MEMORY FOR OBJECT IN CONTEXT AND CONGRUENCY:

AN EYE TRACKING STUDY OF OBJECT MEMORY IN FULL TERM AND PRETERM SAMPLES

By

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Abstract

The object in context paradigm was used to examine the effects of context and semantic congruence on object recognition memory for 6 adults born prematurely and 6 adults born full term. An eye tracker was used to track saccades during encoding and recognition phases for objects appearing in semantically congruent, incongruent, or fourier transform backgrounds. At recognition, the objects remained in the same context or were removed to a white background. Analysis revealed no accuracy differences for the preterm and full term group, but the preterm group spent more time looking at the background relative to the object than the full term group. Overall accuracy was lower for incongruent and Fourier transform conditions than congruent trials for both groups, but the effects of context were consistent across conditions. Implications and future directions will be discussed.
Introduction

The Importance of Memory and Context

Memory is essential to normal functioning in every day life. We need to remember where we put our car keys, the time of our appointments, where our appointments will be, and whom we will meet. In academics, success in any given college course or job is often due in large part to successful encoding and retrieval of information at one point or another. In our personal lives, we remember events we experience with individuals every day. Moreover, all of these episodic events occur within a context, and that contextual feature can have some very interesting impacts on how well or poorly we may be able to recall these memories when we need them.

Contextual sensitivity is a very important feature of our episodic memories; information is better remembered when it is probed in the original learning context. Tulving and Thomson’s (1973) Encoding Specificity model revolutionized the way we look at the interplay between context and memory when they proposed that matching input cues during encoding would facilitate recall in episodic memories. Another landmark study by Godden and Baddeley (1975) taught experienced divers a list of words underwater and on land. Finding that context was indeed a very important component of learning, the divers had better recall for words learned underwater while underwater and the same for the words learned on land. One very recent study by Staudigl, Vollmar, Noachtar, and Hanslmayr (2015) found reinstatement of neural patterns during a task displaying words over movies was degraded when the encoding context [in this case the background movie] did not match, but highly beneficial when it did, thus providing even further evidence of the importance of context on memory. Given the importance of
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episodic memory in daily function, and that every memory we seek to encode occurs within a context, it is easy to see why contextual facilitation of memory encoding and retrieval has continued to be an interesting subject in the area of memory research.

**The Object in Context Paradigm**

One paradigm investigating the impact of context on memory is an object-in-context paradigm, which utilizes a set of pictures with objects centered within a 2 dimensional natural visual scene (Hayes, Nadel, & Ryan, 2007). The participants are instructed to intentionally encode the target object embedded in the scene. At test, usually 5 minutes later, the context of a target object shifts from a visually rich scene to a new background, and recognition for the object is negatively impacted. This difficulty recognizing an object when shifted from one background scene to a new one is referred to by Hayes et al. (2007) as a context shift decrement (CSD). In the same study, a CSD of this type was found on the basis of functional magnetic resonance imaging (fMRI) to be largely associated with parahippocampal functions. Emerging evidence implicates parahippocampal activation to be largely responsible for domain-specific processing, that is relational binding (between scene and object) is inflexible where it is Parahippocampal dependent, while hippocampal activation is established as a more flexible and domain-general processing (Davachi, 2006). Finding successful recognition of an object to be associated with parahippocampal activity led Hayes at al. (2007) to conclude encoding of objects in scenes requires automatic binding of the target object with the scene, rather than independent encoding of the object. More recently, Edgin, et al. (2014) found that this CSD was not present in children between 4.5 to 13 years of age, although it was present for younger preschoolers and adults. The lack of context dependence in the
school-aged children was interpreted as a reflection of developmental changes during childhood. Specifically, Edgin et al. hypothesized that infants and memory impaired groups rely on a more unitized representations (i.e., objects and scenes are processed as a whole), modulated by cortical and parahippocampal regions, relative to adults, who have more flexible type of encoding processes the object and the scene as different representations that can be configured flexibly. This flexible encoding may rely on the hippocampus. Finally, the re-emergence of context effects in adults could be due to better encoding of object-scene relations or an increasing benefit of the semantic associations in the scene content. Therefore, we varied semantic content to determine if it modulated context effects.

The Importance of Semantic Congruence in Object Recognition

For the purpose of this paper, congruency will be defined as objects that are semantically congruent with a scene, that is, they seem to belong in their context due to a high frequency of associations between a target object and a particular context (i.e. dishes in a kitchen, towels in bathroom, etc.). Congruency has been demonstrated to aid in facilitation of episodic memory, as it is thought to provide memory cues helpful during the retrieval phase of memory (Crespo-Garcia, Cantero, Pomyalov, Boccaletti, & Atienza, 2010). Additionally, congruency is thought to be important for binding of an object and background during encoding (Hayes et al., 2007). Encoding of congruent scenes and successful retrieval appears to be highly associated with connectivity between the prefrontal Cortex and the medial temporal lobe (Atienza, Crespo-Garcia, & Cantero, 2011).
It is possible the benefit of context on object recognition stems from the unitized representations provided by the parahippocampal gyrus. Upon presentation of an object outside of its context, recognition may be disrupted due to the requirement of recalling only a part of a bound representation. If this is the case, then a CSD should be observable at an equal rate regardless of the level semantic information provided by the context the object appeared in at encoding. The only relevance of context lies in how well the object may be bound to the context.

On the other hand, it is also possible semantic congruency’s ability to facilitate episodic memory is the same mechanism responsible for the CSD. If this is the case, context benefits may relate to our use of prior semantic knowledge during encoding. That is, when we encode a representation, we draw on our knowledge from past experiences to support that memory representation. In this case, we should expect that meaningful congruent associations would be helpful for memory, as adults will have more information to draw on to support flexible representations. Support for this view comes from behavioral and imaging studies that have found congruence aided in relational binding (Brod, Werkle-Bergner, & Shing, 2013; Staresina, Gray, & Davachi, 2009). Furthermore, we know memory congruence relies on reverberating connections between the prefrontal cortex and hippocampus (Atienza et al., 2011), with these connections showing a slow trajectory of development over time (Maril et al., 2011). In the Edgin et al. (2014) study, for instance, the authors suggested this type of flexible memory, supported by the hippocampus and its connections to cortical regions like the prefrontal cortex, is what might underlie the adult context effect. Drawing together the literature on the CSD and memory congruence, we should expect meaningful context is
optimal for encoding in adults. Therefore the CSD would be greater when objects are initially encoded in meaningful scenes, and then have to be recalled without access to that initial meaningful context. That is, the CSD will be bigger for semantically congruent scenes relative to semantically incongruent scenes or scenes with no semantic information (Fourier Transform).

The Importance of Investigating Individuals Born Premature

One population that might help to inform studies of memory and hippocampal function is individuals born premature. The average full term gestation period of a human being is 40 weeks, however significant medical advancements have allowed viability of births even earlier than 28 weeks (extremely preterm). Although extremely preterm births are rare, very preterm (<32 weeks) and preterm (<36 weeks) births make up close to 10% of births. In fact, preterm birthrates are on the rise (Kavsek & Bornstein, 2010). As preterm birth rates rise, it is becoming increasingly important to study the effects of preterm birth on the development and cognitive functioning capacities of preterm children. It is well established that preterm children are at a significantly elevated risk for many neuropsychological, behavioral, social, and cognitive deficits (Anderson & Doyle, 2008; Johnson, 2007), but with the improvement of technologies, older research may no longer produce an accurate profile of developmental issues caretakers should be aware of. Moreover, there is relatively little data on episodic memory in those born preterm, particularly in adulthood, despite well-documented learning difficulties.

Individuals born premature tend to have smaller hippocampi, less enfolded (different shaped hippocampi), and greater asymmetries between hippocampi (Thompson
et al., 2013). Lower cerebral volumes on average and white matter abnormalities have also been documented in infants born preterm (Counsell, Allsop, Harrison et al., 2003). Additionally, prematurity is associated with more brain activation on memory tasks (activity in more areas than in controls), but most tend to perform as well as individuals born full term (Naberhaus, 2009). There is some evidence that individuals born prematurely begin to show memory impairments when task difficulty is high (Vicari, Caravale, & Carlesimo, 2004), however. Many studies agree executive function is also impaired in children as well as adolescents who were born prematurely (Aylward, 2014; Burnett, Scratch, & Anderson, 2013). As noted in previous work, the object in context paradigm appears to be facilitated by areas of the brain made vulnerable by prematurity. These potential differences in memory processing make individuals born prematurely an especially interesting group to examine with this task.

**Eye Tracking for Object in Context**

In a study assessing visual fixations related to congruent and incongruent objects in contexts, Loftus and Mackworth (1978) found incongruent scenes were fixated on earlier and for a longer period of time compared to congruent scenes when the same scene was presented with a congruent and incongruent object in the center at the same time. This task differs greatly from our paradigm, which displays only one scene and object set at a time, with a novel scene and object for each stimulus. Although this study did not assess memory, Loftus and Mackworth (1978) proposed the reason participants may be focusing on the incongruent scenes longer is part of a memorization strategy. A more recent study on visual attention divided semantic congruency and what they termed “syntactic,” that is spatial congruency (i.e. objects obeying the laws of physics) and
suggested the two types of congruency may be processed differently; for the purpose of this study we focused exclusively on semantic component of congruency. In the same study, objects that were semantically incongruent with the scene were found to be recognized slower and associated with longer fixations on the scenes compared to congruent objects (Wu, Wick, & Pomplun, 2014). Understanding the guidance of visual saccades while viewing objects in semantically congruent and incongruent scenes may help us better understand any differences that may arise between individuals born premature compared to full term.

Aims

The purpose of this study will be to examine the effects of congruent and incongruent context on memory of objects. Each participant viewed all of the conditions in a single sitting, was given a short break, and then asked if they recognize the objects they saw amongst lures. We were interested in using the eye tracker to examine differences in the way full term adults and adult individuals born prematurely are encoding and recognizing objects in scenes. Consistent with findings from previous studies, we predicted both groups would do most poorly when an object shifted from a scene to a white background. Furthermore, we predicted switching from a congruent background to a white background would be particularly difficult, due to expected benefit of semantic cues at recognition. Consistent with visual attention studies (Wu et al., 2014), we predicted fixations on the background would be significantly longer for objects in incongruent backgrounds. Fourth, we predicted the preterm group would do more poorly overall than individuals of the same age, as this task requires areas that may be made vulnerable by prematurity (Thompson et al., 2013; Hayes et al., 2007). We also
expected to find the preterm group spending more time looking at the background rather than the objects due to deficits maintaining attention control, as suggested by research on executive function in adolescents and early adulthood individuals born preterm (Burnett, Scratch, & Anderson, 2013). Finally, we suspected individuals born prematurely may not receive as much benefit from congruence due to limited connectivity between the prefrontal cortex and hippocampus, and so might perform poorer overall in the congruent condition (Counsell et al., 2003), a finding that would help us understand the source of the context effects found in previous work.

**Method**

**Participants:**

There were 12 participants in total in the study, each receiving the same consenting, testing, and debriefing consistent with IRB approval. Participants were recruited from introductory psychology courses and given course credit for participation. Participants ranged from 18.83 to 21.46 years of age at the time of testing. There were 9 females and 3 males in total. There were 5 females in the preterm group and 4 females in the full term group. Participants were grouped into Full Term and Preterm groups with 6 students in each group. Participants were categorized as Full Term if gestational age was greater than 39 weeks (39-40 weeks represented in sample), and categorized as individuals born Preterm if gestational age was less than 37 weeks (27-36 weeks represented in sample; 3 at <33 weeks; 3 between 34-36 weeks). Gestational age was based on self-report and confirmed with medical records where possible. All participants were included in the analysis, but two participants’ IQ scores were discarded from analysis because their scores were invalid (nonnative English/Spanish speaker).
Procedures:

The University of Arizona IRB approved all procedures. Participants attended two appointments in a University-based laboratory. During the first session (approximately 1.5 hours), participants completed a demographic survey form, the Kauffman Brief Intelligence Test 2 (Kaufman & Kaufman, 2004), and several assessments of memory and numerical ability. The experimental task in this study was administered during a second one-hour session. Participants received course credit or financial compensation.

Measures:

Stimuli were created using Adobe Photoshop 6 and programmed with SMI software created for use with the Eye Tracker. During consenting, participants were told we were studying memory for objects in backgrounds. All participants were tested individually and in the same room using the same equipment and procedures. Participants were told they will see a series of everyday objects (e.g., a hair brush, a bag) in different household scenes on a computer screen, and should try to remember the objects in the center of the screen while an eye tracker records their saccades. Eye tracker data was collected using SMI iView Red-m eye-tracking in Experiment Center 3.4 (Sensomotoric Instruments, Inc, Boston, MA). Participants were between 60 and 75 centimeters from the eye tracker and monitor. Eye tracker was mounted to the bottom of a 53x23 cm screen. Calibration was performed before encoding and before recognition until X and Y results yielded scores < 1.0 for both.

During the encoding phase of the experiment, there were 3 conditions consisting of 30 stimuli: Congruent, Incongruent, and Fourier Transform. Congruent stimuli
consisted of objects paired with scenes that would be typical in everyday life (e.g. a
television remote controller on a coffee table), while incongruent stimuli consisted of
objects paired with scenes atypical of everyday life (e.g. a shoe on a table). These
pairings were based on pilot ratings with a small group of college-aged participants.

During recognition, there were 10 conditions (3 original stimulus, 3 original
object paired with a white or new background, and 4 lure conditions):
Congruent, Congruent, Congruent, White, Incongruent, Incongruent, Incongruent, White,
FourierTransform, FourierTransform, FourierTransform, White, Lure, White,
Lure, Congruent, Lure, Incongruent, Lure, FourierTransform.

Stimuli were presented at random across all conditions in a single encoding block
and single recognition block. Participants viewed a fixation slide (see below) set to
change when participants looked at a central fixation target for 500ms, and were able to
view each stimulus for 3000ms during both encoding and recognition phases consistent
with Edgin et al., (2014). Three seconds for retrieval was chosen based on our pilot data
suggesting that some children required over 2 seconds to respond. During the recognition
phase, participants were asked to respond verbally with a “yes” or “no” whether they had
seen the object in the center of the screen during the previous encoding phase. An
experimenter entered verbal responses manually during an answer prompt stimulus
immediately following the test stimulus. Finally, participants were administered the
KBIT II, a brief intelligence test to match participants across conditions if the KBIT II
was not administered during the first testing session. Test Retest reliability for the KBIT
II has been shown to be high (scores for all three subtests range between 0.76-0.93) for
ages 4-90 years. Internal consistency reliability has also been demonstrated for all three
subtests in ages 4 to 90 years (0.78-0.96). Validity has also been demonstrated by high correlations with multiple comparable cognitive ability tests. The KBIT II includes three subtests demonstrating verbal knowledge, problem solving for matrices and riddles. The verbal knowledge portion of the test assesses receptive knowledge, asks a participant to point to one of six pictures in a booklet with prompts asking for general information such as nature, geography, arts, and science. The riddle portion assesses comprehension, reasoning, and vocabulary knowledge by asking participants to point to a picture or respond verbally to answer the riddle. In the matrices section, people, objects, designs, and symbols are pictured in a booklet and the participants are assessed on their ability to understand the relationship between the pictures (Kaufman & Kaufman, 2004).

During debriefing, the object in context paradigm and developmental nature of this study was explained. The scenes and conditions are paired as presented in table 1:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Encoding Phase</th>
<th>Recognition Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congruent</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

(Kaufman & Kaufman, 2004)
### Incongruent

<table>
<thead>
<tr>
<th>Incongruent</th>
<th>Incongruent</th>
<th>Incongruent White</th>
<th>Incongruent White</th>
</tr>
</thead>
</table>

### Fourier Transform

<table>
<thead>
<tr>
<th>Fourier Transform</th>
<th>Fourier Transform</th>
<th>Fourier Transform White</th>
<th>Fourier Transform White</th>
</tr>
</thead>
</table>

### Lures

#### Recognition Phase Only

<table>
<thead>
<tr>
<th>LureCongruent</th>
<th>LureIncongruent</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LureFourier Transform</th>
<th>LureWhite</th>
</tr>
</thead>
</table>
Fixation Target

Table 1: Example stimuli presented for each phase and condition.

All objects and scenes came from Internet searches. Stimuli were color and size matched for each set across encoding and recognition phases. All objects were centered and sized to fit into a 14x10cm box, which was subsequently used as the area of interest for the eye-tracking data analysis.

Results

General Cognitive Ability

Table 2 shows the mean verbal, performance, and full scale IQ scores for the preterm and full term groups. The groups did not differ significantly in any of these standardized cognitive test scores.

<table>
<thead>
<tr>
<th>Group</th>
<th>FT</th>
<th>PT</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Score</td>
<td>96.25 (6.70)</td>
<td>104 (11.65)</td>
<td>1.19</td>
<td>.27</td>
</tr>
<tr>
<td>Performance Score</td>
<td>103 (10.34)</td>
<td>107.33 (12.79)</td>
<td>.61</td>
<td>.56</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>97.25 (5.91)</td>
<td>107 (13.21)</td>
<td>1.37</td>
<td>.21</td>
</tr>
</tbody>
</table>

Table 2: Mean verbal, performance and full scale IQ scores for the study groups

Object in Context Task Accuracy
Figure 2 shows the accuracy data by condition for the Preterm and Full Term groups. Given that the mean accuracy during the lure trials was close to ceiling (>90%), we did not consider these trials in subsequent analyses. We also removed them from the graph as a result. A repeated measures ANOVA with condition (congruent, incongruent or fourier transform) as the repeated effect and context switching and gestation group as factors showed a significant main effect of condition, $F(2,40) = 5.16, p = .01$, with follow-up paired samples t-tests showing that accuracy was lower for the Incongruent and Fourier Transform trials than the congruent trials. There was also a significant context switch effect, $F(1,20)=6.53, p = .02$, where accuracy was lower when objects were transferred to new contexts in the recall phase, regardless of the type of trial. No interaction was found between conditions and switching. There was also no effect of group on accuracy, and there were no interactions by group.

Figure 2. Mean Accuracy in the full term and preterm groups during different conditions of the Object in Context Paradigm. Lures have been removed due to accuracies >.90 and nonsignificant differences between conditions.
Eye Tracking Results: Encoding Phase

As illustrated in Figure 3, a main effect of condition was found in terms of proportion of time spent looking at the object relative to the background context (proportion of looking time) in the encoding phase of the Object in Context task, $F(2,20)=4.44, p = .025$.

Specifically, participants looked at the object more during the fourier transform trials relative to the congruent and incongruent scene trials. Although the mean time spent looking at the background relative to the object was longer in the preterm group, this effect did not reach significance and there were no interactions between group and condition.

![Figure 3: Proportion of time spent looking at the object relative to the background context during the encoding phase of the Object in Context task](image)

Eye Tracking Results: Recall Phase

Figure 4 shows the proportion of time spent looking at the object relative to the background by condition for each group during the recognition phase of the Object in Context Task. We performed a repeated measure ANOVA with condition (congruent, incongruent, fourier transform) context switch, and group as factors. There was a trend for a three-way interaction between condition, context switching and group, $F(2,40)=3.0, p=.06$. The preterm group spent less time looking at the object during the no-switch
trials, specifically during the no-switch congruent and no-switch incongruent trials. There was also a two-way interaction between the switch effect and condition, $F(2,40)=14.22, p<.001$. Both groups spent more time looking at the background when it was a congruent or incongruent no-switch trial relative to the fourier transform trials. Additionally, a main effect was found for condition in general: participants looked longer at objects when it was a congruent or incongruent background, as opposed to a fourier transformed background, $F(2,40)=13.62, p<.001$. There was a main effect of switching, $F(1,20)=4.65, p=.04$. Participants looked longer at the object during switch trials compared to no-switch trials. Finally, there was a main effect found of group, $F(1,20)=4.75, p=.04$. Individuals born preterm tended to look less at the object and more at the background than those born full term.

Correlations between accuracy and viewing times

It was possible that looking preferences hinged on accuracy, because we used a fairly lengthy 3-second eye tracker interval. Therefore, to determine whether there was a relation between accuracy and looking time, we looked at correlations between accuracy...
and proportion of looking time. There was no significant correlation found between the
time spent viewing the object relative to the scene and individual accuracy at recognition,
\( r = .02, p = .96 \). There was also no correlation found for time spent viewing the object
relative to the scene and accuracy during the recognition phase, \( r = -.346, p = .27 \)

**Discussion**

We sought to understand differences in individuals born premature and full term
differ in memory performance for objects in semantically related and unrelated scenes.
In keeping with our hypothesis, both groups showed poorer performance when a context
shifted, but, running counter to another hypothesis, there were no significant group
differences in accuracy for either group. Additionally, the CSD was not more
pronounced in the congruent context condition, although the Fourier transform and
incongruent context conditions had lower overall accuracy for both groups, which also
countered one of our hypotheses. Also countering our hypothesis, the preterm group did
not appear to receive less benefit of context with no significant differences in
performance compared to the full term group in terms of accuracy. In keeping with the
hypotheses eye tracking data did reveal some differences between the groups, though
both groups did not look longer at the incongruent scenes as suggested. The eye tracking
data revealed both groups spent more time looking at the background for congruent and
incongruent contexts compared to Fourier transform contexts, leading us to conclude our
earlier hypothesis that participants would spent more time looking an incongruent
backgrounds cannot be confirmed. In confirmation of our other eye-tracking hypothesis,
the preterm group looked longer at the backgrounds relative to the objects during the
recall phase across all trials compared to the full term group. This study has multiple implications for understanding the effect of context on memory.

Behavioral

The results indicate a context shift is detrimental at recognition across contexts with or without semantic information, regardless of whether an individual is born full term or preterm. This is in keeping with decades of research (Godden & Baddeley, 1975; Staresina, et al., 2009; Atienza et al., 2011). In further support of this effect, the high accuracy for the lures across all conditions indicates that our effect is genuine and not caused by confusion or apathy on the part of participants. However, the lower overall accuracy between the semantically rich congruent context and the semantically confusing or nonexistent Incongruent and Fourier transform conditions suggest semantic information may facilitate the general recognition level, but not mediate the context shift.

Eye Tracking: Encoding

At encoding the eye tracker showed participants spent more time looking at the object in Fourier transform trials compared to Congruent or Incongruent trials in both groups. We believe this result indicates participants were most drawn to the object, as it was the only informative piece on the screen at that moment in the Fourier Transform condition. Additionally, the mean time spent looking at the object relative to the background was trending toward a significant difference in the preterm group, with more time spent on the background, not the object (opposite the effect in term born controls). Contrary to the hypothesis, the incongruent scenes did not attract significantly more saccades than congruent scenes for either group. However, our design differed from Wu et al.’s paradigm (2014) that placed incongruent scene/object pairings throughout the
scene, but our objects began in the middle of the screen. The placement of a number of incongruent objects could have led to more background scene viewing in that study.

**Eye Tracking: Recognition**

Again, we found participants looked significantly less at the Fourier transform backgrounds. Interestingly, at recognition the preterm group spent more time looking at the background in general compared to the full term group. Our hypothesis proposed this group effect is likely due to less efficient encoding or retrieval processes (Burnett et al., 2013). However, in light of the accuracy data suggesting no significant group differences in accuracy, it is more likely that our results suggest individuals born premature may require more processing of the background scene to determine if an object was seen. Neuroimaging investigations may reveal brain differences in the neural substrates guiding encoding and retrieval given these results. Additionally, significant differences were found between switch and no switch trials for congruent and incongruent trials, but in these trials the participants would have been looking at the background. Therefore, we should expect them to spend time looking at the object instead of the blank space.

**Behavioral and Eye Tracking-Exploratory Analysis**

In order to determine whether there was a relation between accuracy and time spent looking at the object or background, we looked at correlations between accuracy and proportion of time spent looking at the object relative to the background. We wanted to make sure that the differences between the full term and preterm groups were not simply the more accurate a participant was; the more they could look around. This doesn’t seem to be the case, as all correlations were not significant in both the encoding and recognition phases. In interpreting this data it is important to stress the point we
can’t assume we’re capturing all of the processing with the eye tracker, as there is very likely covert attention as well.

**Broader Implications**

The results from the eye tracking data suggest individuals born premature may be looking at the world differently, and perhaps this is indicative they may be processing the world differently. Furthermore, we think our data supports the view that semantic information is not responsible for the CSD, although semantic information appears to have its own independent effect benefitting overall memory performance. Future work should examine the neural basis of these effects in preterm infants and across levels of congruency.

**Limitations**

The most apparent limitation of this study is the small sample size. More important than the sample size, however, is the type of sample. Our preterm group consisted entirely of college students, who are obviously successful individuals. Within our preterm group there was high variability both in terms of gestational ages and medical histories, as well as performance. College students, although often varying in background and cognitive abilities, represent a population that has developed successful coping strategies for any previous cognitive, economic, etc. limitations. Therefore, our preterm sample is representative of a highly functioning sample, and not likely an accurate reflection of memory performance in adulthood for all individuals born prematurely, as individuals born prematurely make up a very broad spectrum of outcomes. Nevertheless, it is important to recognize high neuroplasticity may account for the successful outcomes of preterm individuals with highly successful outcomes as
observed in our sample. Further, the sample described here is very divided between mildly and very preterm individuals. Future work should focus on groups born at earlier gestational ages (<32 weeks, specifically). Despite these limitations, there does appear to be some subtle differences in their processing of the task, which could help us to determine the mechanisms underlying compensation.

One additionally notable limitation for our study was the placement of the object consistently in the center of the screen. This had the effect of forcing participants to concentrate on the middle of the scene. Some studies have positioned the objects throughout a scene (Wu et al., 2014), which gives a participant more reason to look around a scene. However, positioning the objects throughout the scene can cause an issue with participants misunderstanding what they should be expected to remember, and would have likely caused more encoding of the background. Because we wanted to understand if encoding of the background to the scene was automatic, it was best to make the target object as explicit and obvious as possible. Our data also lacks a measure of reaction time, as we used a long 3-second window. The decision had to be made between obtaining reaction time data or a controlled response window, and so we decided to give participants more time to look around in hopes to best capture how much processing of the scene occurred during recognition. As mentioned above, use of the eye tracker with this paradigm was not able to capture peripheral attention measures, and so we cannot comment on how covert attention played a role in processing.

**Future Directions**

In spite of limitations, this study was able to examine binding phenomenon in episodic memory in a new way. The finding that semantic congruence aids memory
independently from context alone is a crucial step towards gaining a broader picture about underlying mechanisms that facilitate our episodic memories. Future studies should examine semantic congruence effects in younger children, as Edgin et al. (2014) demonstrated differing context effects in children. Also missing from our study were reaction times, which could reveal differences in processing speeds between conditions and groups. Our study was able to highlight potential processing differences resulting in long-term effects of prematurity, and adding reaction time differences could provide more information about the effects of these differences on processing. With regard to the premature group, it is important to study more individuals with wider gestational age differences and long-term outcomes. Perhaps recruiting non-college individuals would yield a better sample to examine variability within this group. Furthermore, accuracy differences between individuals born preterm and full term may be highlighted if task difficulty is increased in future studies, as suggested by Vicari et al. (2004), given overall accuracy was very high for both groups. It may also be interesting to change from an intentional encoding paradigm to a shallow encoding paradigm as seen in Staudigl et al. (2015). A shallow encoding paradigm may help answer more questions about facilitating processes of binding.

References


