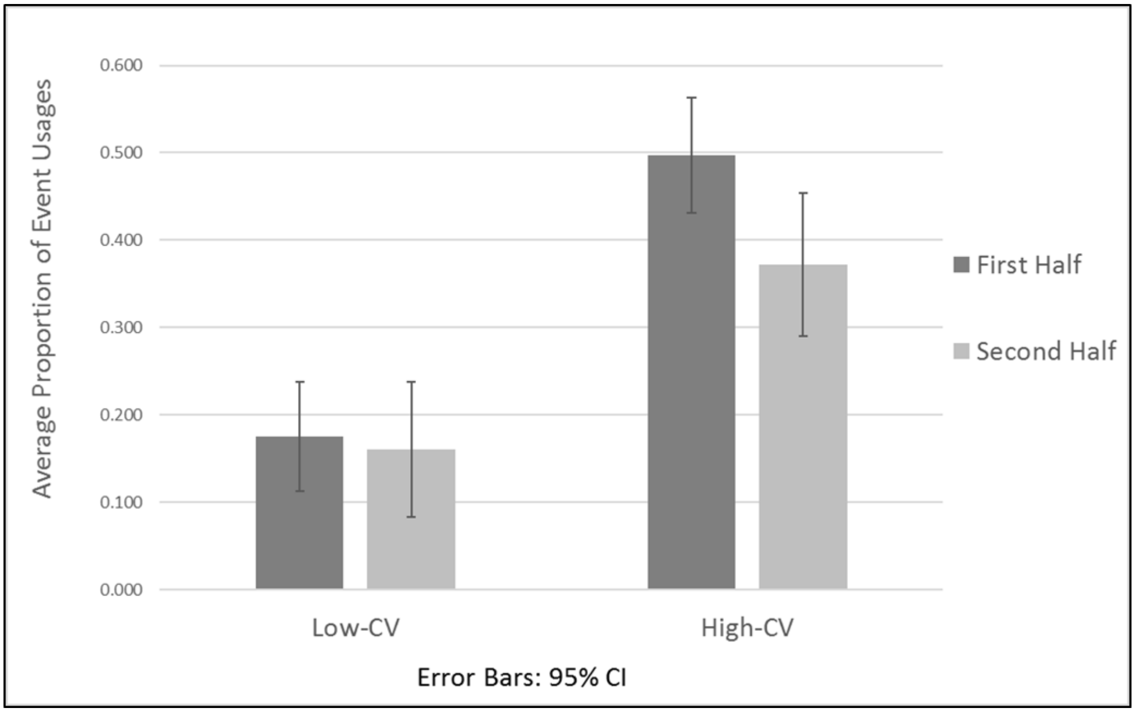

Figure 2.7. Proportion of Event Usages from CV Conditions.

The mixed-model ANOVA also found that low-CV participants had lower proportion of event usages compared to high-CV participants (see Figure 2.6), $F(1,55) = 31.33$, $p < .001$, $\eta_p^2 = .36$. In addition, the mixed-model ANOVA also revealed a significant decrease in proportion of usages judged to be in the event category by the participants from the first five minutes to the last five minutes of generation, $F(1,55) = 14.48$, $p < .001$, $\eta_p^2 = .21$. There was also an interaction between CV conditions and the generation process on the proportion of event usages, $F(1,55) = 9.09$, $p = .004$, $\eta_p^2 = .14$. As seen in Figure 2.7, this interaction most likely reflected a greater decrease in proportion of usages judged to be in the event category over time by participants from the high-CV condition, $t(26) = 4.58$, $p < .001$, $d = .93$; compared to almost no change in this judgement by participants from the low-CV condition, $t(29) = .59$, $p = .561$, $d < .001$.

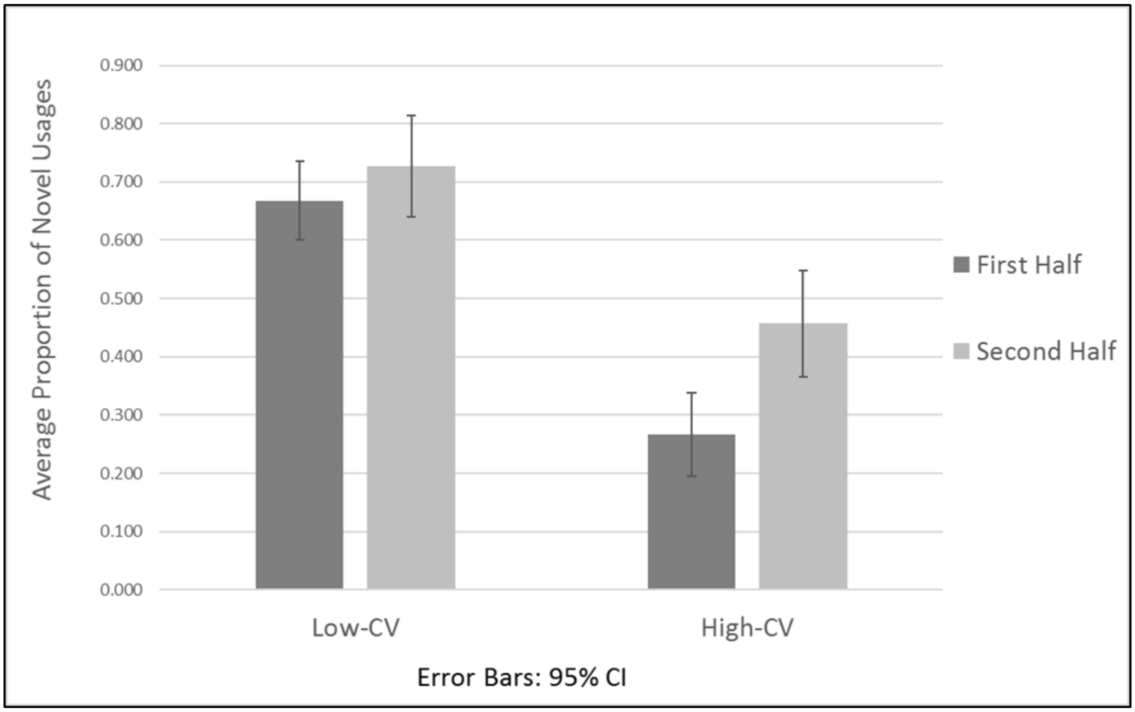

Figure 2.8. Proportion of Novel Usages from CV Conditions.

Participants displayed inverse pattern in proportion of usages from novel categories between high-CV and low-CV conditions. The mixed-model ANOVA found that low-CV participants had higher proportion of novel usages compared to high-CV participants (see Figure 2.8), $F(1,55) = 42.68$, $p < .001$, $\eta_p^2 = .44$. In addition, the mixed-model ANOVA also revealed a significant increase in proportion of usages judged to be in the novel category by the participants from the first five minutes to the last five minutes of generation, $F(1,55) = 30.25$, $p < .001$, $\eta_p^2 = .36$. There was also an interaction between CV conditions and the generation process on the proportion of novel usages, $F(1,55) = 8.45$, $p = .005$, $\eta_p^2 = .13$. As seen in Figure 2.8, this interaction most likely reflected a greater increase in proportion of usages judged to be in the novel category over time by participants in the high-CV condition, $t(26) = -4.85$, $p < .001$, $d = -1.00$;

compared a smaller increase in this judgement by participants from the low-CV condition, $t(29) = -2.40$, $p = .023$, $d = -.44$.

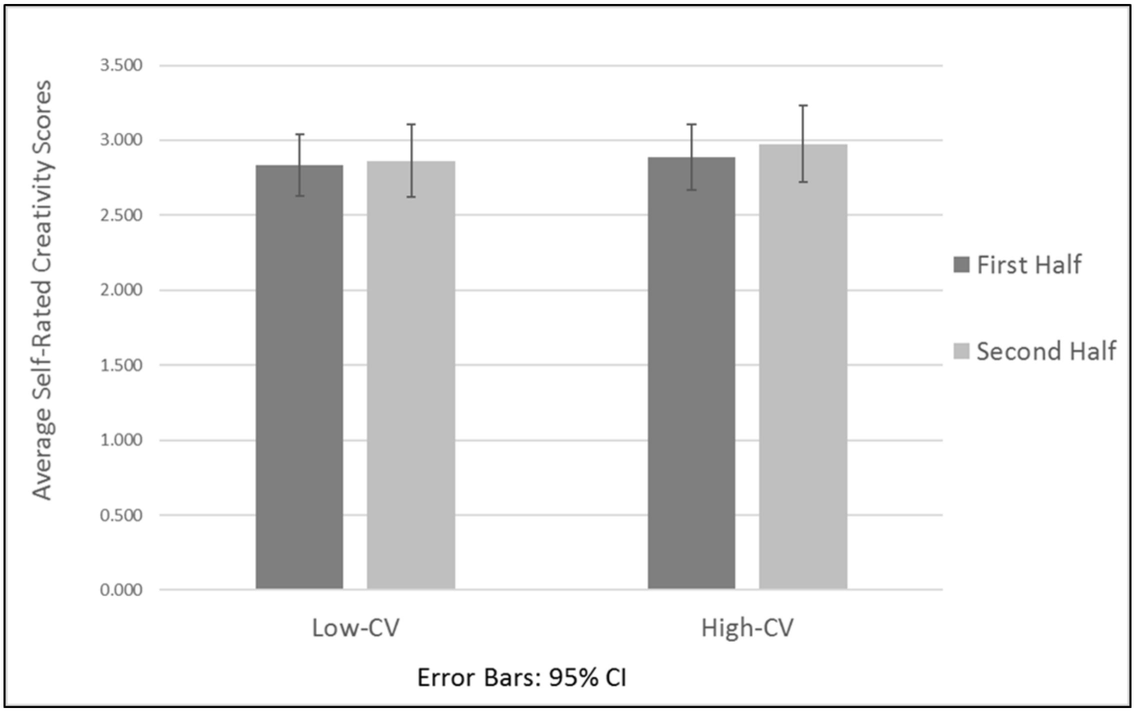

Figure 2.9. Self-Rated Creativity Scores from CV Conditions.

Analyses for the creativity scores confirmed my hypothesis for coder-rated scores but not self-rated scores. The mixed-model ANOVA failed to uncover a significant difference between high-CV and low-CV conditions on self-rated creativity scores (see Figure 2.9), $F(1,55) = .31$, $p = .578$, $\eta_p^2 = .006$. The self-rated creativity scores also did not change over time, $F(1,55) = .74$, $p = .391$, $\eta_p^2 = .01$. There was no significant interaction between CV conditions and the generation process on self-rated creativity scores, $F(1,55) = .18$, $p = .675$, $\eta_p^2 = .003$.

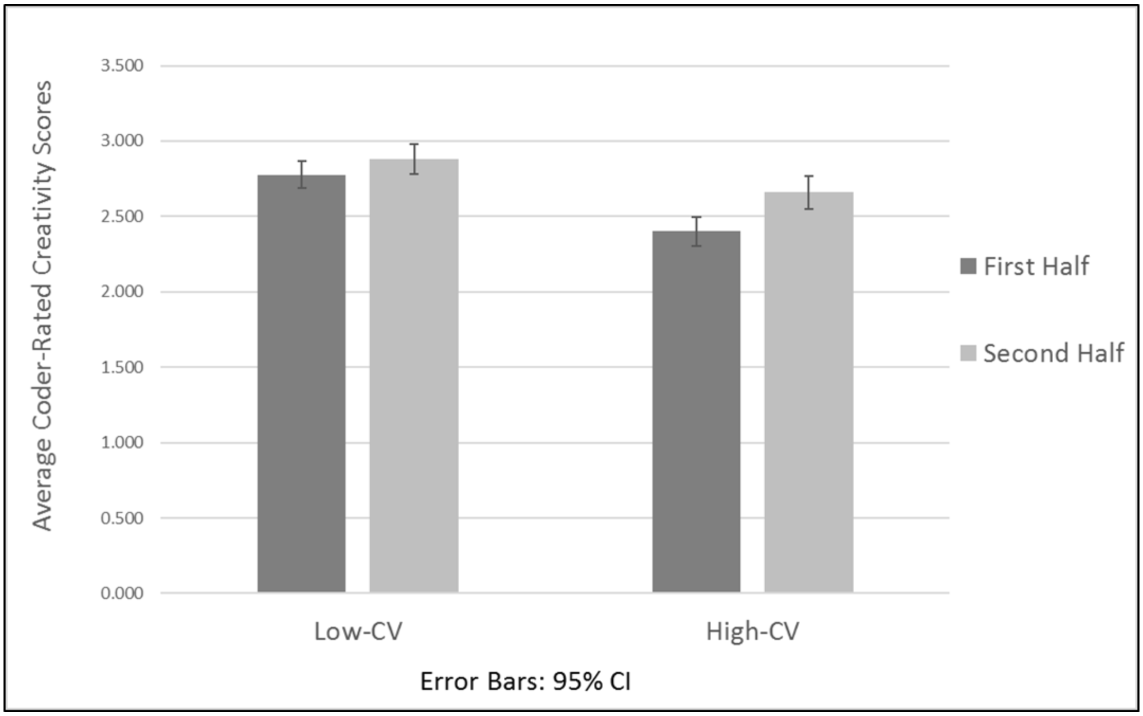

Figure 2.10. Coder-Rated Creativity Scores from CV Conditions.

For coder-rated scores, the hypothesis that creativity scores would differ as a function of CV was supported. The mixed-model ANOVA found that low-CV participants had higher coder-rated creativity scores compared to high-CV participants (see Figure 2.10), $F(1,54) = 27.21$, $p < .001$, $\eta_p^2 = .34$. In addition, the mixed-model ANOVA also revealed a significant increase in coder-rated creativity scores from the first five minutes to the last five minutes of generation, $F(1,54) = 20.05$, $p < .001$, $\eta_p^2 = .27$. There was also a marginally significant interaction between CV conditions and the generation process on coder-rated creativity scores, $F(1,54) = 3.52$, $p = .066$, $\eta_p^2 = .06$. As seen in Figure 2.10, this interaction most likely reflected a greater increase in coder-rated creativity scores over time from the high-CV condition, $t(25) = -4.35$, $p < .001$, $d = -.85$; compared a smaller increase in the scores from the low-CV condition, $t(29) = -1.91$, $p = .067$, $d = -.35$.

Summarizing the rating based results, participants in low-CV condition generated more novel usages and fewer usages based on semantic and episodic memory than participants in high-CV condition. Usages generated from low-CV condition were also judged to be more creative than those from high-CV condition. Along with difference on λ estimates reported earlier, these results suggest that the CV manipulation indeed affected the accessibility to various types of memory during divergent thinking tasks and this led to commensurate changes in creative behavior but only for independently rated creativity. With regards to change over time, rating of usages from various categories as well as coder-rated creativity scores differed to a greater extent in the high-CV condition compared to the low-CV condition. This would indicate that participants' dependency on memory decreased from the beginning to the end of the generation process in the high-CV condition, which was predicted by the oppositional processes theory. Furthermore, similar to Experiment 1, the discrepancies between self-rated and coder-rated creativity scores were also found in Experiment 2.

CHAPTER 7

EXPERIMENT 2: DISCUSSION

The oppositional processes theory highlighted the involvement of memory accessibility during divergent thinking tasks (i.e., past usages interfere with the ability to generate novel usages). The theory predicted that unaltered usages from memory associated with high-CV objects can potentially hinder generation of novel usages for these objects in the alternative uses task. Results from Experiment 2 confirmed this prediction and supported the oppositional processes theory. With unfamiliar cues (low-CV condition), participants still needed to activate usages in memory; but such usages would not be associated with the low-CV cue, they can be more creative in choosing which and how they combine usages and the object. With familiar cues (high-CV condition), participants were more likely to simply retrieve a usage they knew about the object and wrote it down at the beginning of the generation process; they were less likely to directly retrieve usages towards the end of the generation process.

Results from Experiment 2 indicated that participants from the high-CV condition can potentially switch from a memory based method of generating usages to a more creative and novel method of generating usages. However, the two conditions still differed in proportion of novel usages and coder-rated creativity toward the second half of the generation process. This was likely a limitation of generation time used in Experiment 2 (i.e., 10 minutes) and the two conditions could become more equivalent in their creativity level and generation pattern of usages given sufficient time (i.e., 30 minutes). The oppositional processes theory would predict a similar interaction if participants had longer generation time; they should generate usages close in creativity for both high and low-CV cues toward the end of the generation period; at earlier time blocks, participants will be more creative with low context-variability cues than high-CV cues.

The oppositional processes theory also predicts interactions between generation time blocks and CV conditions on average generation time, proportions of novel, knowledge and event categories. At later time blocks, participants should generate responses at a similar rate, with about the same proportions for novel, knowledge and event categories regardless of the type of cues given (i.e., high versus low-CV). At earlier time blocks, participants given high-CV cues will generate responses faster, with low proportions classified as novel responses, but higher proportions from knowledge and event classifications, compared to participants given low-CV cues.

The main purpose for Experiment 3 was to study whether the CV conditions in Experiment 2 can reach a similar level of novelty and creativity given enough time while also replicating the interactions between the CV conditions and the generation process on various usage generation and rating based measures. Experiment 3 had a similar design from Experiment 2 in that participants were also randomly assigned to either high-CV or low-CV conditions. The main difference between the experiments was the generation time allowed for each cue, which was 30 minutes for Experiment 3 and only 10 minutes for Experiment 2.

CHAPTER 8

EXPERIMENT 3: MATERIALS AND METHODS

Participants

Experiment 3 had 53 participants in total. 27 participants were randomized to the low-CV condition (*M* age = 19.74, 7 females) and 26 (*M* age = 19.61, 8 females) were randomized to the high-CV condition. All participants were undergraduates recruited from the introductory psychology research participation pool at Arizona State University

Materials

A mixed-factorial experimental design was implemented with three factors: CV was manipulated between-subjects (CV: low and high); time block and cue type was manipulated within-subjects (each participant received two different cues and generated usages for each cue for 30 minutes, which was broken down to three 10-minutes time blocks). The cues were selected in corresponding pairs of high versus low-CV to reduce the possibility that item specific factors other than context-variability may confound the results. Only two of the cue pairs from Experiment 2 were re-used for this experiment. The first cue pair consisted of canteen (CV: 11) and bottle (CV:314); the second cue pair consisted of diaper (CV:12) and shirt (CV: 396).

Procedures

All experimental procedures and coding protocols were identical to those from Experiment 2. The only difference was the amount of time participant spent on generating usages for each cue. Participants had 30 minutes to generate usages for one cue in Experiment 3 (60 minutes in total with two cues). They were informed of the length of the generation process before generating usages. For detailed description of experimental procedure and coding protocol, please refer to the methods section of Experiment 2.

CHAPTER 9

EXPERIMENT 3: RESULTS

For coder-rated creativity scores, an acceptable reliability was found among the coders. The average measure of ICC was .80 with 95% confidence interval from .30 to .92.

The data were analyzed with mixed-model ANOVAs with CV (high-CV versus low-CV) as a between-subject factor; time blocks (three 10-minutes blocks during generation) and cue pair type (canteen-bottle, diaper-shirt) as two separate within-subject factors to test the overall main effect of CV and time blocks, as well as interactions between them. The results were categorized under “usage generation based results” and “usage rating based results”. Usage generation based results refers to average number of usages, generation time, N and λ estimates. Usage rating based results refers to proportions of knowledge / event / novel usages, self-rated and coder-rated creativity scores. Overall, the difference between CV conditions was not very prominent in experiment 3 compared to Experiment 2. However, several important interactions between CV conditions and the generation process on usage rating based measures were replicated.

Usage Generation Based Results

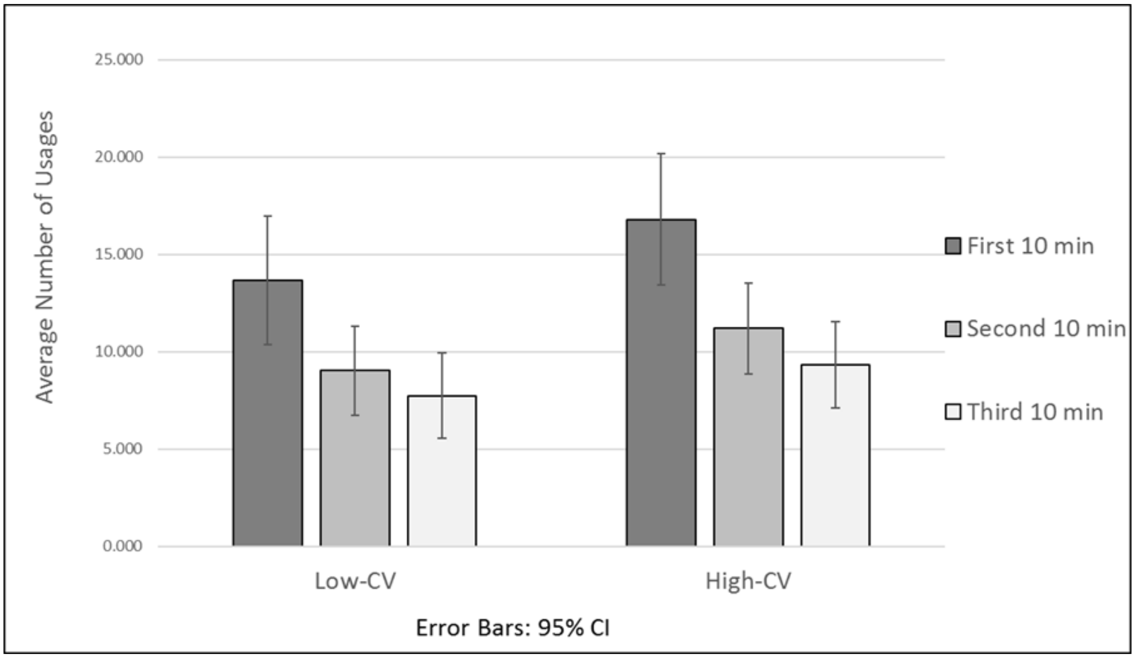

Figure 3.1. Number of Usages from CV Conditions over Time.

Similar to what was found in Experiment 2, the number of generated usages did not differ between high and low-CV conditions, $F(1,51) = 1.71$, $p = .197$, $\eta_p^2 = .03$. However, the hypothesis that number of usages would differ as a function of time blocks was supported. As seen in Figure 3.1, the mixed-model ANOVA found a significant decline in number of generated usages across the three time blocks, $F(2,102) = 72.80$, $p < .001$, $\eta_p^2 = .59$. Furthermore, within-subject contrasts revealed this decline over time had a quadratic trend, $F(1,51) = 21.37$, $p < .001$, $\eta_p^2 = .30$. There was no significant interaction between time blocks and CV conditions on number of usages, $F(2,102) = .92$, $p = .401$, $\eta_p^2 = .02$.

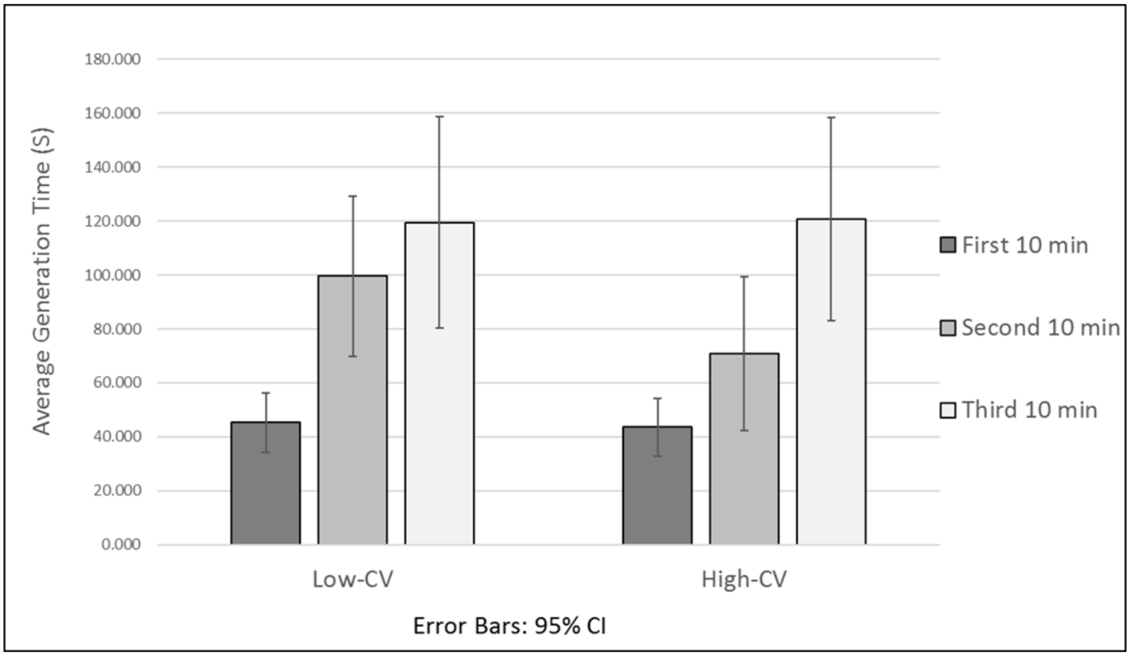

Figure 3.2. Generation Duration from CV Conditions over Time.

Also similar to what was found in Experiment 2, generation time did not differ between high and low-CV conditions, $F(1,46) = .35$, $p = .558$, $\eta_p^2 = .01$. However, the hypothesis that generation time would differ as a function of time blocks was supported. As seen in Figure 3.2, the mixed-model ANOVA found a significant increase in generation time across the three time blocks, $F(2,92) = 30.07$, $p < .001$, $\eta_p^2 = .40$. Furthermore, within-subject contrasts revealed this decline over time had a linear trend, $F(1,46) = 44.89$, $p < .001$, $\eta_p^2 = .49$. There was no significant interaction between time blocks and CV conditions on generation time, $F(2,92) = 1.43$, $p = .244$, $\eta_p^2 = .03$. However, within-subject contrasts revealed a quadratic trend in how these two factors interact, $F(1,46) = 4.29$, $p = .04$, $\eta_p^2 = .09$. As seen in Figure 3.2, this trend mostly likely is caused by the difference in generation time between high and low-CV conditions from the second time block.

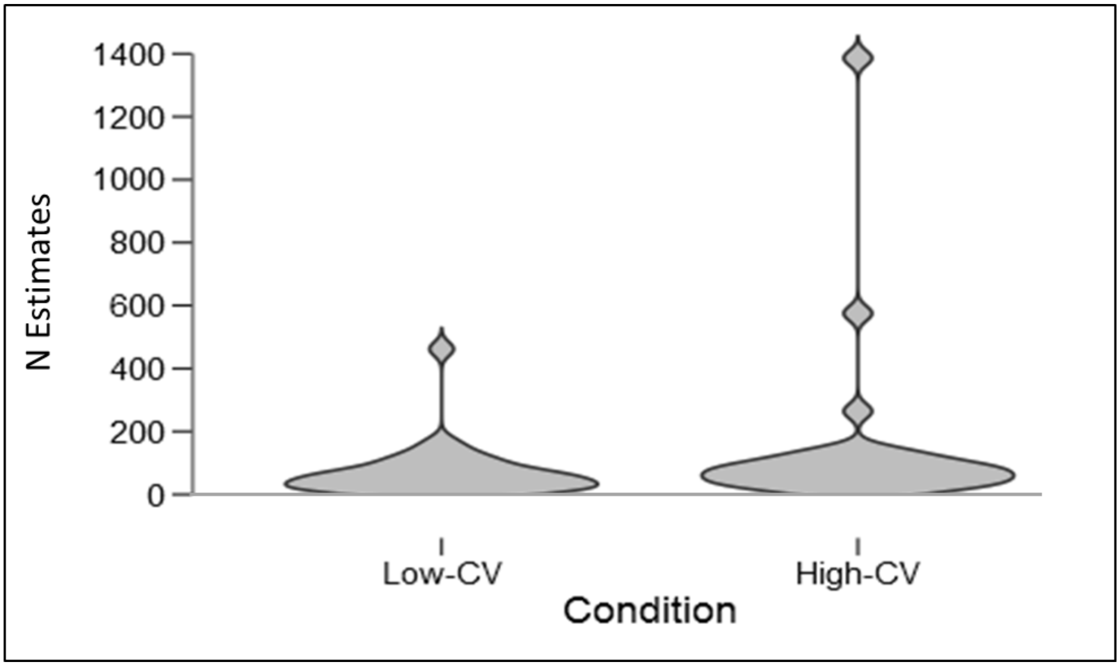

Figure 3.3. Probability Density Distribution of *N* Estimates.

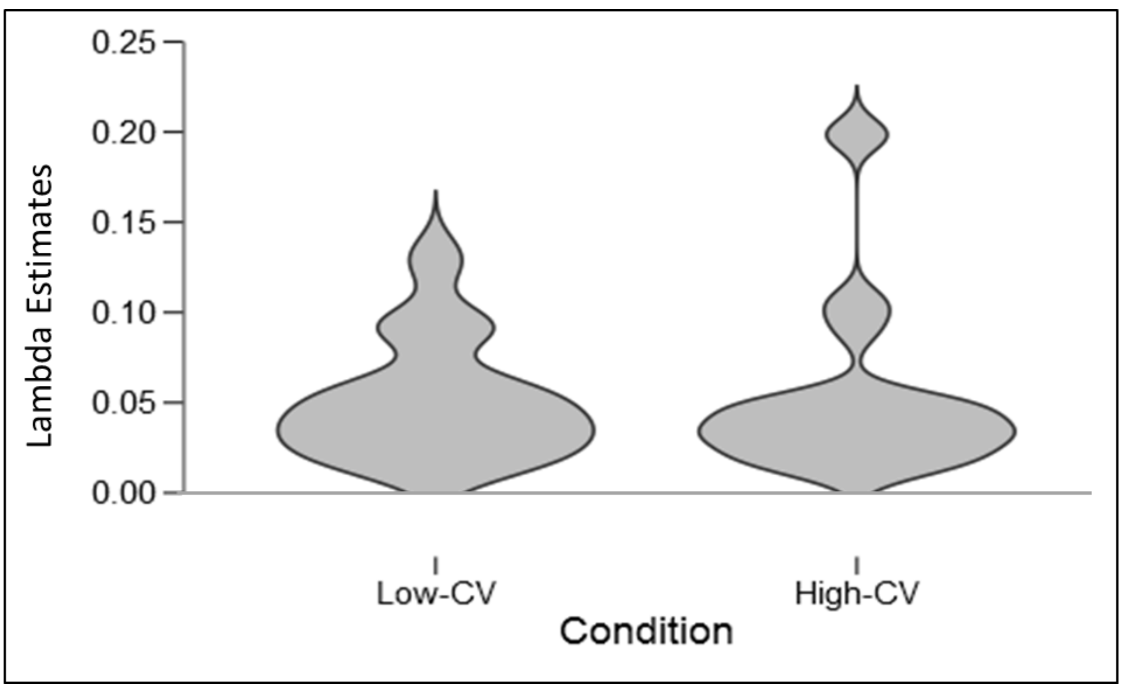

Figure 3.4. Probability Density Distribution of λ estimates.

As seen in Figures 3.3 and 3.4, even though the range of values can vary a great deal for λ and *N* estimates in Experiment 3, the densest regions are very close between the two conditions. The mixed-model ANOVA revealed no significant difference between conditions for *N* estimates, $F(1,51) = 1.39$, $p = .193$, $\eta_p^2 = .03$; there was no significant difference between conditions for λ estimates either, $F(1,51) = .03$, $p = .865$, $\eta_p^2 = .001$.

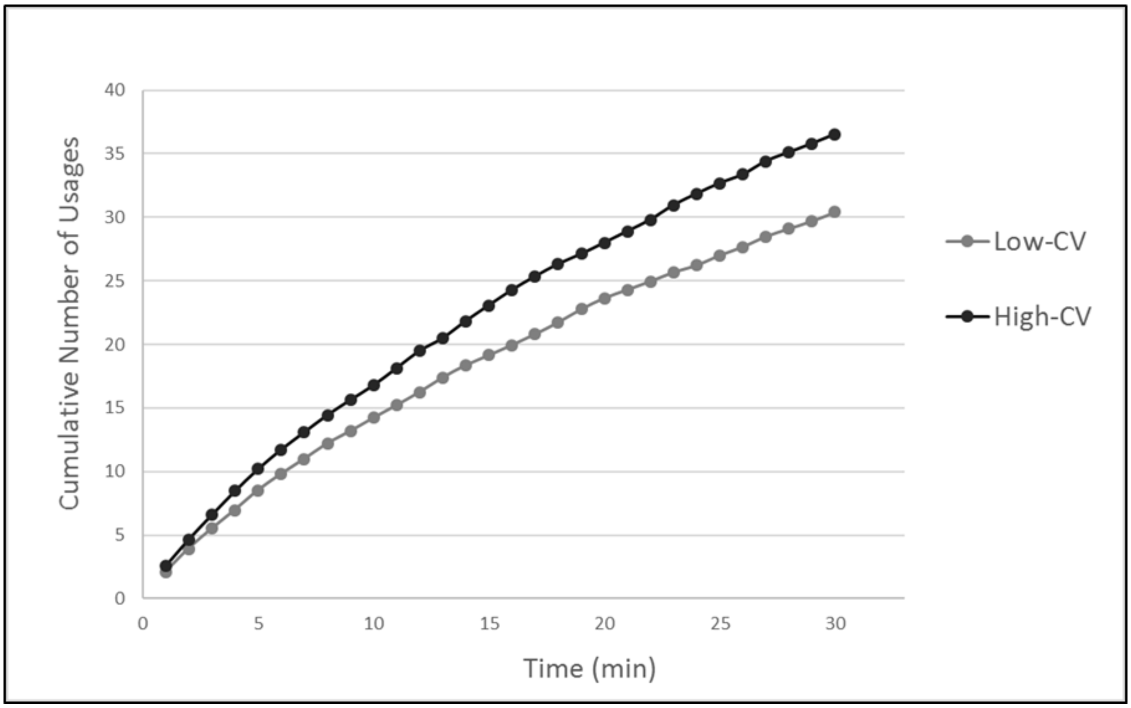

Figure 3.5. Cumulative Generation Curve from Experiment 3.

Overall, usage generation based results revealed that participants output less usages with much longer generation time during as the generation process lasted for 30 minutes. On the other hand, the CV of the cues did not impact the number of usages and generation time on each usage. These null results indicated that the overall generation pattern was similar across high/low-CV conditions (see Figure 3.5), which may explain why the estimated asymptotes and rates to approach the asymptotes were also similar across two conditions.

Usage Rating Based Results

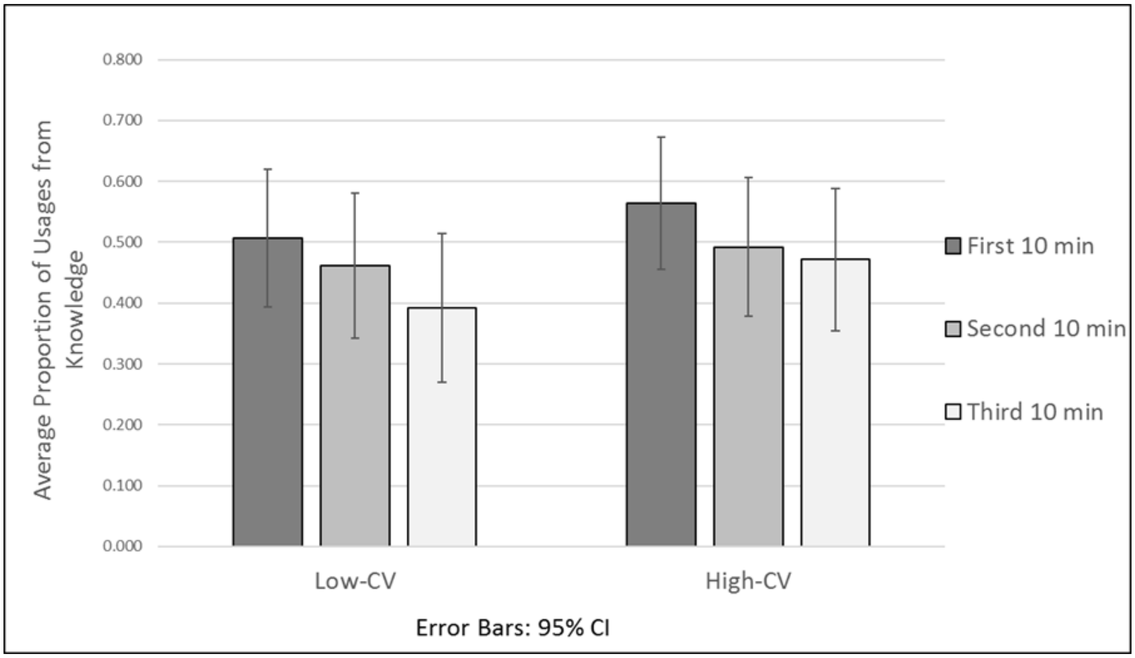

Figure 3.6. Proportion of Knowledge Usages from CV Conditions over Time.

Contrary to what was found in Experiment 2, proportion of usages judged to be from knowledge by participants did not differ between high and low-CV conditions, $F(1,46) = .56$, $p = .457$, $\eta_p^2 = .01$. However, the hypothesis that proportion of knowledge usages would differ as a function of time blocks was supported. As seen in Figure 3.6, the mixed-model ANOVA found a significant decrease in the proportion of usages judged to be from knowledge by participants across the three time blocks, $F(2,92) = 6.44$, $p = .002$, $\eta_p^2 =.12$. Furthermore, within-subject contrasts revealed this decline over time had a linear trend, $F(1,46) = 13.66$, $p = .001$, $\eta_p^2 =.23$. There was no significant interaction between time blocks and CV conditions on the proportion of knowledge usages, $F(2,92) = .37$, $p = .695$, $\eta_p^2 = .01$.

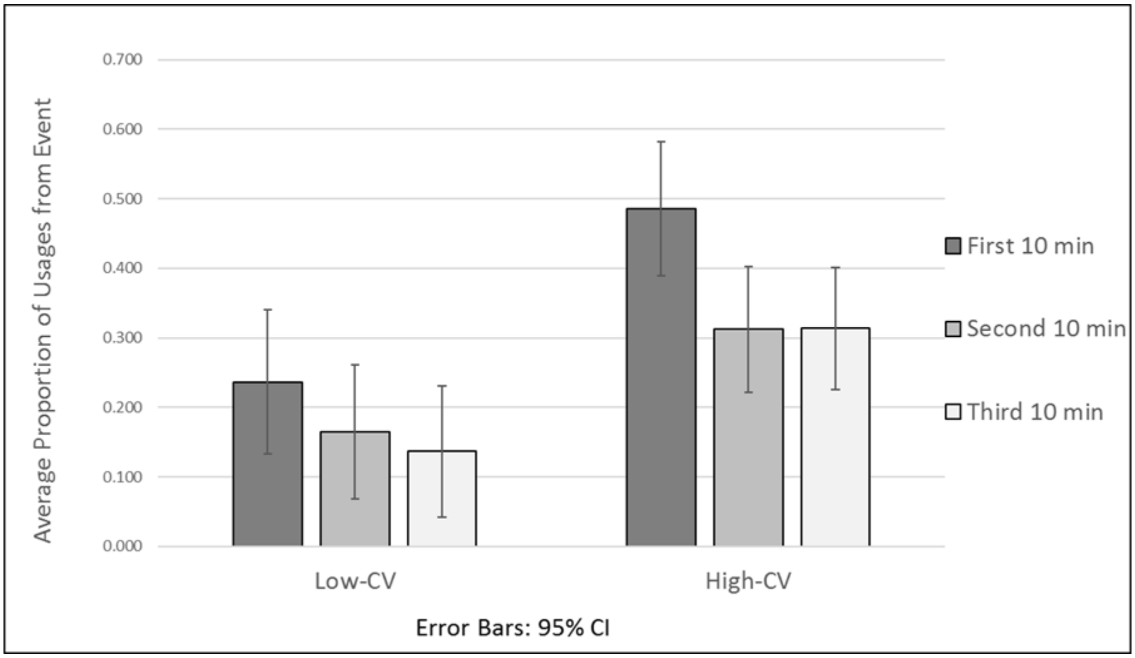

Figure 3.7. Proportion of Event Usages from CV Conditions over Time.

Similar to what was found in Experiment 2, proportions of event usages were judged to be higher by participants from the high-CV condition compared to those from the low-CV conditions (see Figure 3.7), $F(1,45) = 9.85$, $p = .003$, $\eta_p^2 = .18$. The hypothesis that proportion of event usages would differ as a function of time blocks was also supported, the mixed-model ANOVA found a significant decrease in the proportion of responses judged to be from event by participants across the three time blocks, $F(2,90) = 20.16$, $p < .001$, $\eta_p^2 = .31$. Furthermore, within-subject contrasts revealed this decline over time had a quadratic trend, $F(1,45) = 7.22$, $p = .01$, $\eta_p^2 = .14$. There was a marginally significant interaction between time blocks and CV conditions on proportion of event usages, $F(2,90) = 2.45$, $p = .09$, $\eta_p^2 = .05$. As seen in Figure 3.6, this interaction mainly reflects the sharper drop in proportion of event usages from the first time block to the later ones in the high-CV condition, compared to a smaller drop in the low-CV conditions.

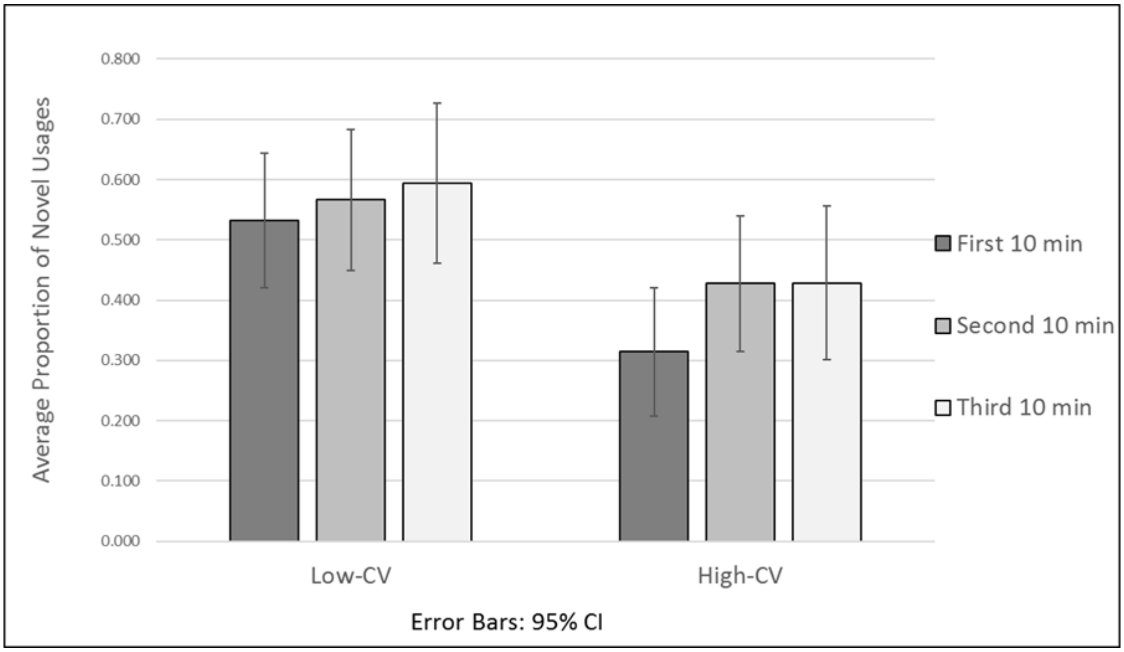

Figure 3.8. Proportion of Novel Usages from CV Conditions over Time.

Also similar to what was found in Experiment 2, proportions of novel usages were judged to be lower by participants from the high-CV condition compared to those from the low-CV conditions (see Figure 3.8), $F(1,46) = 5.32$, $p = .026$, $\eta_p^2 = .10$. The hypothesis that proportion of novel usages would differ as a function of time blocks was also supported, the mixed-model ANOVA found a significant increase in the proportion of responses judged to be novel by participants across the three time blocks, $F(2,92) = 5.02$, $p = .009$, $\eta_p^2 = .10$. Furthermore, within-subject contrasts revealed this increase over time had a linear trend, $F(1,46) = 6.67$, $p = .01$, $\eta_p^2 = .13$. There was no significant interaction between time blocks and CV conditions on proportion of novel usages, $F(2,92) = .90$, $p = .412$, $\eta_p^2 = .02$.

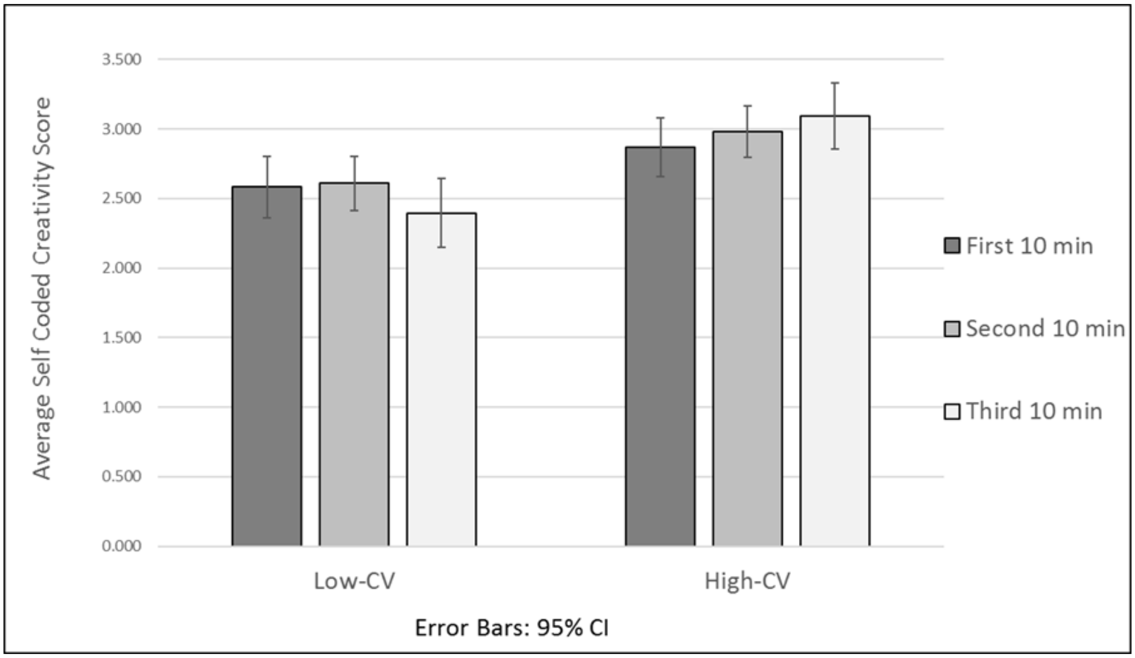

Figure 3.9. Self-Rated Creativity Scores from CV Conditions over Time.

Contradicting to what was found in Experiment 2, creativity scores rated by participants themselves were actually higher from the high-CV condition compared to the low-CV condition (see Figure 3.9), $F(1,46) = 10.86$, $p = .002$, $\eta_p^2 =.19$. The hypothesis that self-rated creativity should not differ as a function of time blocks was supported, as the mixed-model ANOVA found no significant difference across the three time blocks, $F(2,92) = .81$, $p = .447$, $\eta_p^2 = .02$. However, there was a significant interaction between time blocks and CV conditions on self-rated creativity scores, $F(2,92) = 7.14$, $p = .001$, $\eta_p^2 =.13$. Furthermore, within-subject contract revealed a linear trend in this interaction, $F(1,46) = 10.70$, $p = .002$, $\eta_p^2 =.19$. As seen in Figure 3.9, self-rated creativity scores increased slightly over three time blocks in the high-CV condition while they dropped slightly in the third time block in the low-CV condition.

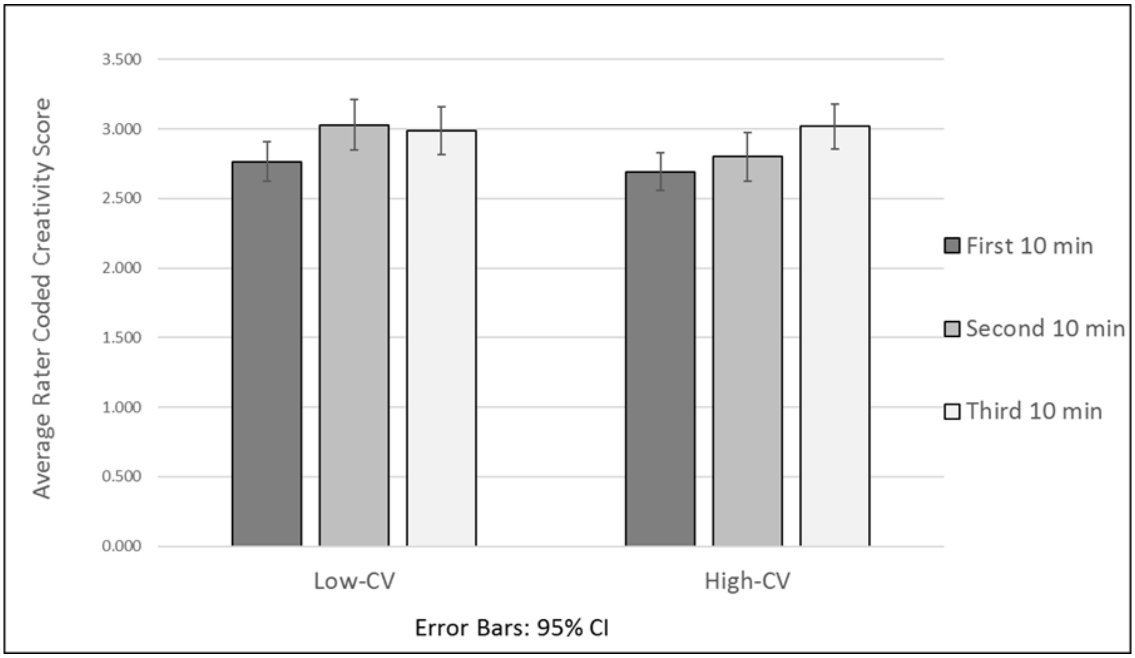

Figure 3.10. Coder-Rated Creativity Scores from CV Conditions over Time.

Contradicting to what was found in Experiment 2, creativity scores rated by coders were not significantly different between the high-CV condition and the low-CV condition (see Figure 3.10), $F(1,46) = .78$, $p = .381$, $\eta_p^2 = .02$. The hypothesis that coder-rated creativity should differ as a function of time blocks was supported however, as the mixed-model ANOVA found a significant increase in coder-rated creativity scores across the three time blocks, $F(2,92) = 19.48$, $p < .001$, $\eta_p^2 =.30$. Within-subject contract revealed that this increase in coder-rated scores had a linear trend, $F(1,46) = 33.41$, $p < .001$, $\eta_p^2 =.42$. There was also a significant interaction between time blocks and CV conditions on coder-rated creativity scores, $F(2,92) = 4.21$, $p = .018$, $\eta_p^2 =.08$. Furthermore, within-subject contract revealed a quadratic trend in this interaction,

$F(1,46) = 8.05$, $p = .007$, $\eta_p^2 = .15$. As seen in Figure 3.9, this interaction mainly reflects the difference in coder-rated creativity scores between high and low-CV conditions in the second time block, $t(48) = 1.73$, $p = .09$, $d = .48$.

Summarizing the rating based results, participants in the low-CV condition generated more novel usages and fewer usages based on episodic memory than participants in the high-CV condition. Unlike Experiment 2 however, usages generated from the high and low-CV conditions in Experiment 3 had similar creativity rating from coders when scores were averaged over 30 minutes. Creativity scores were only different between high and low-CV conditions when they were averaged across the second 10 minutes of the generation process. Taken these results together with consideration of findings from Experiment 2, memory reliance appeared to affect creativity in a less prominent manner when generation time is extended to a significant amount. These results would suggest that given enough time, direct usages from memory does not have the same amount of influence over creative usage generation as they normally would have with limited time for usage generation.

CHAPTER 10

GENERAL DISCUSSION

Empirical Support for the Oppositional Theory

The overall goal of the current experiments was to test predictions from the oppositional processes theory. Specifically, the theory predicts that direct retrieval from memory could interfere with the generation process and inhibit people from developing novel and creative ideas. Across three experiments, it was found that participants tend to generate more novel usages during the alternative uses task when the manipulation hinders their access to memory. Experimenter-coded creativity ratings for these generated usages were also higher under conditions of reduced memory accessibility in Experiments 1 and 2. Although this result was not as prominent in Experiment 3, it is possible that the effect of memory was diluted when participants were given much longer generation time than previous experiments. As we observed in Experiment 3, participants from both high-CV and low-CV conditions received similar creativity ratings from the experimenters during the first and last 10 minutes of the generation process; they were only different in their creativity ratings during the second 10 minutes of the generation process. This quadratic pattern indicated that given longer generation time, the effect of memory reliance may not alter creativity as consistently as it did in the previous two experiments.

The oppositional processes theory also made predictions based on the classic “serial order effect” found in alternative uses tasks (Beaty & Silvia, 2012; Christensen et al., 1957; Ward, 1969). In both Experiment 1 and 3, where time blocks were treated as a within-subject variable, participants were judged to be more creative during later time blocks than earlier ones. They also had more novel responses from later time blocks. Inversely, participants had more responses based on episodic and semantic memory from earlier time blocks which was consistent with prior findings (Gilhooly et al., 2007). These results supported the oppositional processes theory by showing that as reliance on memory decreased over time, creativity and novelty improved and thus producing the serial order effect in these tasks.

Across the three experiments, there were also differences in the cumulative generation patterns between more memory dependent conditions (i.e., old-usage and high-CV conditions) vs. less memory dependent conditions (i.e., new-usage and low-CV conditions). These differences existed because participants were less constrained by usages from memory in new-usage and low-CV conditions, so their generation patterns would not decelerate as much as the generation patterns created by participants from the old-usage and high-CV conditions. A recent study by Hass (2017) compared the generation curves from semantic recall tasks and the curves from the alternative uses tasks. He also found that while responses from both types of tasks decreased over time; the deceleration was greater in semantic recall tasks. Hass (2017) also found that response output in the alternative uses tasks do not cluster as much as the semantic recall tasks. Summarizing these findings, they showed that even though memory retrieval may still be involved during divergent thinking tasks, the underlying process is distinguishable from a more typical memory process involved in semantic recall tasks.

Throughout the three experiments conducted to examine the oppositional processes theory, both the methods of manipulating access to memory and the time allocated for idea generation were different from one experiment to another. Experiment 1 took a straightforward approach in manipulating memory accessibility by telling participants to either generate usages from memory or not from memory without any mention of creativity. Direct manipulation of memory accessibility in Experiment 1 turned out to be very effective in influencing the rater-coded creativity scores of the generated usages. However, this manipulation required changes to the instructions of the alternative uses task and effectively turned one condition into a recall task rather than a creativity task. Experiment 2 mitigated this problem by adopting a more natural approach using context-variability (CV) of object cue words to manipulate memory accessibility. Experiment 2 did not use the same generation time from Experiment 1 because the main focus of Experiment 2 was testing the new manipulation method. Results from Experiment 2 suggested that changing the CV of cue words during alternative uses tasks did affect the creativity of generated usages. Since the CV manipulation turned out to be successful in Experiment 2, the purpose of Experiment 3 was to replicate the same manipulation under much longer generation times to study how CV of cues may interact with time. Although the CV manipulation was not as effective as it had been in Experiment 2, its interaction with time provided much needed insight to the role memory plays during creative usage generation. Combining the results from the three experiments, they suggest that memory can have strong inhibitory effects of creativity during the alternative usages task; however, this effect is finite and can be overcome if enough time was given to the participant.

The oppositional processes theory was proposed and studied in this series of experiments in hopes that it can further our understanding of how people generate truly novel and original ideas beyond what they already know. The theory focuses on the relation between novel idea generation and direct retrieval of ideas from episodic and semantic memory. The theory states that these two processes can oppose and inhibit each other, and by suppressing direct memory retrieval (either through instruction in Experiment 1, or through giving participants less common objects in Experiments 2 and 3), creativity in generated ideas can be improved. The oppositional processes theory primarily focuses on the inhibition of memory and how this may lead to more creative idea generation. Although results from the three experiments provided some empirical support to the oppositional processes theory, the relation between memory and creativity can be multifaceted and our current theory may reflect only one aspect of this relation. There is in fact, another class of "constructive episodic simulation" theories that emphasizes how memory activation and recombination can facilitate creative idea generation (Addis, Pan, Musicaro & Schacter, 2014; Addis & Schacter, 2012; Benedek et al., 2014; Schacter, Addis & Buckner, 2007). It is important to compare, contrast and potentially consolidate the oppositional processes theory and the constructive episodic simulation theory to further our understanding of the relation between memory and creativity

The Constructive Episodic Simulation Theory

The constructive episodic simulation theory stated that imagining the future and remembering the past share common neural networks and that the imagination of the future requires recombination and activation of episodic details from the past (Addis et al., 2014; Addis & Schacter, 2012; Schacter et al., 2007). Imagination of the future is linked to creativity in divergent thinking tasks through the need to simulate a variety of plausible alternatives to a given cue. In one study, Addis et al. (2014) gave participants short events and asked them to fill in details for these events by either imagining that the events had happened in the past or will happen in the future. They also gave participants the alternative usages task and scored their creativity. Addis et al. (2014) found that creativity rating from the alternative usages task was correlated with number of episodic details participants included in their imagination of future events. Benedek et al. (2014) provided further support for constructive episodic simulation theory with neurophysiological evidence. Benedek et al. (2014) collected fMRI data from participants while they performed alternative usages tasks. They also asked participants to judge whether the generated usages came from memory or were novel. Benedek et al. (2014) found that the left inferior parietal cortex (i.e. an area associated with episodic retrieval) had higher activation during novel usage generation compared with old usage generation.

At first glance, findings and claims to support the constructive episodic simulation theory appear contradictory with the oppositional processes theory. The constructive episodic simulation theory suggested that episodic memory retrieval and its activation of associated neural regions are necessary for novel usage generation; while the oppositional processes theory suggested that ideas directly retrieved from memory tend to be less creative than novel ones and people can be more creative by suppressing direct retrieval from memory. Upon closer examination to the constructive episodic simulation theory, however, it is revealed that direct retrieval from memory should not favor creative generation either. In Addis et al. (2014), while creativity ratings from output during the alternative uses task were correlated with the number of episodic details in future simulations; they were not correlated with the number of episodic details from past events. This result suggests that the ability to recall events from the past is not associated with creativity and that it is the usage of those features for simulating future events that correlates. In another study, Addis, Chen, Roberts and Schacter (2011) found that recombination of past episodic details to construct specific events in the future involves greater activation from the hippocampus region than remembering generic events (Addis, Cheng, Roberts & Schacter, 2011). These results suggested that direct retrieval of higher frequency (i.e., generic) events and reconstruction of more elaborate events using episodic details are very different processes; furthermore, only the reconstruction of elaborate events using episodic details can be related to creative idea generation.

Reconciliation of the Two Theories

Based on these findings, a possible reconciliation between the apparent discrepancy between the constructive episodic simulation theory and the oppositional processes theory can be deducted. Generally speaking, the constructive episodic simulation is better suited when the retrieved details from memory are more remote from the common usages of the object cue in the alternative uses task. The oppositional processes theory is better suited when one simply retrieves usages close to the common and most frequent usages associated with the object cue in the alternative uses task. Therefore, on one hand, memory can help improve creativity when more remote concepts are retrieved (i.e., the constructive episodic simulation theory); on the other hand, memory accessibility could harm creativity when more common and salient concepts are retrieved (i.e., the oppositional processes theory). The oppositional processes theory can now be further elaborated after this consolidation with the constructive episodic simulation theory. The oppositional processes theory still regards novel idea generation and memory retrieval as two opposite processes and may hinder each other. However, novel idea generation process may now be viewed as a reconstruction process based upon simulated episodic details. Similarly, the memory retrieval process is now more specifically retrieval of unaltered and common ideas without further effort to reconstruct them in novel patterns. In other words, the oppositional process theory is about direct usage retrieval during the alternative uses task and how such retrieval interferes with simulation of contexts and/or novel episodic pairings of details.

It is important to take both theories into consideration when interpreting results from the three experiments conducted in this study. In Experiment 1, the constructive episodic simulation theory helps explain why participants still claimed that some of their usages came from semantic and episodic memory even when they were told not to generate usages from memory. This happened because they still require retrieval of certain episodic details in order to recombine them and generate novel usages. The instruction for participants in the new-usage condition did not suppress all retrieval from memory, rather, it was successful in inhibiting the most obvious and common usages associated with the object cue, therefore allowing participants to be more creative.

The context-variability (CV) manipulation in Experiments 2 and 3 proved important to validate the oppositional processes theory especially considering what the constructive episodic simulation theory may predict in this situation. Because the high-CV cues normally have more episodic details and therefore greater amount of retrieval associated with them; the constructive episodic simulation theory may predict that having high-CV cues can improve creativity. Inversely, the oppositional processes theory would predict low-CV cues can improve creativity because they naturally facilitate easier inhibition with less common usages associated to them. Result showed that low-CV indeed allowed participants to be more creative in Experiment 2. This result demonstrates that under tighter time constraint, inhibition of direct common usages was more important than greater number of episodic details associated with a cue. Interestingly, in Experiment 3, the benefit from inhibition of direct usages in the low-CV condition and the benefit from greater activation of episodic details in the high-CV condition appeared to be equal when participants had a sufficient amount of time to generate usages (i.e., null result in coder-rated scores between conditions). It was possible that time affects inhibition and retrieval from memory differently. Retrieval of details became more prevalent when more time was given to participants; while inhibition of common and salient usages became less prevalent as the usages were exhausted in both conditions.

Overall, when compared to the constructive episodic simulation theory, the oppositional processes theory placed more emphasis on the role of inhibiting salient and common memory and how it promotes creativity. Chrysikou, Motyka, Nigro, Yang and Thompson-Schill (2016) provided further support for the oppositional processes theory by showing the downside of enhanced activation of common and salient information during the alternative uses task. Chrysikou et al. (2016) compared participants' generated usages when the cues were presented with either only word texts, word texts with pictures, or only pictures. They found that participants tended to stick to more common and ordinary (i.e., less creative) usages of the object when the picture was present. This result suggested that enhanced activation of the more common and salient information provided by the picture cue had a constraining effect on people's output during creative generation. In a more general sense, past research has shown that cognitive inhibition can be linked to creative idea generation. Benedek, Franz, Heene and Neubauer (2012) measured cognitive inhibition through random motor generation tasks and a variety of divergent thinking tasks similar to the alternative uses task. They found that cognitive inhibition was positively correlated with fluency during divergent thinking tasks. Groborz and Nęcka (2003) also studied the relation between cognitive inhibition and creativity. They found that the reaction time for incongruent items in tasks such as the Stroop task was lower in participants who had higher creativity; meaning participants with greater cognitive control can be more creative. These results suggest that there exists some relation between cognitive inhibition and creativity and the effect they have on each other can go both ways. The oppositional processes theory elaborates this relation in the sense that creativity can be improved when more common and salient ideas associated with the task are inhibited.

Future Directions and Conclusions

Following this line of discussion on cognitive inhibition and creativity, one very promising future direction to study is the relation between various cognitive abilities (especially memory related ones) and how they may predict one's creative potential. The main purpose of this future study is to provide support that memory retrieval and inhibition can be statistically related to creativity as proposed by oppositional processes theory. A second purpose of this study is to explore how memory retrieval and inhibition in episodic and semantic domains explains shared variance between divergent thinking and other cognitive abilities (i.e., general-fluid intelligence; gF). Past research has found that creativity in divergent thinking tasks was correlated with gF as well as executive functions such as updating and inhibition (Benedek et al., 2012; Benedek, Jauk, Sommer, Arendasy & Neubauer, 2014). Replicating previous findings on creativity and gF and exploring the relations between creativity and long-term memory tasks are important and can also provide another form of support for oppositional processes theory.

Another future study worth pursuing is one where both manipulation methods used in the current experiments are combined. Such a study can shed light on how retrieval and inhibition of memory interact with each other during divergent thinking tasks. For example, if inhibition of direct retrieval is forced through instruction (i.e., new usage task), one could potentially predict participants given high-CV cues can now be more creative because there are more episodic details involved with them. Studying the relation between inhibition and retrieval of memory help further consolidate the oppositional processes theory and the constructive episodic simulation theory. Such studies should also provide us with a more complete picture of how memory affects creativity in general.

In conclusion, the oppositional processes theory was inspired from numerous previous works on divergent thinking that found the “serial order effect”, structural similarities between alternative usages and semantic fluency tasks, and theoretical developments in the episodic future simulation literature. We developed the theory that made predictions regarding how memory accessibility can inhibit creative idea generation and designed experimental manipulations to offer empirical support for the oppositional processes theory. Our experimental manipulations involved altering people’s level of memory reliance during divergent thinking tasks. Even though some theory and findings claim that retrieval of episodic details can serve as backbone to construction of creative ideas; results from our experiments generally confirmed the oppositional processes theory by showing that participants with less activation of common and salient information from memory tend to be more creative. These results point to possible interventions that may work to improve human creativity and potential.

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