ADULTS' LONG-TERM MEMORY AS A FUNCTION OF BIRTH EXPERIENCE

KAR YIN MICHELLE AU

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Abstract

The growing rate of caesarean-section births has aroused concerns as it has shown to be associated with increasing biological and neurodevelopmental risks, but whether such neurodevelopmental impacts manifest behaviorally remain questionable. With studies demonstrating an attentional disruption in c-section-delivered infants and adults, similar effects are hypothesized to filter up the cognitive processing stream to memory function. The current study, therefore, aims to examine the birth experience effect on adults' long-term memory. Vaginal-delivered and c-section-delivered adults participated in a two-day, memory-based visual search task. Results revealed that the two birth groups exhibited similar long-term memory retention and discrimination. However, memory differences might have been limited due to testing at a single retention interval as differences might manifest over longer intervals. Nonetheless, this finding suggests a negligible birth experience impact on adult's long-term memory. Whether birth experience affects specific memory pathways and early memory development, as well as affecting memory differentially by c-section types, are yet to be examined.

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1. Introduction

1.1 A global surplus of caesarean (c-section) births

Caesarean-section-delivery (c-section) is an increasingly common birth mode across the world as indicated by data from 1990 to 2018 in which Eastern Asia had the greatest percentage increase of c-section births at 44.9%, followed by Western Asia at 34.7% and Northern Africa at 31.5% (Betran et al., 2021). According to the World Health Organization in 2015, c-section births have already far exceeded the optimal rate of 10%. As of 2018, the global c-section birth rate was 21.1% (Betran et al., 2021), and Canada had about 28.9% c-section births in 2020 (OECD, 2020). C-section births are also predicted to globally increase to a rate of 28.5% and in Eastern Asia, particularly, to 63.4% by 2030 (Betran et al., 2021). This global trend, largely attributed to increasing planned but medically unnecessary c-section births, has aroused great concerns given its potential medical risks like any other complicated surgeries (Chu et .al 2017), and its association with physical health problems such as asthma and obesity in children (Keag et al., 2018; Sandall et al., 2018). Some studies have also linked c-section birth with poorer neurodevelopment, for example, c-section-delivered 4-month-olds exhibited a lower score in the Ages and Stages Questionnaires in all tested domains (i.e. communication, gross and fine motor, problem solving, and personal-social) (Zaigham et al., 2020). Though further scrutiny has recently been raised as c-section birth has been correlated with an increased risk of developmental disorders such as attention-deficit disorder and autism spectrum disorder (Curran et al., 2015; Liu et al., 2022; Zhang, 2019), there has been a significant dearth of investigations about its underlying impact on brain and cognitive development. Given the growing rate of global c-section births and their potential impact on neurodevelopment, it is therefore important to investigate any fundamental brain and cognitive impacts of c-section birth that might have huge implications for child development and warrant a careful birth-time decision on delivery mode.

1.2 Birth experience effects on cognition

Limited studies have investigated the cognitive effects of c-section birth. In one recent instance, though, Polidano et al. (2017) showed that 4- to 9-year-old c-section-delivered children who participated in the Longitudinal Study of Australian Children (i.e. an internationally recognized longitudinal cohort survey of child health and development) exhibited poorer performance on different cognitive tests (i.e. Peabody Picture Vocabulary Test, Who Am I?, and Matrix Reasoning test) relative to vaginal-delivered children, suggesting a birth experience effect on different aspects of cognition.

Whether effects of c-section birth are manifested behaviorally for specific cognitive functions remains an unknown quantity. To this end, a study by Adler and Wong-Kee-You (2015) investigated the birth experience effects on visuospatial attention in 3-month-olds through the use of a Posner-like spatial cuing task (Posner, 1980). In this task, infants learned to associate a cue to a subsequent target location, thereby facilitating attentional allocation and eye movement responses to that cued target location. Relative to vaginal-delivered infants, the results revealed that c-section-delivered infants exhibited slower saccadic eye movements to the cued location, indicating a disruption of attentional processes in c-section-delivered infants. Similarly, with a different paradigm, slower attentional allocation and saccadic eye movements were observed in 3-month-olds in a visual search task that required the detection of a single target (e.g. R) located randomly among a visual array of distractors (e.g. P) (Rahimi & Adler, 2019). By having one distinguishable featural difference between target and distractors (i.e. R has a diagonal leg), the paradigm functioned as a pop-out search display because feature-present stimulus (e.g. R) has been shown to capture selective attention and be detected more efficiently than feature-absent stimulus (e.g. P) in both infants and adults (Adler & Gallego, 2014; Adler & Rovee-Collier, 1994; Gerhardstein et al., 1998; Treisman & Gelade, 1980). That c-section impacts cognition and attention early in life has been further supported by neurological evidence that relative to 2-week-old vaginal-delivered infants, c-section-delivered infants had reduced white matter in multiple brain regions and reduced functional connectivity in the default mode network (Deoni et al, 2019) which typically serves the function of modulating visual attention (Scheibner et al., 2017).

Furthermore, that disruption of visual attention has also been observed in adults (Rahimi & Adler, 2019), suggesting that the neurocognitive disruption due to c-section birth is not transient but may be more permanent, enduring into adulthood. This case is supported by recent data that revealed slower saccadic eye movements and attentional allocation by c-section-delivered adults in a similar spatial cueing task as used in Adler and Wong-Kee-You (2015) and in a congruency task (Stevens et al., under review). Furthermore, the persistent attentional impacts found in c-section-delivered adults relative to vaginal-delivered adults were substantiated by brain imaging data that showed atypical connectivity of visual regions and default mode network (Stevens et al., under review), similar to that found by Deoni et al. (2019) with infants.

The idea of a permanent birth experience effect on cognition, however, was previously argued against by Deoni et al.'s (2019) longitudinal study because c-section-delivered infants showed lower white matter volume in different brain regions compared to vaginal-delivered infants at 3 months of age, but the differences gradually decreased and diminished by approximately age 3 years. Similarly in studies conducting cognitive tests, although c-section-delivered children showed a relatively poorer performance (Polidano et al., 2017), vaginal-delivered and c-section-delivered adults showed an equivalent performance in the Cambridge Neuropsychological Test Automated Battery (Dinan et al., 2022). Despite the seemingly transient birth experience effect on cognitive tests performance and white matter development, white matter volume was measured in multiple brain regions which would also involve various cognitive functions simultaneously and, therefore, might mask any specific birth experience impacts on attention or other specific cognitive mechanisms. Suggestively, birth experience may affect certain cognitive functions such as attention more than others.

Overall, these behavioral and neurological studies support a specific and persistent birth experience effect on visuospatial attention. Whether these effects are manifested behaviorally and persistently in other associated cognitive functions, such as memory, remains unknown, and is therefore, the focus of the current study.

1.3 Attentional studies predict a birth experience effect on memory

As mentioned, previous studies have provided evidence that birth experience affects adult's visuospatial attention as found with multiple paradigms (Rahimi & Adler, 2019; Stevens et al., under review) and is associated with aberrant brain connectivity (Stevens et al., under review). Given the tight linkage between attention and memory in neurocognitive functioning (Adler et al., 1998; Bettencourt et al. (2021); Ciaramelli et al., 2008; Craik & Lockhart, 1972; Lockhart & Craik, 1990; Rotshtein et al., 2011; Sauseng et al., 2008; Treisman, 1988; Wolfe, 2021), c-section births might therefore also be associated with disrupted memory functioning.

Levels-of-Processing (LOP) framework

The linkage between attention and memory has been formalized in a number of theories (Wolfe, 2021), including the Levels-of-Processing (LOP) framework of memory (Craik & Lockhart, 1972; Lockhart & Craik, 1990), in which the degree of attentional resources allocated to a task determines the depth to which information is processed and encoded. The depth to which information is processed and encoded then serves to establish how elaborate and strong that memory is constructed, subsequently determining the persistence of the memory trace across a retention interval and its ease of retrieval. The allocation of more attentional resources to a stimulus event therefore leads to deeper processing and encoding, leading to stronger and more enduring memory traces for retrieval.

To demonstrate the LOP relation between attention and long-term memory, a study conducted by de Bettencourt et al. (2021) found that long-term memory performance is influenced by different aspects of attention during encoding. That is, in a spatial cueing task, spatial attention (i.e. allocating attentional resources to the cued target location) and sustained attention (i.e. maintaining the allocation of attentional resources to the target) respectively facilitated long-term spatial memory and long-term recognition memory performance as spatial attention prioritized the processing of cued target, and sustained attention increased the quality of target encoding and the resulting memory trace. Thus, consistent with the LOP framework, de Bettencourt et al. (2021) substantiated that increasing processing resources to a target by attentional allocation enhances encoding and memory persistence, as well as long-term memory retrieval of the target information.

In addition to the adult study that supports the LOP relation of attention and long-term memory, the relation has been shown to be operational in early infancy (Adler et al., 1998), indicating attention as a fundamental mechanism of encoding and long-term memory retrieval. In this study, Adler et al. (1998) manipulated 3-month-old infants' attention to a target by taking advantage of visual search effects through two types of 7-block crib mobile arrangements that displayed visual arrays: (1) a pop-out display that contained one unique target block (e.g. a '+' or

‘L’) amidst surrounding six distractor blocks (e.g. ‘L’s or ‘+’s), or (2) a homogenous display with all the blocks displaying the same character (e.g. seven ‘+’s or seven ‘L’s). All infants were first trained with either one of the mobile arrangements and then tested 24 hours later with a homogenous display of blocks displaying only the trained target character. Results showed that infants trained with a ‘+’ as the pop-out target had the longest retention, exhibiting memory for ‘+’s for 9 days, relative to infants who, trained with homogenous “+” arrays or with an ‘L’ as the pop-out target, exhibited memory for ‘+’s for only 7 days and ‘L’s for only 3 days, respectively. Presumably, a pop-out ‘+’ target better captured infants’ selective attention compared to ‘+’s in a homogenous display arrangement or a pop-out ‘L’ target because ‘+’ contains a unique perceptual feature (i.e. line crossing) (Adler & Gallego, 2014; Adler & Rovee-Collier, 1994; Gerhardstein et al., 1998; Treisman & Gelade, 1980), thereby garnering more processing resources and encoding the pop-out ‘+’ target more deeply. As a consequence, memory traces for the pop out ‘+’ target were more persistent and retained for a longer interval which allowed infants to recognize the target after a longer delay. This infant study supported that the memorability of a target changes with the level of attentiveness applied to the target during encoding, demonstrating that the effectiveness of long-term memory retrieval is distally related to the attentional level allocated to the target during encoding.

Guided Search Model

The relation between attention and long-term memory retrieval has also been incorporated in two-stage models of visual information processing and object recognition (Treisman, 1988), as well as their evolved model, Guided Search (Wolfe, 2021). Generally, according to the models, a visual target is first pre-attentively and automatically decomposed into primary perceptual features. Attentional guidance templates, which can be categorized as bottom-up (attend to salient features) or top-down (attend to features that match a specific characteristics), then informs which feature should be most attended to in relation to the current goal. That decomposed features and attentional guidance templates form the “priority map” and activate feature locations accordingly to guide attentional processing. The highlighted attended features and their spatial relations, as well as the guidance templates are then held in working memory. Next, processing resources are serially focused and allocated to the attended features, which then reconstructs the target by binding the features according to their spatial relations. That reconstructed target, stored in working memory, is then compared against the target representation in long-term memory which references another stored guidance template that contains more identifiable information about the expected target. In other words, object recognition occurs when the object representation constructed in working memory matches an object representation stored in long-term memory. Together, these proposed processing frameworks, including the LOP theory (Craik & Lockhart, 1972; Lockhart & Craik, 1990), and the models of Guided Search (Wolfe, 2021), implicate attentional allocation to target features as necessary for encoding and long-term memory retrieval, which consequently underlie the process of object recognition.

These models also show that attention and long-term memory are involved in object recognition through more than one path. One path is that a bottom-up attentional guidance template to salient features of a target during encoding serves subsequent long-term memory retrieval (Wolfe, 2021). This has been demonstrated in studies where training with a target with distinctive feature leads to more enduring memory retrieval than a target with less distinctive feature, suggesting that memory retrieval involves a stimulus-driven attentional mechanism (Adler et al., 1998; Adler & Rovee-Collier, 1994). In addition to the bottom-up pathway of long-term memory retrieval, a top-down pathway based on memory has been demonstrated in visual search tasks, in which a search memory was formed over repeated search attempts as indicated by an improvement in search efficiency (i.e. reduced search time) (Le-Hoa Võ & Wolfe, 2015; Solman & Smilek, 2010). Presumably, this occurs because subsequent searches were facilitated by the memory of target information from preceding searches, through repeatedly attending, processing and encoding of the same target information, suggesting that long-term memory retrieval involves a cognitive-driven attentional mechanism, in addition to the stimulus-driven mechanism.

Neurological evidence

That attentional processing is related to memory retrieval has also been suggested by the functioning of neural structures. In one study, search time and efficiency were impaired when there was a mismatch between the target and an object representation in working memory, and the impaired search efficiency during a representational mismatch in memory was suggested to be a consequence of a neural suppression response (Rotshtein et al., 2011). That is, the suppression of functional connectivity between the pulvinar and its projections to the cortical and subcortical regions acts as a protective mechanism to prevent stored memory from the interference of attended but competing information (Rotshtein et al., 2011), thereby representing a shared neural correlate of attention and memory retrieval. Other brain imaging studies have further examined the neurological association of attention and memory. The posterior parietal cortex, for example, has been consistently shown to be activated during both attentional and memory retrieval processes (Ciaramelli et al., 2008), further supporting the idea of shared neural mechanisms between attention and memory. In another study, spatial attention enhanced synchrony between the oscillatory activities at gamma and theta frequencies, which are associated respectively with attentional and memory processes, have been shown to occur in the posterior brain regions (Sauseng et al., 2008). The enhanced synchrony likely reflected an increased exchange of information between the attentional and memory networks, and the matching process between an attended stimulus and a stored memory representation (Sauseng et al., 2008), further demonstrating the integration of attentional and memory processes during object recognition.

Considering the demonstrated influence of birth experience on infants' and adults' attention, as well as the close behavioural and neurological connections between attention and memory, birth experience might possibly influence infants' and adults' memory, and perhaps long-term memory in particular, as it does their attentional allocation. The goal of the current study, therefore, was to begin the exploration of any potential impacts of c-section births on long-term memory.

1.4 Birth experience effects on long-term memory

To explain the effects of c-section birth on long-term memory, or any cognitive and brain function, a disrupted seeding of gut microbiota is possibly one of the most intriguing mechanisms underlying the cognitive effects of c-section births. Given that gut microbial colonization occurs during, by passage through the birth canal, and right after the birth process, the guts of c-section-delivered infants, who do not experience the passage through the birth canal or labor, are only seeded by skin and environmental bacteria instead of faecal and vaginal bacteria, thus altering their gut microbial profile relative to vaginal-delivered infants (Biasucci et al., 2010). Because the gut microbiome is pivotal to an array of neurochemical and protein syntheses that modulate learning and memory (Maqsood & Stone, 2016), altering the gut microbiome might therefore also alter memory development. The gut microbiome, for example, has been implicated in increasing Brain-Derived Neurotrophic Factor (BDNF), N-methyl-d-aspartate receptor (NMDAR), and gamma-aminobutyric acid (GABA), which all play a role in synaptic plasticity and neuronal signalling in brain regions such as the hippocampus (Maqsood & Stone, 2016), an area that is critical for long-term memory (Bauer, 2008; Bird & Burgess, 2008). In other studies, patients with Alzheimer's disease have also shown a different gut microbiota composition and inflammatory status in the hippocampus compared to healthy adults, with a similar result also being observed in mice (Tan et al., 2020), suggesting the importance of the gut microbiome in hippocampal and long-term memory development. The levels of microRNAs (miRNAs) and messenger RNAs (mRNAs) were also altered in the hippocampus of germ-free mice which lack gut microbiome (Chen et al., 2017). Furthermore, germ-free mice showed an increased perinatal cell death in the hippocampus (Castillo-Ruiz et al., 2018a), which was also found in c-section-delivered mice and was associated with a reduced level of vasopressin, a protein that would normally be produced massively in vaginal-delivered newborns to protect the brain from excitotoxicity at birth (Castillo-Ruiz et al., 2018b). This suggests that the regulation of hippocampal perinatal cell death is inhibited by the reduced vasopressin level in c-section-delivered newborns. Suggestively, these gut microbial studies seem to indicate that hippocampal and long-term memory development are impacted by c-section births.

Additionally, c-section birth has been suggested to affect cognitive functioning and long-term memory development not only via the altered gut microbiome but also by altering other brain molecules such as mitochondrial uncoupling protein 2 (UCP2). In one study, UCP2 knockdown mice showed a lower level of mRNA and protein expression in the hippocampus, as well as impaired memory performance on spatial memory tasks (Wang et al., 2014). Such hippocampal and memory deficits associated with reduced UCP2 could relate to c-section births because

UCP2 production is triggered by the physical stress during labor which is not experienced by c-section-delivered mice who, therefore, exhibit a lower level of UCP2 (Simon-Areces et al., 2012; Seli & Horvath, 2013). Moreover, another finding has suggested that c-section birth acts as an acute stress that alters glucocorticoids release and glucocorticoid receptor sensitivity in the hippocampus of mice (Huang et.al., 2019), pointing to yet another biological mechanism that might differentially impact the long-term memory development in c-section-delivered versus vaginal-delivered individuals.

In support these neurological differences as a function of birth experience, Polidano et al. (2017) revealed that other factors including rate of breastfeeding, obesity and attention deficit disorder only mediated approximately 30% of the cognitive performance differences found between vaginal-delivered and c-section-delivered children, leaving 70% of the differences to be accounted by birth-related biological mechanisms, including the disruption of gut microbiota seeding, UCP2 and glucocorticoids production. Moreover, it is important to note that factors such as the rate of obesity and attention deficit disorder could also be the consequences of c-section births (Curran et al., 2015; Keag et al., 2018; Zhang, 2019), which might in turn then produce the cognitive performance differences. These factors then possibly add to the 70% of cognitive differences that had been accounted by the altered biological mechanisms. Overall, these studies seemingly support the notion that c-section impacts on the neural correlates of long-term memory.

Despite evidence that endorses a birth experience effect on the neurobiology of long-term memory, there are limited behavioral studies that have explored birth experience effects on long-term memory. In one study, however, c-section-delivered mice exhibited poorer spatial learning and memory in a 5-day spatial training task in a Morris water maze (Huang et.al., 2019). Despite the poorer learning and long-term memory observed in the mice, these c-section effects were only observed in adolescence without persisting into adulthood, suggesting that perhaps the cognitive impact of c-section birth on long-term memory is an early behavioral manifestation but not a permanent impairment, which is consistent with the transient birth experience effect on white matter volume (Deoni et al., 2019) and cognitive tests performance (Dinan et al., 2022; Polidano et al., 2017). That the birth experience effects on long-term memory seems to be transient, however, appears to contradict the attentional studies conducted by Rahimi and Adler (2019), and Stevens et al. (under review), which implicate a more persistent birth experience effect on attention and cognition. As of now, our knowledge of the full impact of birth experience on long-term memory functioning is unfortunately limited as no behavioral research has been conducted directly to verify whether birth experience influences long-term memory in human adults. This lack of any substantial evidence therefore informs the current research question and hypothesis. That is, whether c-section birth, relative to vaginal birth, negatively affect adults' long-term visual memory, as it affects adults' visual attentional allocation (Rahimi & Adler, 2019; Stevens et al., under review).

1.5 Visual search paradigm based on long-term memory

As previous research has shown a birth experience effect on adults' attention in a visual search task (Rahimi & Adler, 2019) and that attention plays a role in forming search memory (Le-Hoa Võ & Wolfe, 2015; Solman & Smilek, 2010), the current study used a visual search paradigm as a means to investigate the impact of birth experience on adults' long-term visual memory. In a typical visual search paradigm, selective detection of a visual target from amidst an array of surrounding distractors is required, often by attending to the salient featural differences between the target and distractors (McElree & Carrasco, 1999; Treisman & Gelade, 1980). By requiring that detection of the target be based on stored target features that was encoded one day earlier rather than based on an immediate percept, visual search can be transformed to consist of a long-term memory component in addition to the typical attentional and immediate memory components (Friedman et al., 2018).

Whether a visual search paradigm assesses memory functioning is debatable, however, as a study has shown that a target memory formed during search could not be retrieved during future search if it conveyed no or only minimal search benefits (Wolfe et al., 2000). That situation might occur when detecting the target by the deployment of random eye movements is as efficient as detecting the target by the memory retrieval of the target-locating eye movements. That random eye movement is chosen as the default search strategy is because memory retrieval typically requires more time-consuming and higher-order cognitive processing and resources. So, choosing which particular search strategy to deploy depends on the cost effectiveness trade-off between search efficiency and memory load. The higher the level of search difficulty, therefore, the greater the motivation and the need to shift search strategy from random to memory-based eye movements to conserve processing time and resources as memory allows for advanced preparation and generation of purposeful eye movements by knowing what target feature or featural location to localize. For example, one study found that the larger the search display scale in a repeated visual search task, the higher the accuracy in generating the first saccadic eye movement based on memory of the target location (Solman & Smilek, 2010). This study further indicated that the amount of search time saved by spatial memory-based eye movements outweighed the typical cost of allocating cognitive resources for memory retrieval. A subsequent study further supported that memory benefits increased as a function of search difficulty through manipulating stimulus eccentricity and discriminability (Solman & Smilek, 2012). In order to assess long-term memory with the visual search paradigm, therefore, the level of search difficulty was carefully controlled in the current study to maximize the use of memory in search. Differences in search performance over repeated search in vaginal versus c-section birth groups, hence, would be more likely due to their differences in memory functioning, thereby enabling the question as to whether birth experience differentially impacts long-term memory to be addressed.

In a previous study that assessed the birth experience impact on attention in a repeated visual search paradigm with infants and adults (Rahimi & Adler, 2019), simple characters R and P were used as the target and distractors. Search performance was consequently determined by random eye movements rather than memory-based eye movements as it only required the detection of one simple salient featural difference (i.e. the presence or absence of a diagonal leg) through bottom-up attentional allocation. Further, search performance was assessed in a single session rather than multiple sessions, so long-term memory was not probed during the task. Finally, the featural difference could be detected by young infants which implies target search was relatively simple, thus the search's difficulty level was likely not sufficient to invoke memory-based eye movements and search in adults. As memory was the primary testing variable in the current study, however, the same visual stimuli could not be used here as a more challenging search was needed to motivate memory-based visual search.

To design more complicated stimuli that would motivate memory-based search, a study conducted by Friedman et al. (2018) served as a broad template because they accessed long-term visual memory with a repeated visual search paradigm. Freidman et al.'s study was conducted over two consecutive days (the full study was conducted over three days but the experiment on Day 3 is not relevant to the purpose of the current study) with a 24-hour delay (Day 1 encoding phase and Day 2 memory testing phase). In their experiment, the search display consisted of two categories of clothing items (summer and winter), each with two subcategories (upper-body and lower-body). The search target was always a summer clothing item embedded among an array of winter clothing items. Since there was no single salient featural difference between the winter and summer items, processing of categorical information based on items' functional characteristics was required for accurate summer target detection. If random eye movements are used in search, then processing of categorical information would be required for every randomly localized item until a summer target was initially detected, a sequence approach that would be relatively cognitive demanding and time-consuming. Search that was based on stored summer target information was instead, therefore, likely involved to save processing time and resources. Further, long-term memory specific to target featural information was assessed in this study. That is, by not informing the participants about the clothing subcategories, only upper-body summer clothing items served as the target during the encoding phase and both upper- or lower-body summer clothing were shown 24 hours later during the testing phase. Long-term memory specific to the target information was evident as search accuracy improved during encoding and persisted after 24-hour, but only if encoding and testing trials consisted of the same target subcategory.

In sum, the previous study by Friedman et al. (2018) with a repeated visual search paradigm demonstrated evidence for adults' selective long-term memory after a 24-hour delay for sub-categories (upper- or lower-body) of categorical items (summer clothing). Their repeated visual search paradigm is therefore relevant for the current study in understanding the birth experience impact on adults' long-term memory because it increases the search difficulty and the use of search memory beyond that of the Rahimi and Adler's (2019) visual search task which mostly involved random search of simple salient stimulus in a single session.

1.6 Hypothesis and goals

Given that persistent impaired visual attention and neurological mechanisms are associated with c-section births (Adler & Wong-Kee-You, 2015; Rahimi & Adler, 2019; Stevens et al., under review) and attention has been linked to long-term memory behaviourally and neurologically (Adler et al., 1998;Ciaramelli et al., 2008; Craik & Lockhart, 1972; deBettencourt et al., 2021; Lockhart & Craik, 1990; Le-Hoa Võ & Wolfe, 2015; Rotshtein et al., 2011; Sauseng et al., 2008; Treisman, 1988), c-section births might therefore also be associated with persistent impaired long-term memory. In addition, evidence showed birth experience effects on the brain components of long-term memory which might manifest behaviorally in human memory development (Biasucci et al., 2010; Castillo-Ruiz et al., 2018a; Castillo-Ruiz et al., 2018b; Chen et al., 2017; Huang et al., 2019; Maqsood & Stone, 2016; Polidano et al., 2017; Simon-Areces et al., 2012; Seli & Horvath, 2013; Stevens et al., under review; Tan et al., 2020; Wang et al., 2014). The behavioural manifestation of birth experience in long-term memory, however, was found to be transient in mice (Huang et al., 2019), a finding supported by a similar transient effect found on white matter volume (Deoni et al., 2019) and cognitive tests performance (Dinan et al., 2022; Polidano et al., 2017). The current study therefore aims to understand whether the persistent birth experience effects exhibited for attention would extend to human upstream memory mechanism. With the usage of the repeated visual search paradigm that has been previously used to access long-term visual memory (Friedman et al., 2018), c-section birth is hypothesized to be associated with poorer long-term memory in c-section-delivered adults than in vaginal-delivered adults, as it affects adults' attention in visual search (Rahimi & Adler, 2019). This is expected to be manifested by poorer recognition of the target subcategory and poorer discrimination of a novel target subcategory 24 hours after encoding in c-section-delivered adults.

2. Methods

2.1 Participants

A total of 114 participants, ranging in age from 18 to 35 years old (*M* = 22.2, *SD* = 4.15), were recruited online to take part in a two-day experiment through the Undergraduate Research Participant Pool at York University, with course credits given as the inducement for participating. Participants were separated into two groups of adults: vaginal- and c-section-delivered individuals. Participants were scheduled for two consecutive days on Zoom, for 15-minutes online sessions at the same time of each day, that best suited their availability and to avoid interference with their sleep-wake cycle. All experiments were conducted online using Version 6.5.2 of Inquisit Web software (Millisecond Software, 2021). Informed consent and demographics information were collected. Participants were excluded (*n* = 14) if they were born prematurely, without normal vision, with records of traumatic brain injuries, learning disabilities, neurological and psychiatric disorders. Inattentive participants were additionally excluded (*n* = 24) on the basis of two other criteria: participants must have responded correctly on at least 50% of the total trials during (1) the entire encoding phase on day 1 and (2) the second half of the encoding phase.

The final sample data included a total of 39 vaginal-delivered and 37 c-section-delivered adults, including 24 planned c-section-delivered and 13 emergency c-section-delivered individuals. The vaginal group had 32 females and 7 males, and the c-section group had 25 females and 12 males. There were 39 Asian, 5 African American, 3 Hispanic, 7 Caucasian, and 3

Mixed, including 19 of them from the lower socio-economic status, 23 from the middle socio-economic status, and 34 from the higher socio-economic status.

2.2 Stimuli

Search stimuli were based on the previous adult visual search study that demonstrated selective long-term memory of target information (Friedman et al., 2018). These stimuli included lower-body summer clothing (e.g. flipflops, sandals, and short pants), upper-body summer clothing (e.g. hats, short sleeve shirt, and tanks), lower-body winter clothing (long pants, loafers with fur, and boots), and upper-body winter clothing (beanies, long sleeve shirts, scarfs, and winter jackets), with each subcategory containing 30 possible items of different styles and colour (Figure 1). In each search trial, clothing items were displayed within a 29 x 16 cm window and positioned in a circular configuration with a radius to each stimulus' center from the screen center of 2.9 cm. The size of each item was 13% of the window size. There was also a black fixation cross (**x**), 6 % of the window size, located at the center of each search display. The recommended size of participants' computer monitor was 13 inches, but the displayed window size was fixed across participants irrespective of their computer monitor size, enabling stimulus and array size to be controlled across participants.

Figure 1. Examples of clothing items. (a) lower-body summer clothing, (b) upper-body summer clothing, (c) lower-body winter clothing, (d) upper-body winter clothing.

Consistent with Friedman et al.'s (2018) study, the search target in the current experiment was always a summer clothing item located randomly among four or five distractors of winter clothing items. To assess long-term memory in each participant, two phases of visual search were conducted over two consecutive days with a 24-hour delay (Day 1 -- encoding phase and Day 2 -- memory testing phase). Across all the encoding trials on Day 1, the displayed search target originated from only one and always the same summer clothing subcategory, with which subcategory was assigned being counterbalanced across participants. Consequently, half of the participants searched for lower-body summer clothing and the other half searched for upper-body summer clothing during the encoding phase. The five displayed distractors were either lower-body or upper-body winter clothing items within each trial, and the distractors were different from each other in each trial. All the displayed stimuli, including targets, and their locations were randomized across trials. To limit guessing and stereotypic spatial bias, 18% of the trials did not contain a search target and 31% contained four instead of five distractors.

To assess long-term memory retention of the target information presented during the encoding phase, a familiar target condition during the memory testing phase consisted of presenting the same stimulus as the encoding phase. Encoding and memory testing with the same target subcategory in a familiar target condition, however, was not able to address the specificity of the information encoded in memory and retained over the long term. That is, whether specific information about target features or general information of summer item category were encoded and retained could not be answered by the familiar target memory condition. To assess specificity of memory retention, a novel target memory condition was therefore designed by presenting a novel target subcategory during testing relative to encoding. For example, if a search target of lower-body summer clothing was assigned to a participant during the encoding phase, upper-body summer clothing would be the target during the memory testing phase in the novel target condition, and vice versa. By presenting a novel target subcategory during memory testing, specificity of long-term memory for target featural information was assessed, enabling the investigation of how birth experience might specifically impact on this aspect of long-term memory. Whether a participant was in the familiar or novel target memory condition was assigned randomly and counterbalanced across participants in each birth group.

2.3 Procedures

Both the encoding and memory testing phases consisted of 88 visual search trials, without any breaks in between. Prior to the start of each encoding phase experimental session, experimental procedures were explained to each participant. Participants were instructed to fixate on the fixation cross and then search for the summer clothing item among several winter clothing items. They were informed that there would only be one or no summer item in each search trial. They were also given verbal descriptions of both subcategories of summer items and that either one of the subcategories would be presented but they were unaware of which subcategory was assigned. Information regarding the winter clothing items were not provided. They were also instructed to sit in front of their computer at a distance approximate to their own's arm length and were reminded to maintain that distance and keep their hand on the mouse throughout the experiment. They were informed that the task would last about 15 minutes and were told to pay attention and try to perform to the best of their ability as the stimulus presentation timing would be brief (no exact timing was provided) and they might get tired over the course of the session. Before the actual experiment, to ensure they understood the task, there were five practice trials, with feedback given after each trial as to whether the participants' answer was right or wrong, as well as a longer stimulus presentation timing (1000 ms) relative to the actual experimental trials. After the practice trials, they were informed that the stimulus presentation timing would be a bit shorter for the experimental trials and that no feedback would be given during the actual trials.

Based on Friedman et al. (2018), at the outset of each trial, a white blank screen with a fixation cross was presented for 2 s to serve as a cue of the upcoming search display and to make sure that all items in the circular search display at its onset were equidistant from the focus of attention. Next, the search display was presented for 500 ms, followed by the presentation of a visual mask for 200 ms and a blank screen for 100 ms. At the end of each trial, a grey circle of the same size as the search items was displayed at each item location for 5 s, with a mouse cursor in the center of the display (Figure 2). Participants were instructed to move the cursor and click on the circle that matched the target's location. If no target was detected, participants were instructed to click on a grey box labelled as "no target" which was located just above the top circle. The reaction time to click a grey circle or grey box and the accuracy of the clicking response were measured.

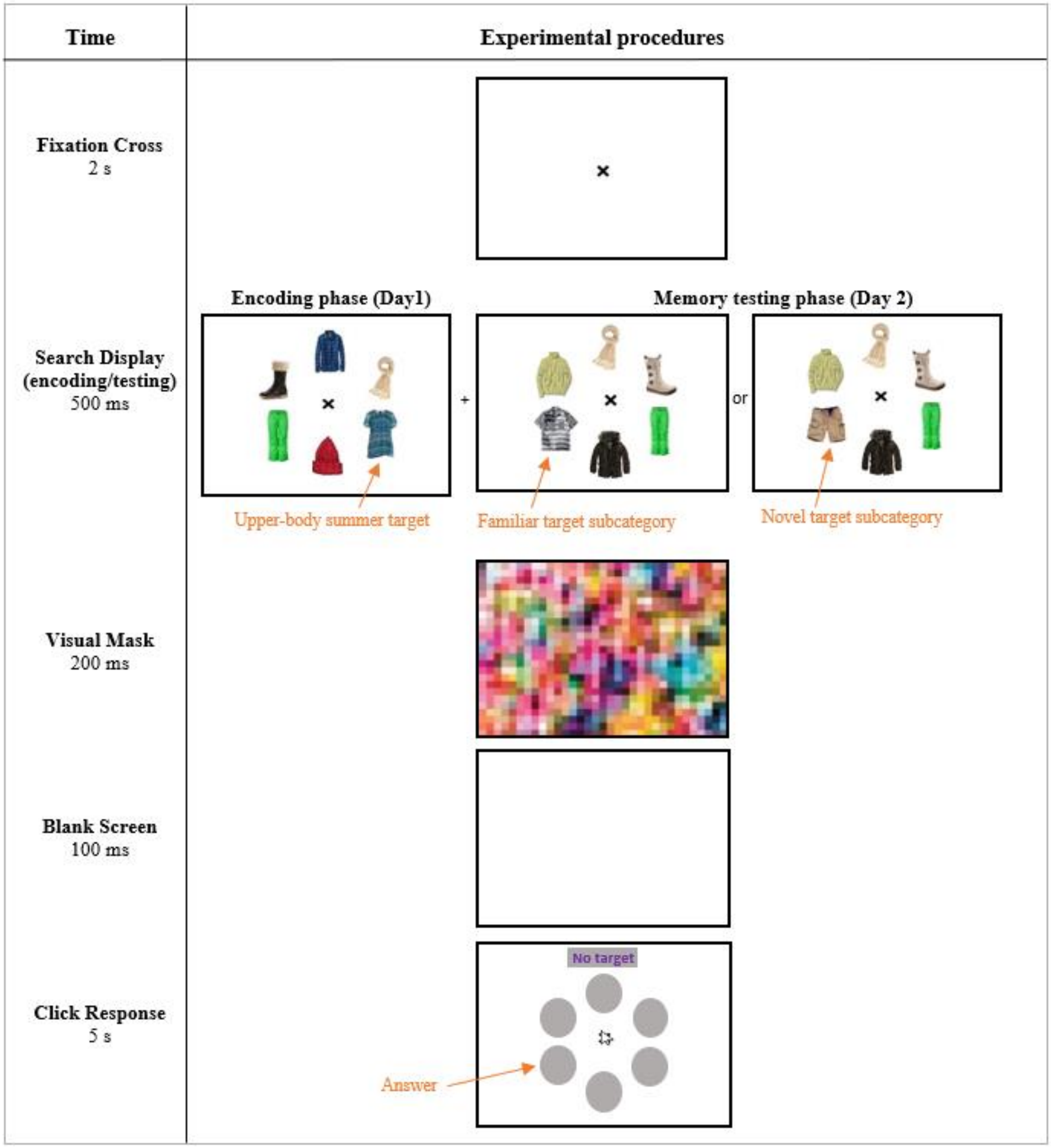

Figure 2. Experimental procedures. Example demonstrating Day 1 encoding and Day 2 memory testing phase procedure in both familiar and novel target memory condition. Fixation cross was presented for 2 s for the upcoming visual search display which lasted for 500 ms. During encoding phase, one upper-body summer clothing (target) was located among five lower- or upper-body winter clothing (distractors). During memory testing phase, a familiar (upper-body) or a novel (lower-body) target subcategory was presented. Next, visual mask was presented for 200 ms, followed by 100 ms of blank screen. Lastly, a grey circle at each clothing's location and a grey box labelled as "no target" was displayed for 5 s. Participants were instructed to move the centered mouse cursor to click on the circle (bottom-left) that matched the target location or click on the grey box if no target was detected.

2.4 Statistical analysis

The dependent variables for measuring memory in the current study were: (1) reaction time, (2) percent of accuracy (number of correct trials out of the total 88 trials), (3) hit rate (number of correct trials out of the number of trials with a target), and (4) correct rejection rate (number of correct trials out of the number of trials without a target) for both encoding and memory testing phase. To assess learning within a phase and long-term memory across phases, each phase was split into two time periods (first half and second half) for the analysis. A learning ratio for each variable was calculated by dividing its mean value from the second half of the encoding phase by its mean value from the first half of the encoding phase, which represented the learning progress and memory formation during encoding. One participant who scored 0 on correct rejection rate during the first half of the encoding phase was excluded from the analysis of learning ratio of correct rejection rate as computation of a ratio was not possible. A savings ratio was also calculated by dividing the mean value from the first half of the memory testing phase, before new learning could be instantiated, by the mean value from the second half of the encoding phase. The savings ratios represent the degree of long-term retention relative to immediate retention, which provided a measure of how much of the encoded information was retained and retrieved after 24 hours. Since savings ratios were the primary variables for long-term memory comparison between birth groups, false alarm rate was not used in the current analysis because there were many cases of undefinable calculations of the ratio (i.e. the value of denominator is zero while the numerator is a non-zero number) and, thus, these cases would necessitate additional data exclusion from the current sample and decrease power for a significance determination. All data analysis was performed using R Studio version 1.3.1073 (RStudio Team, 2020).

3. Results

3.1 Assumption tests

Normality during encoding phase

Shapiro-Wilk normality tests were conducted to assess data distributions in the encoding phase of each birth experience group in each memory condition. For the vaginal group in the familiar target memory condition, the test showed a normal distribution of the means of all the dependent variables during encoding (accuracy percentage, W (19) = 0.9, p = 0.06; reaction time, W (19) = 0.97, p = 0.8; hit rate, W (19) = 0.9, p = 0.05; correct rejection rate, W (19) = 0.91, p = 0.08). Similarly, for the c-section group in the familiar target memory condition, the test indicated a normal distribution for all the mean variables (accuracy percentage, W (19) = 0.9, p = 0.05; reaction time, W (19) = 0.96, p = 0.49; hit rate, W (19) = 0.98, p = 0.95; correct rejection rate, W (19) = 0.96, p = 0.57).

In contrast, for the vaginal group in the novel target memory condition, the test showed a normal distribution of all the mean variables except for correct rejection rate (accuracy percentage, W (20) = 0.96, p = 0.62; reaction time, W (20) = 0.94, p = 0.19; hit rate, W (20) = 0.95, p = 0.43; correct rejection rate, W (20) = 0.88, p = 0.02). Finally, for the c-section group in the novel target memory condition, the test indicated a normal distribution for all the mean variables except for reaction time (accuracy percentage, W (18) = 0.94, p = 0.25; reaction time, W (18) = 0.89, p = 0.04; hit rate, W (18) = 0.98, p = 0.94; correct rejection rate, W (18) = 0.92, p = 0.13).

Variances during encoding phase

Levene's tests were also conducted to assess data variances in the encoding phase of the two birth experience groups in each memory condition. In the familiar target memory condition, the two birth experience groups had equal variances for all the variables (accuracy percentage, F =

0.54, p = 0.47; reaction time, F = 0.32, p = 0.58; hit rate, F = 2.29, p = 0.14; correct rejection rate, F = 0.86, p = 0.36). Similarly, the two birth experience groups in the novel target memory condition had equal variances for all the variables (accuracy percentage, F = 0.76, p = 0.39; reaction time, F = 0.42, p = 0.52; hit rate, F = 0.22, p = 0.64; correct rejection rate, F = 0.64, p = 0.43).

Overall, in the encoding phase, most of the variable data sets of each birth experience group in each memory condition had passed the assumption tests of normal distribution and equal variance. Only the data of mean correct rejection rate in the vaginal group and the mean reaction time in the c-section group, both in the novel target memory condition, were abnormally distributed during encoding, and therefore non-parametric tests were performed for any subsequent between-group comparisons that involve these two data sets.

3.2 Encoding phase analyses

Target subcategory learning

Since target clothing subcategories were counterbalanced across participants in each birth experience group of each memory condition, learning differences between the two subcategories were examined by conducting a 3-way analysis of variance (ANOVA) on each mean value of the dependent variables during encoding, with Target Subcategory (lower-body/ upper-body), Birth Experience (vaginal/c-section), and Memory Condition (familiar/ novel) as the between-groups factors.

For accuracy percentage, there was a main effect of target subcategory, F (1, 68) = 4.78, p = 0.03, ηp^2 = 0.07, indicating that correct detection of lower-body clothing items (M = 0.69, SD = 0.11) during encoding was higher than upper-body clothing items (M = 0.64, SD = 0.09). , However, there were no main effects of birth experience, F (1, 68) = 0.09, p = 0.77, or memory condition, $F (1, 68) = 0.83$, $p = 0.37$. None of the two-way interaction effects were significant (target subcategory and birth experience, $F (1, 68) = 1.7$, $p = 0.2$; target subcategory and memory condition, $F (1, 68) = 0.88$, $p = 0.35$; birth experience and memory condition, $F (1, 68) = 0.2$, $p = 0.66$). There were also no significant three-way interaction effects, $F (1, 68) = 0.45$, $p = 0.5$.

For the other three variables, no main effects or interaction effects were found. For reaction time, there were no significant main effects (target subcategory, $F (1, 68) = 0.36$, $p = 0.55$; birth experience, $F (1, 68) = 0.02$, $p = 0.88$; memory condition, $F (1, 68) = 0$, $p = 1$), two-way interaction effects (target subcategory and birth experience, $F (1, 68) = 0.99$, $p = 0.32$; target subcategory and memory condition, $F (1, 68) = 0.91$, $p = 0.35$; birth experience and memory condition, $F (1, 68) = 0.09$, $p = 0.76$), or three-way interaction effects, $F (1, 68) = 1.21$, $p = 0.28$. A non-parametric, Mann-Whitney U test was also conducted on the mean reaction time of c-section group in the novel target memory condition, with Target Subcategory as the between-groups factor, and no significant differences were found between lower-body (Mdn = 1250.5) and upper-body (Mdn = 1007.49) targets, $U (N_{lower} = 9, N_{upper} = 9) = 30$, $z = -0.93$, $p = 0.39$.

For hit rate, there were no significant main effects (target subcategory, $F (1, 68) = 2.07$, $p = 0.16$; birth experience, $F (1, 68) = 0.56$, $p = 0.46$; memory condition, $F (1, 68) = 1.49$, $p = 0.23$), two-way interaction effects (target subcategory and birth experience, $F (1, 68) = 1.14$, $p = 0.29$; target subcategory and memory condition, $F (1, 68) = 0.49$, $p = 0.49$; birth experience and memory condition, $F (1, 68) = 0.09$, $p = 0.76$), or three-way interaction effects, $F (1, 68) = 1.13$, $p = 0.29$.

For correct rejection rate, there were no significant main effects (target subcategory, $F (1, 68) = 3.87$, $p = 0.05$; birth experience, $F (1, 68) = 0.56$, $p = 0.46$; memory condition, $F (1, 68) = 0.17$, $p = 0.68$), two-way interaction effects (target subcategory and birth experience, $F (1, 68) = 2.01$,

$p = 0.16$; target subcategory and memory condition, $F(1, 68) = 0.22$, $p = 0.64$; birth experience and memory condition, $F(1, 68) = 0.05$, $p = 0.82$), or three-way interaction effects, $F(1, 68) = 0.33$, $p = 0.57$. A Mann-Whitney U test was also conducted on the mean correct rejection rate for vaginal group in the novel target memory condition, with Target Subcategory as the between-groups factor, and again, no significant differences were found between lower-body (Mdn = 0.88) and upper-body (Mdn = 0.63) targets, U (N_{lower}= 11, N_{upper} = 9) = 30, z = -1.5, $p = 0.15$.

During the encoding phase, the absence of a main or interaction effects of target subcategory, birth experience, and memory condition for each mean dependent variable suggests that the two birth experience groups in the two memory conditions did not differ in their learning of the two target subcategories, and therefore, data of the two target subcategories were pooled within each birth experience group and memory condition for each dependent variable. Although learning differences between target subcategories was discovered as measured by mean accuracy percentage, as shown by its significant main effect, data of the two target subcategories were pooled as the effect size was small and no interaction effects were found between the target subcategories and the other two between-groups factors. Thus, pooling the data would not likely affect the interpretation of subsequent performance within an individual birth experience group of any memory condition.

Overall learning differences between groups

After pooling data from the two target subcategories (upper- and lower-body summer clothing) within each birth experience group in each memory condition, learning differences were further assessed between birth experience groups by conducting a 2-way ANOVA on the mean value of each dependent variable during the encoding phase, with Birth Experience and Memory Condition as between-groups factors. For all the variables, results revealed non-significant main effects of birth experience and memory condition, as well as non-significant interaction effects.

For accuracy percentage, no significant effects were found (birth experience, F (1, 72) = 0.15, p = 0.7; memory condition, F (1, 72) = 0.73, p = 0.39; interaction effect, F (1, 72) = 0.2, p = 0.66. For reaction time, no significant effects were found (birth experience, F (1, 72) = 0.04, p = 0.85; memory condition, F (1, 72) = 0.003, p = 0.96; interaction effect, F (1, 72) = 0.06, p = 0.81). A Mann-Whitney U test conducted on reaction time in the novel target memory condition, with Birth Experience as the between-group factor, revealed no significant differences, U ($N_{vaginal}$ = 20, $N_{c\text{-}section}$ = 18) = 177, z = -0.09, p = 0.94, between the vaginal (Mdn = 1056.66) and the c-section (Mdn = 1135.76) groups. For hit rate, no significant effects were found (birth experience, F (1, 72) = 0.68, p = 0.41; memory condition, F (1, 72) = 1.39, p = 0.24; interaction effect, F (1, 72) = 0.11, p = 0.74). For correct rejection rate, no significant effects were found (birth experience, F (1, 72) = 0.39, p = 0.53; memory condition, F (1, 72) = 0.15, p = 0.7; interaction effect, F (1, 72) = 0.03, p = 0.87). A Mann-Whitney U test, conducted on correct rejection rate in the novel target memory condition, with Birth Experience as the between-group factor, revealed no significant differences, U ($N_{vaginal}$ = 20, $N_{c\text{-}section}$ = 18) = 184.5, z = 0.13, p = 0.9, between the vaginal (Mdn = 0.78) and c-section (Mdn = 0.81) groups.

Overall, the lack of any significant results suggests that the two birth experience groups in each memory condition exhibited similar learning and, therefore, any subsequent differences in the savings ratios between birth groups would seemingly not be due to initial learning differences but rather due to differences in memory processing.

Learning ratios differences between groups

Further, learning performance was examined between birth groups by conducting 2-way ANOVAs on the mean learning ratios (i.e. mean value from the second half of the encoding phase divided by the mean value from the first half of the encoding phase) for each dependent variable, with Birth Experience and Memory Condition as the between-groups factors. Results revealed no significant main effects or interaction effects for all the variables.

For accuracy percentage, no significant effects were found (birth experience, F (1, 72) = 0.49, p = 0.49; memory condition, F (1, 72) = 0.73, p = 0.4; interaction effect, F (1, 72) = 0.83, p = 0.37). For reaction time, no significant effects were found (birth experience, F (1, 72) = 0.08, p = 0.77; memory condition, F (1, 72) = 0.98, p = 0.33; interaction effect, F (1, 72) = 0.05, p = 0.82). A Mann-Whitney U test conducted on reaction time in the novel target memory condition, with Birth Experience as the between-groups factor, revealed no significant differences, U ($N_{vaginal}$ = 20, $N_{c\text{-}section}$ = 18) = 190, z = 0.29, p = 0.78, between the vaginal (Mdn = 0.83) and c-section (Mdn = 0.86) groups. For hit rate, no significant effects were found (birth experience, F (1, 72) = 0.76, p = 0.39; memory condition, F (1, 72) = 0.0.2, p = 0.89; interaction effect, F (1, 72) = 0.001, p = 0.98). For correct rejection rate, no significant effects were found (birth experience, F (1, 71) = 0.12, p = 0.73; memory condition, F (1, 71) = 0.25, p = 0.62; interaction effect, F (1, 71) = 0.95, p = 0.33). A Mann-Whitney U test conducted on correct rejection rate in the novel target condition, with Birth Experience as the between-groups factor, revealed no significant differences, U ($N_{vaginal}$ = 19, $N_{c\text{-}section}$ = 18) = 223.5, z = 1.6, p = 0.11, between the vaginal (Mdn = 1.1) and c-section (Mdn = 1.31) groups.

The lack of any significant differences in learning ratios further supported the idea that there were no learning differences between the birth experience groups in each memory condition which would mediate any subsequent birth differences in savings ratios as memory differences between birth experience groups.

Learning of individual group

Although no differences were found between birth experience groups in each memory condition for learning measures, whether or not learning was initially achieved by either birth experience group in each memory condition was not examined. Planned comparisons (two-tailed) were therefore performed on each dependent variable for each birth experience group in each memory condition, by comparing the mean values from the first half of the encoding phase to the mean values from the second half of the encoding phase.

In the familiar target memory condition, for accuracy percentage, both birth experience groups showed a significant increase (vaginal, t (18) = 3.34, p = 0.004, d = 0.77; c-section, t (18) = 4.94, p = < 0.001, d = 1.13) from the first half (vaginal, M = 0.62, SD = 0.14; c-section, M = 0.6, SD = 0.11) to the second half (vaginal, M = 0.7, SD = 0.11; c-section, M = 0.69, SD = 0.08) of the encoding phase. For reaction time, both birth experience groups showed a significant decrease (vaginal, t (18) = -5.09, p < 0.001, d = -1.17; c-section, t (18) = -4.71, p < 0.001, d = -1.08) from the first half (vaginal, M = 1257.64, SD = 276.97; c-section, M = 1234.59, SD = 266.53) to the second half (vaginal, M = 1035.91, SD = 230.01; c-section, M = 1054.3, SD = 281.72) of the encoding phase. For hit rate, both birth experience groups showed a significant increase (vaginal, t (18) = 2.91, p = 0.009, d = 0.67; c-section, t (18) = 4.52 p = <0.001, d = 1.04) from the first half (vaginal, M = 0.62, SD = 0.14; c-section, M = 0.58, SD = 0.11) to the second half (vaginal, M =0.71, SD = 0.12; c-section, M = 0.69, SD = 0.1) of the encoding phase. For correct rejection rate, only the vaginal group showed a significant increase, t (18) = -2.88, p = 0.01, d = 0.66, from the first half (M = 0.6, SD = 0.29) to the second half (M =0.77, SD = 0.29) of the encoding phase, whereas no significant increase was observed in the c-section group, t (18) = 0.56, p = 0.58, from the first half (M = 0.71, SD = 0.22) to the second half (M = 0.73, SD = 0.18) of the encoding phase.

In the novel target memory condition, for accuracy percentage, both birth experience groups showed a significant increase (vaginal, t (19) = 5.56, p < 0.001, d = 1.24; c-section, t (17) = 6.51, p = < 0.001, d = 1.54) from the first half (vaginal, M = 0.62, SD = 0.13; c-section, M = 0.6, SD = 0.11) to the second half (vaginal, M = 0.72, SD = 0.11; c-section, M = 0.74, SD = 0.1) of the encoding phase. For reaction time, only the vaginal group showed a significant decrease, t (19) = -2.58, p = 0.02, d = -0.58, from the first half (M = 1218.36, SD = 248.25) to the second half (M = 1053.83, SD = 266) of the encoding phase, whereas the c-section group did not show any significant decrease, t (17) = -2.04, p = 0.06, from the first half (M = 1237.68, SD = 283.97) to the second half (M = 1084.25, SD = 371.04) of the encoding phase. For hit rate, both birth experience groups showed a significant increase (vaginal, t (19) = 4.55, p < 0.001, d = 1.02; c-section, t (17) = 5.32 p = <0.001, d = 1.25) from the first half (vaginal, M = 0.64, SD = 0.12; c-section, M = 0.61, SD = 0.12) to the second half (vaginal, M =0.74, SD = 0.11; c-section, M = 0.74, SD = 0.13) of the encoding phase. For correct rejection rate, only the c-section group showed a significant increase, t (17) = 4.41, p = <0.001, d = 1.04, from the first half (M = 0.6, SD = 0.28) to the second half (M = 0.79, SD = 0.22) of the encoding phase, whereas the vaginal group did not show any significant increase, t (19) = 1.03, p = 0.31, from the first half (M = 0.63, SD = 0.34) to second half (M= 0.7, SD = 0.3) of the encoding phase.

Overall, most of the planned comparisons revealed a significant performance change from the first half to the second half of the encoding phase, indicating learning and improvement in visual search was exhibited by both birth experience groups in each memory condition. Particular measures, that being correct rejection rate for the c-section group in the familiar target memory, correct rejection rate for the vaginal group in the novel target condition, and reaction time for the c-section group in the novel target memory condition, however, were not found to be facilitated between halves of the encoding phase. Although it is unclear of why a lack of learning was shown with these particular measures, the lack of an increase in correct rejection rate for the c-section group in the familiar target memory condition could have been due to the correct rejection rate already being relatively high in the first half of encoding, so perhaps they were already close to ceiling performance and performance improvement would be limited. Further, in the novel target memory condition, the lack of an increase in correct rejection rate by the vaginal group and the lack of a decrease in reaction time by the c-section group could have been due to high sampling variability as indicated by their abnormal data distribution during encoding and their relatively large standard deviations. Despite the apparent lack of learning showed by these three measurements, learning was robustly shown by other measurements and therefore, generally implying information encoding and the use of memory-based search strategy instead of random eye movements. Consequently, subsequent performance during the memory testing phase would seemingly be based on the capacity of long-term memory retention and discrimination.

3.3 Memory analyses

With the previous analyses overwhelmingly demonstrating that there were no differences between the birth experience groups in their initial learning, any differences during the memory testing phase on day 2 would have to be due the impact of birth experience on memory functioning. Subsequent analyses, therefore, will focus on performance during the memory testing phase and comparison to performance during the encoding phase.

Memory differences between groups

To examine whether birth experience affects long-term memory in adults, a 2-way ANOVA was conducted on the mean savings ratio (i.e. mean value from the first half of the memory testing phase divided by the second half of the encoding phase) of each dependent variable, with Birth Experience and Memory Condition as the between-groups factors.

For accuracy percentage, result revealed a main effect of memory condition, F (1, 72) = 18.19, $p < 0.001$, but there was no main effect of birth experience, F (1, 72) = 0.35, $p = 0.56$, and no interaction effect, F (1, 72) = 1.14, $p = 0.29$. Similar results were observed for hit rate (birth experience, F (1, 72) = 0.007, $p = 0.93$; memory condition, F (1, 72) = 21.73, $p < 0.001$; interaction effect, F (1, 72) = 0.99, $p = 0.32$). In contrast, no main effects or interaction effect were found for reaction time (birth experience, F (1, 72) = 0.38, $p = 0.54$; memory condition, F (1, 72) = 0.38, $p = 0.54$; interaction effect, F (1, 72) = 0.01, $p = 0.92$). A Mann-Whitney U test, conducted on reaction time in the novel target memory condition, with Birth Experience as the between-groups factor, found no significant differences, U ($N_{vaginal}$ = 20, $N_{c\text{-}section}$ = 18) = 191, z = 0.32, $p = 0.76$), between the vaginal (Mdn = 1.05) and the c-section (Mdn = 1.04) groups. Similar to reaction time, no main effects or interaction effect were found for correct rejection rate (birth experience, F (1, 72) = 0.16, $p = 0.69$; memory condition, F (1, 72) = 0.61, $p = 0.44$; interaction effect, F (1, 72) = 0.07, $p = 0.79$). A Mann-Whitney U test on correct rejection rate in the novel target memory condition, with Birth Experience as the between-groups factor, showed no significant differences, U ($N_{vaginal}$ = 20, $N_{c\text{-}section}$ = 18) = 221.5, z = 1.22, $p = 0.23$), between the vaginal (Mdn = 0.98) and the c-section (Mdn = 1) groups. In sum, the lack of main effects of birth experience or interaction effects between birth experience and memory condition suggests that there were no significant differences in the long-term memory retention and discrimination as a function of one's birth experience.

Memory of individual group

To determine whether or not either birth experience group exhibited long-term memory and discrimination rather than just whether they differed from each other, planned comparisons (one-tailed) were performed for each memory condition to compare whether mean savings ratios of variables were significantly less (or significantly more for reaction time) than a hypothetical savings ratio of 1.00, which would represent perfect memory retention.

For the vaginal group in the familiar target memory condition, the group exhibited a mean savings ratio for accuracy percentage (M = 1.06, SD = 0.09) not significantly less than 1 (Figure 3a.), t (18) = 2.82, p = 0.99, for reaction time (M = 0.97, SD = 0.14) not significantly greater than 1 (Figure 3b.), t (18) = -0.78, p = 0.78, for hit rate (M = 1.09, SD = 0.16) not significantly less than 1 (Figure 3c.), t (18) = 2.48, p = 0.99, and for correct rejection rate (M = 1.01, SD = 0.35) not significantly less than 1 (Figure 3d.), t (18) = 0.08. For the c-section group in the familiar target memory condition, the group exhibited a mean savings ratio for accuracy percentage (M = 1.04, SD = 0.20) not significantly less than 1 (Figure 3a.), t (18) = 1.00, p = 0.83, for reaction time (M = 1.01, SD = 0.29) not significantly greater than 1 (Figure 3b.), t (18) = 0.11, p = 0.46, for hit rate (M = 1.05, SD = 0.21) not significantly less than 1 (Figure 3c.), t (18) = 1.09, p = 0.85, and for correct rejection rate (M = 1.02, SD = 0.34) not significantly less than 1 (Figure 3d.), t (18) = 0.28, p = 0.61. These results would seem to indicate that both birth experience groups exhibited long-term memory retention when familiar target information from encoding phase was presented during memory testing.

In the novel target memory condition, the vaginal group exhibited a savings ratio for accuracy percentage ($M = 0.89$, $SD = 0.11$) significantly less than 1 (Figure 3a.), t (19) = -4.33, $p < 0.001$, $d = 0.97$, for reaction time ($M = 1.02$, $SD = 0.19$) not significantly greater than 1 (Figure 3b.), t (19) = 0.43, $p = 0.34$, for hit rate ($M = 0.86$, $SD = 0.12$) significantly less than 1 (Figure 3c.), t (19) = -4.87, $p < 0.001$, $d = 1.09$, and for correct rejection rate ($M = 1.07$, $SD = 0.75$) not significantly less than 1 (Figure 3d.), t (19) = 0.39, $p = 0.65$. For the c-section group in the novel target memory condition, the group exhibited a mean savings ratio for accuracy percentage ($M = 0.94$, $SD = 0.13$) significantly less than 1 (Figure 3a.), t (17) = -1.82, $p = 0.04$, $d = 0.43$, for reaction time ($M = 1.04$, $SD = 0.13$) not significantly greater than 1, t (17) = 1.33, $p = 0.1$, for hit rate ($M = 0.91$, $SD = 0.19$) significantly less than 1 (Figure 3b.), t (17) = -2.09, $p = 0.03$, $d = 0.49$, and for correct rejection rate ($M = 1.14$, $SD = 0.40$) not significantly less than 1, t (17) = 1.49, $p = 0.92$. These results would seem to indicate that both birth experience groups exhibited long-term memory discrimination in terms of accuracy percentage and hit rate, when novel target information was presented during memory testing relative to the encoding phase. This long-term memory discrimination by both birth groups was not evident, however, in terms of reaction time and correct rejection rate, which might not be particularly surprising given the high variability in these measures and the lack of improvement in these two measurements during encoding. Subsequent performance on these two measurements, therefore, would not have absolute value changes to be influenced by any long-term memory effects. Instead, performance would be similar to the respective group's baseline performance during encoding.

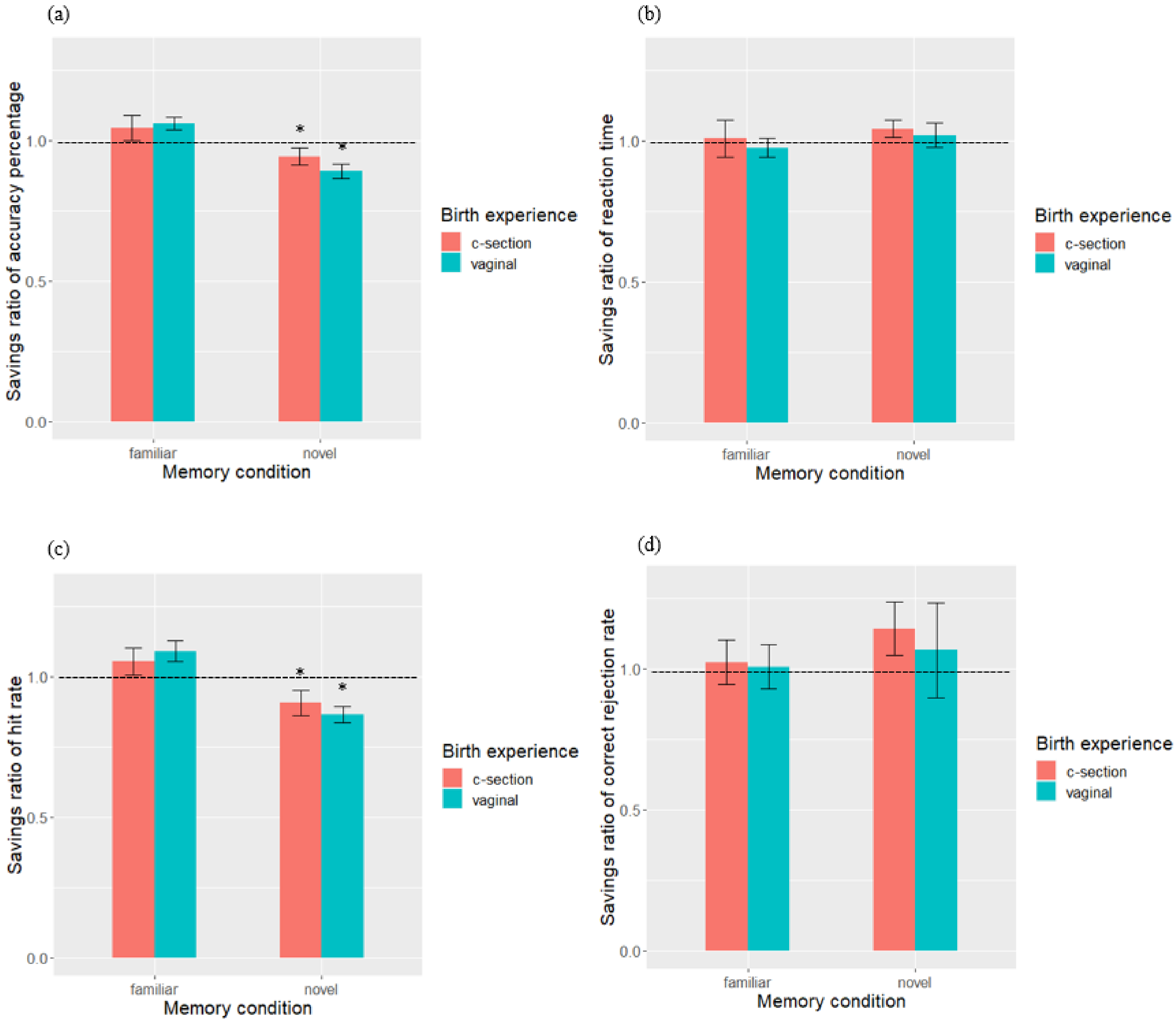

Figure 3. Saving ratios of two birth groups. Graphs showing the mean savings ratios of (a) accuracy percentage, (b) reaction time, (c) hit rate, and (d) correct rejection rate for vaginal and c-section birth groups in familiar and novel target memory conditions. For both birth groups, only savings ratios of accuracy percentage and hit rate in the novel target memory condition were significantly less than the hypothetical ratio of 1 (dotted line).

4. Discussion

Previous studies have demonstrated a potential association between c-section births and neurodevelopmental disorders (Curran et al., 2015; Liu et al., 2022; Zhang, 2019), yet, only a limited number of studies have investigated the impact of c-section on any of the fundamental cognitive functions that would be affected in neurodevelopmental disorders. To date, only a few behavioral and neurological studies have shown a negative c-section impact on infants' (Adler & Wong-Kee-You, 2015; Deoni et al., 2019) and adults' visual attention (Rahimi & Adler, 2019; Stevens et al., under review). Given the close behavioral and neural linkage of attention and long-term memory (Adler et al., 1998; Bettencourt et al., 2021; Ciaramelli et al., 2008; Craik & Lockhart, 1972; Lockhart & Craik, 1990; Rotshtein et al., 2011; Sauseng et al., 2008; Wolfe, 2021), as well as evidence which shows c-section effects on the neurological components of long-term memory and its behavioral manifestation in mice (Chen et al., 2017;Castillo-Ruiz et al., 2018a; Castillo-Ruiz et al., 2018b; Huang et al., 2019; Maqsood & Stone, 2016; Polidano et al., 2017; Simon-Areces et al., 2012; Seli & Horvath, 2013; Wang et al., 2014), the current study hypothesized that c-section birth, relative to vaginal birth, would negatively affect long-term memory in visual search and that the effects would be evident in adults, as it affects adults' visual attention (Rahimi & Adler, 2019; Stevens et al., under review).

General findings

To explore the birth experience effect on long-term memory in adults, the current study used a two-day visual search paradigm that incorporated a component of long-term memory in addition to an attentional component (Friedman et al., 2018). As visual search can either be based on random eye movements or a memory-based search strategy, the choice between is determined by the cost effectiveness trade-off between search efficiency and memory load (Wolfe et al., 2000).

To invoke the use of search memory, the current study was therefore predicated on the task being designed to be relatively difficult by having short durations of stimulus presentation and the need to process target category information (beyond just the surface level perceptual features) to produce an accurate response. That the formation of search memory occurred was generally supported by the significant improvement in search performance during the encoding phase (Le-Hoa Võ & Wolfe, 2015; Solman & Smilek, 2010). Consequently, search performance after the 24-hour delay would likely be based on long-term memory of search and target information, which was also substantiated by the lack of learning differences between birth groups in each memory condition during target encoding.

Given that search performance after 24-hour was seemingly determined by long-term memory, results from the familiar and novel target memory conditions suggest that vaginal-delivered and c-section-delivered adults exhibited similar memory retention and discriminability. That both birth groups have similar capacity of long-term memory is consistent with the longitudinal study showing that birth differences in white matter volume diminished by age 3 years (Deoni et al., 2019), and the children and adults' studies that did not show a consistent birth differences in cognitive tests performance (Dinan et al., 2022; Polidano et al., 2017), as well as the previous mice study which showed that the impact of c-section on long-term memory did not persist beyond adolescence into adulthood (Huang et al., 2019). Generally, the current findings seem to suggest that birth experience does not influence adults' long-term memory.

Retention intervals

Despite the current finding of no birth differences in long-term memory after a 24-hour delay, other studies have demonstrated that long-term memory differences may only be observed over longer retention intervals when there are differences in initial encoding or strength of the memory trace. Adler et al. (1998), for example, revealed that although all infants exhibited long-term memory retention after a 24-hour delay, some infants exhibited retention over a longer delay depending on the level of attentional allocation to the target during encoding. This suggests that memory performance differences due to encoding differences might not be expressed initially but could be observed over longer retention intervals. The current study, however, only tested long-term memory at one retention interval and therefore, birth differences in memory encoding that might be manifested over time were not assessed. Moreover, future research should further examine any birth experience effects on long-term memory over longer retention intervals.

Dichotomy of processing levels

That, both the vaginal-delivered and c-section-delivered adults have similar capacity of long-term memory, however, is contradictory to the significant attentional differences found in vaginally versus c-section born infants and adults (Adler & Wong-Kee-You, 2015; Deoni et al., 2019; Rahimi & Adler, 2019; Stevens et al., under review). Contradictory birth experience effects on memory and attention perhaps could be attributed to the dichotomy of processing levels. That is, bottom-up processing is more likely to be affected by c-section than top-down processing, as suggested by the previous attentional studies which only found deficits with a bottom-up attentional task, but no deficits have been found with a top-down attentional task (Adler & Wong-Kee-You, 2015; Rahimi & Adler, 2019). Memory mechanisms, therefore, which are a component of top-down cognitive processing might not be significantly impacted by birth experiences, as top-down attentional processing does not seem to be impacted.

Further, the dichotomic aspect of attentional processing, as exemplified by the Guided Search model (Wolfe, 2021) in which long-term memory retrieval is guided by two distinct attentional pathways, may play a role in modulating any birth experience effects on long-term memory either through memory-based top-down attentional guidance or stimulus-driven bottom-up attentional guidance. The two attentional guided memory pathways framework has also been substantiated by a finding that memory retrieval is mediated differently by top-down and bottom-up attention through the dorsal parietal cortex and ventral parietal cortex, respectively (Ciaramelli et al., 2010). Consequently, if long-term memory is mediated differently by top-down and bottom-up attentional mechanisms as suggested by the Guided Search model and by evidence of distinct neural pathways, then perhaps the specific birth experience effects on bottom-up attentional mechanisms (Adler & Wong-Kee-You, 2015; Rahimi & Adler, 2019) will only extend to bottom-up attentionally guided memory processing. Long-term memory retrieval in the current visual search task, however, was not specifically based on bottom-up attention because selective attention to search targets was guided by stored categorical information or specific featural information rather than the saliency of surface level perceptual features. Top-down attentional memory in addition to the bottom-up attentional memory mechanism, therefore, was likely involved and any birth experience effects on long-term memory might not be fully detected with the current paradigm. In the future, a more specific task that targets bottom-up attentional guided memory should be designed to better investigate the exact linkage between birth experience and long-term memory.

In addition, the sensitivity of the different processing levels to birth experience effects may be explained by the differential developmental trajectories between different processing levels. That is, higher-level processing has a longer developmental trajectory and develops at a more leisurely rate than lower-level processing and, therefore, would be more protected from early disruption because early functioning mostly relies on lower-level processing (Johnson, 2001). As a consequence, lower-level mechanisms such as stimulus-driven attention are available to be influenced by the aberrant birth events, whereas higher-level mechanisms such as memory are not yet available to be affected. The higher-level memory processing system then has time to compensate via typical maturation later in development after neurological disruptions were exerted by c-section, limiting the impact of birth experience on higher-level memory processing but not on lower-level attentional processing.

Alternative to the idea that higher-level memory processing would be less affected by early disruption because it was not functionable during early development, higher-level memory processing would then be affected by later disruption when later functioning relies on higher-level processing (Johnson, 2001). In fact, there are ample external factors appear later in life that could affect one's memory performance such as lifestyle, education and child-care environment (Burger, 2009; Labban & Etnier, 2013; Peisner-Feinberg, 2001), which could then moderate any existing birth experience effects on long-term memory. For example, one study has suggested ways to restore gut microbial balance in c-section-delivered individuals including by breastfeeding and probiotic supplementation (Moya-Pérez et al., 2017). These methods might compensate for the early microbial perturbation impact on neurodevelopment and thereby any birth experience effects on long-term memory. In support of this possibility of compensation, another study manipulated the gut microbiota as a treatment or prevention of Alzheimer's disease in which abnormal gut microbiota and hippocampal development were shown in these patients (Tan et al., 2020). That reversal of cognitive deficits by the restoration of gut microbiome can occur may explain the current absence of birth differences in adults' long-term memory and perhaps the diminished birth experience effects on adult mice's long-term memory (Huang et al., 2019), and on white matter volume by age 3 years (Deoni et al., 2019).

Furthermore, a birth experience effect limited to lower-level attentional processing but sparing higher-level memory processing would seemingly be consistent with the transient birth experience effect found for infants' white matter volume as white matter volume was assessed in multiple brain regions simultaneously which might mask the potential birth experience effects in any specific lower-level cognitive functions (Deoni et al., 2019). If this is the case that later seeding and experience modulate any impacts of birth experience on long-term memory functioning, then probing at an age prior to the modulation should reveal whether birth mode impacts memory functioning. To better examine the birth experience effects on long-term memory, therefore, birth experience as a function of long-term memory should be studied in young infants, in addition to adults, to determine any birth experience impacts on early long-term memory development and whether the effects persist.

Dichotomy of c-section types

In addition to the differential impacts on top-down, higher-level memory processing and bottom-up, lower-level attentional processing, c-section delivery is not a unitary category of birth mode but can be subdivided further into medically unnecessary emergency and medically necessary planned c-sections. These two types of c-section births are also differentiated from each other by their unique birth experiences which might lead to different extents of neurodevelopmental consequences due to the neurological linkage between birth experiences and brain development. That is, infants delivered by planned c-sections do not experience any birth processes associated with labor and traversing the birth canal, which could alter birth-related biological mechanisms that affect brain development, such as an altered seeding of gut microbiota that affects neurochemical compounds necessary for learning and memory mechanisms (Biasucci et.al., 2010; Chen et al., 2017; Castillo-Ruiz et al., 2018a; Castillo-Ruiz et al., 2018b; Huang et al., 2019; Maqsood & Stone, 2016; Simon-Areces et al., 2012; Seli & Horvath, 2013; Tan et al., 2020). Altered production of other related biological molecules in the hippocampus that were typically triggered by the stress during birth canal traversal (Simon-Areces et al., 2012; Seli & Horvath, 2013; Wang et al., 2014) would also likely occur as a function of the minimal labor and birth canal exposure experienced during planned c-section birth. On the other hand, infants delivered by emergency c-sections experience some of the birth processes associated with labor and those birth-related biological mechanisms would be disrupted to a lesser extent, enabling the cognitive developmental trajectory to be relatively preserved compared to infants delivered by planned c-sections.

Consistent with a possible behavioral manifestation of c-section type differences, in the attentional study conducted by Rahimi and Adler (2019), differences in attentional behaviour between the types of c-sections were found. That is, 3-month-old infants delivered by planned c-sections exhibited poorer bottom-up attentional allocation in a visual search task than either infants who had been delivered by emergency c-sections or those who had been delivered vaginally, who did not differ from each other. This differential effect between planned and emergency c-sections, however, did not persist in adults. Instead, over time, deficits in the attention of those delivered by emergency c-section manifested, approximating the aberrant attentional allocation of planned c-section individuals and, therefore, yielding both types of c-section birth adults being different from those born vaginally (Rahimi and Adler, 2019). A possible cognitive and attentional difference attributed to c-section types, therefore, may also manifest in memory development. Perhaps the experiential differences between c-section types enabled the development of memory mechanisms to be less affected by emergency c-section relative to planned c-section. If this dichotomy between c-section types plays a role in early memory development as it does for early attentional development, the current finding of birth experience effect might have been moderated by the long-term memory performance of emergency c-section group because data of emergency and planned c-section individuals were combined as one c-section group.

To this point, an analysis was conducted by separating the individuals born by emergency and those born by planned c-sections and comparing the mean savings ratios between the three birth groups (vaginal, emergency c-section and planned c-section). In the familiar target condition, results revealed a trend that both the emergency c-section group and vaginal group exhibited a better long-term memory retention than the planned c-section group (Figure 4.), which is consistent with the differential birth experiences and related biological mechanisms between the c-section types. It is surprising, however, that the emergency c-section group outperformed the vaginal group as the vaginal group would be expected to exhibit the best performance due to experiencing a typical birth experience and, therefore, typical birth-related biological factors, as well as being inconsistent with previous evidence that vaginal-delivered infants and adults exhibited the best attentional performances (Adler & Wong-Kee-You, 2015; Rahimi & Adler, 2019). Further, it was also surprising that emergency c-section group did not exhibit better long-term memory discrimination in the novel target memory condition as in the familiar target memory condition, perhaps suggesting that these individuals have higher capacity in encoding and retaining general target categorical information but not the specific target featural information. One possible explanation, however, is that due to the current sample size of the emergency c-section group (n =13) being fairly small and unbalanced compared with the size of the planned c-section (n = 24) and vaginal (n = 39) groups and, thus, the analysis is likely unrepresentative and under-powered. Exactly how or if long-term memory is impacted by the types of c-sections therefore remains unknown and needs to be further examined.

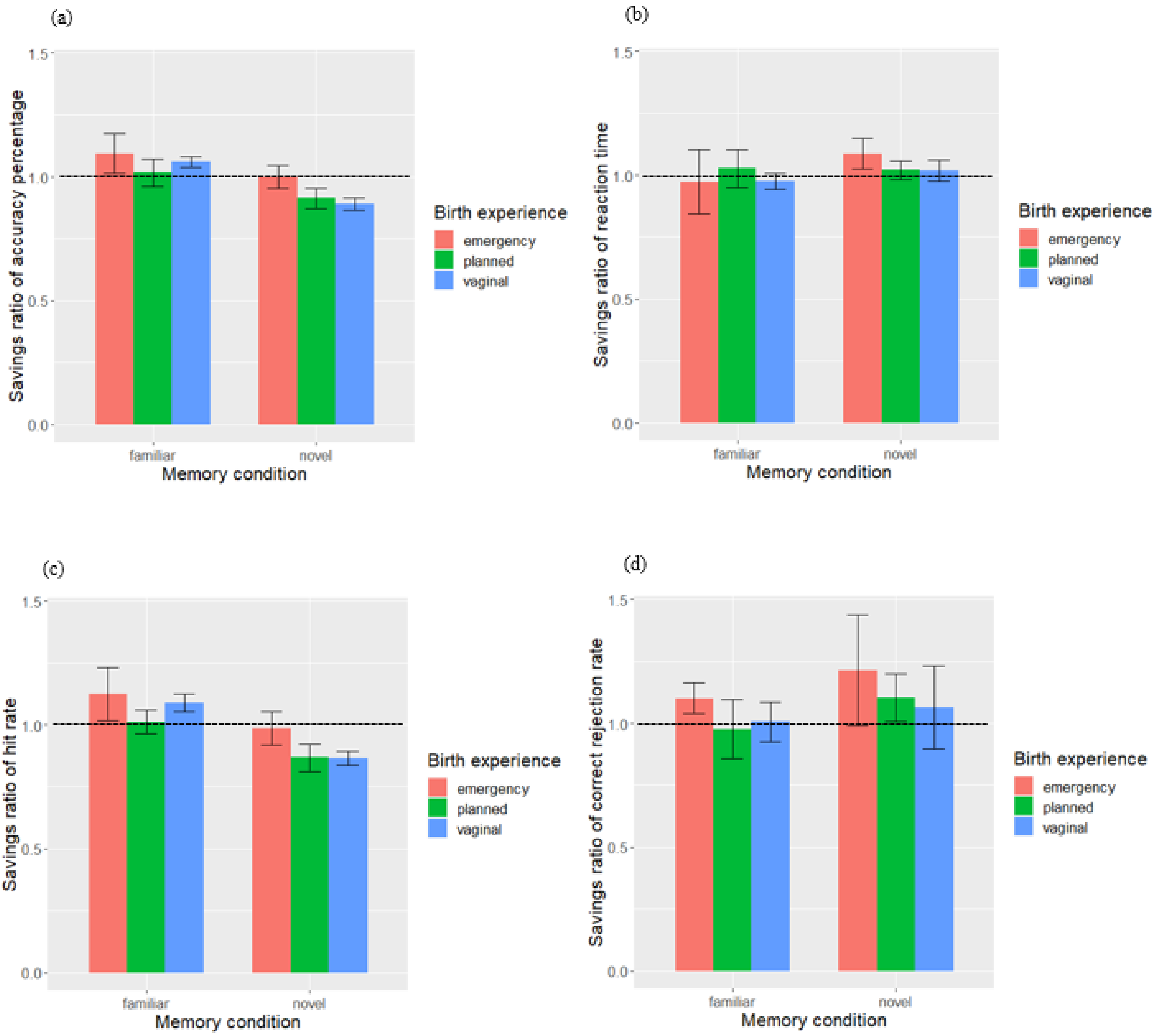

Figure 4. Savings ratios of three birth groups. Graphs showing the mean savings ratios of (a) accuracy percentage, (b) reaction time, (c) hit rate, and (d) correct rejection rate of vaginal, planned and emergency c-section birth groups in familiar and novel target memory conditions.

Sampling variability

Finally, some of the otherwise observable birth experience effects on long-term memory might have been masked by the high sampling variability in the current study. One of the reasons for such a high variability might be the fact that, as with any online study, participants' external environment is difficult to properly control, including their monitor size, mouse speed, distance from the stimuli and other external distractions. Supporting such a high variability occurs in an online experiment, one study has demonstrated an increase of invalid survey data in undergraduate samples when data were collected online relative to data that were collected in-person either on a computer or on paper (Al-Salmon & Miller, 2017), suggesting a similar increase of invalid data in the current online study. Besides, the current visual search task requires a high level of attentiveness given the need to detect a categorical target within a short time interval, which may further increase the probability of getting invalid data beyond that in the online survey experiment and lead to a high data variability in the current study.

To study the exact linkage of birth experience and long-term memory, a similar study should therefore be replicated in-lab with infants and adults, by comparing long-term memory performance between vaginal, emergency and planned c-section birth groups, and with a task that focuses on bottom-up attentional guided memory, as well as assessing long-term memory over longer retention intervals. If birth experience is found to impact long-term memory in such a study, this would indicate that the specificity of birth experience effects is not limited to attentional mechanisms but also filters further upstream to higher-level cognitive mechanisms. Consequently, if memory is found to be altered due to c-section birth, other cognitive and brain functions then might also be at risk and would need to be assessed for their sensitivity to birth experience effects. If such a finding is validated together with the current finding of no birth experience effect on adults' memory, it would indicate that the deviation in brain and cognitive development induced by c-section births is specific, and perhaps is a delayed but non-permanent effect. Such a finding would also support the role of neuroplasticity for some fundamental cognitive functions, a central concept in cognitive development which proposes the brain's ability to change and adapt as a result of experience (Pascual-Leone et al, 2005).

5. Conclusion

Overall, the results of the current study suggest a lack of c-section impact on adults' long-term memory retention and discriminability in visual search. That is, any long-term memory impact by c-section might be negligible because memory as a top-down and higher-level cognitive mechanism might not be significantly influenced by early neural disruption perpetuated by c-section birth, and perhaps could be modulated by external factors such as microbial restoration with age and one's social environment. The impacts of c-section birth found in the current study, however, might also be limited by the single retention interval testing, and by which type of c-section births is experienced. Future research should therefore examine the birth experience effect on long-term memory over longer retention intervals and between c-section types. Research should also study any birth experience impacts on the early development of long-term memory and to replicate the study in a more controlled setting with a larger sample and a different paradigm that can specifically distinguish between top-down and bottom-up attentional guided memory. Despite all the limitations of the current study and lack of any evidence that c-section birth disrupts memory functioning in adults, this study suggests that birth experience may involve a more subtle effect, impacting certain levels of cognitive functioning more than others. Such finding can only increase our understanding on the role of birth and the extent of c-section birth plays in brain and cognitive development, potentially, on neuroplasticity, in the context of the booming rate of c-section births and the possibly unnecessary use of c-section delivery.

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7. Appendices

1.1 Consent Form

Visual and Cognitive Development Project

Informed Consent Form (Adults)

Project: Online Assessment of Birth Effects on Attention and Memory

Principal Investigator: Scott A. Adler Ph.D., York University.

Overview:

You are being asked to participate in a research study by Dr. Scott A. Adler, an Associate Professor at York University. Your participation in this study is entirely voluntary. Please read the information below and ask questions about anything you do not understand before deciding whether or not to participate.

Purpose of Study:
This study is designed to examine the impact that the birth experience has on visual attention performance and memory functioning over the long term into adulthood.

Procedure:

There are two sessions involved in this study. During each session of this study, images will be presented to you on a computer screen and you will be asked to select one of the stimuli on the screen by responding with moving the mouse to click on the appropriate location.

Anticipated Benefits to Participants and Society:

This study will help us to better understand the development of attention. This could lead to advances in other areas such as perception and general cognitive processing.

Potential Risks and Discomforts:
Participation in this study does not pose any foreseeable risks other than fatigue. **If new information related to the Benefits and Risks of the study is obtained, you will be informed immediately.**

Compensation:

At the end of each session, you will receive course credit for the undergraduate Introduction to Psychology course (Psyc 1010).

Participation and Withdrawal
Your participation in this research is entirely voluntary. If you decide to participate, you are subsequently free to withdraw your consent and discontinue participation at any time without penalty or loss of rights. If you

withdraw, you will still receive the appropriate course credit. The information obtained from this study may be presented at scientific conferences or in scientific journals, but your name will never appear in any public document. In order to ensure confidentiality, your name and other identifying information will be filed separately from the experimental data.

YORK UNIVERSITÉ UNIVERSITY

Visual and Cognitive Development Project

Signature Section (Adults)
Project: Online Assessment of Birth Effects on Attention and Memory

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1.
2. I have read and understood the description of the research project. I understand the purpose of the current study, the purpose of my participation, the procedures involved, potential benefits, and the potential risks to me if I participate. I have asked for and received a satisfactory explanation of any language or details of the study that I did not fully understand.
3.

I understand that my participation in the study is voluntary. I may withdraw from the study at any point in time. It has been explained to me that the results of the study are confidential. I understand that I will receive credit in my undergraduate psychology course as compensation for participating in this study.

All my information will be kept confidential to the fullest extent allowed by law and securely stored in the locked offices of the Project and on password protected computers for a period of 5 years. After this time, all documents associated with me will be shredded and computer files will be deleted. I understand, however, that all analyzed data generated by my participation will be kept indefinitely, for the possibility of reanalysis at a later date.

4. I hereby consent to participate. I have been given a copy of this consent form and the attached information sheet.
5.
6. If, at a later time, I have any questions, I may contact Scott A. Adler, Ph.D., at York University (416-736-5115, ext. 33389, or 416-736-2100 ext. 20036, or adler@yorku.ca) for additional information.
7.
8. This research has received ethics review and approval by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics, 5th Floor, Kaneff Tower,York University (telephone 416-736-5914 or e-mail ore@yorku.ca).
9.
10. My signature below indicates that I agree to participate in the study and it also serves as confirmation that I will receive course credit for undergraduate introduction to psychology course end of the research session.

Participant:

Signature: Date: _____

7.2 Demographic Questionnaire

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Visual and Cognitive Development Project

Online Assessment of Birth Effects on Attention and Memory

DEMOGRAPHIC BACKGROUND QUESTIONNAIRE

Today's date: ______________________

Participant ID: _____________ (to be completed by researcher)

Name: _________________________________ E-mail address: _________________

Date of birth (Day/Month/Year):_________________

Gender (how you describe yourself): __ Male __ Female __ Non-Binary __ Other __ Prefer not to answer __ Write in __________________

Country of birth: _________________________ Handedness: ______________________

If not born in Canada, when did you come to Canada? (Month/Year) _____________________

Ethnicity (Please indicate how you describe your ethnic/racial background):

__ Aboriginal peoples, First Nations, or Indigenous peoples of the Americas

__ Black, African American, or African Canadian __ Chinese

__ Filipino __ Japanese __ Korean __ Latin American __ Middle Eastern

__ South Asian __ Southeast Asian __ West Asian __ White or Caucasian

__ Other (please specify): ______________

Were you born prematurely? __ Yes (before 37 weeks) __ No (37 weeks and after)

Were there any birth complications during your birth ? __ Yes __ No

If yes, please specify:

____

You were born: __ Vaginally __ Via Caesarean

If Caesarean, was it __ Planned __ Emergency

Do you have normal or corrected to normal vision? __ Yes __ No

Do you have normal hearing? __ Yes __ No

Have you ever suffered a traumatic brain injury? __ Yes __ No

Do you suffer from any neurologic or psychiatric disorder? __ Yes __ No

If yes, please specify:

____

Do you have a learning disability? __ Yes __ No

If yes, please specify:

____

Please indicate your highest level of education:

_____*No high school diploma*

_____*High school graduate*

_____*Some college or college diploma*

_____*Bachelor's Degree*

_____*Graduate or professional degree*

Please select the letter that best describes your family income:

__ Less than $20,000

__ Between $20,000 and $40,000

__ Between $40,000 and $60,000

__ Between $60,000 and $90,000

__ Between $90,000 and $120,000

__ Between $120,000 and $150,000

__ More than $150,00