THE EFFECT OF C-SECTION BIRTH ON ATTENTION TASK PERFORMANCE AND CORTICAL GREY MATTER INTEGRITY

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Abstract

Past evidence suggests that Caesarean section (C-section) birth is a factor in reduced performance on visual attention tasks, as well as altered intrinsic functional neural networks, for both infants and adults born via C-section. The present study tested C-section and vaginally born adults on six tasks: a visual search task, the Attention Network Task, the Sustained Attention to Response Task, the Stroop Task, the Trail Making Test, and an *n*-back task. Adults born via C-section were less accurate on target-absent conditions in the visual search task. No other tests showed significant differences based on birth method. Additionally, whole-brain voxel-based morphometry analysis was conducted on the anatomical magnetic resonance imaging data of adults to identify potential effects of C-section birth on cortical grey-matter integrity. Findings suggest that there is an effect of C-section birth on top-down attention but were not significant for other hypotheses in the experiment and MRI analysis.

Keywords: C-section, top-down and bottom-up attention, voxel-based morphometry, visual attention, visual search

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Introduction

Despite the World Health Organization's recommendation to keep rates of Caesarean sections (C-sections) between 10% and 15% (Betrán et al., 2007), they have become the most common surgical procedure for women worldwide (Cho & Norman, 2013). In some places like Latin & Central America, rates of C-sections have reached 40% of all births, and in North America rates are around 32% (Singh, Hashmi, & Swain, 2018). In some cases, a country may report higher C-section rates due to an increased need for C-sections. For example, in developing countries, C-sections can often improve the chances for a successful birth as access to emergency healthcare resources may be limited or unreliable (Menacker et al., 2006).

However, rising rates of C-section procedures are not completely due to necessity. In Western nations, like the United States of America, elective (i.e., non-medically indicated) C-sections have become popular, as they are thought to be a safe, controlled alternative to vaginal birth (Betrán et al., 2007). They might also be a popular option for doctors in private healthcare systems because they can charge more for the procedure (Singh, Hashmi, & Swain, 2018). Evidence of the rising popularity of C-sections among higher-income mothers in Australia suggests that rates are unrelated to an increased need for C-sections and are more related to an increase in C-section desirability among expectant mothers (Fox et al., 2019). C-sections are also a desirable option for women who have an "intense" fear of childbirth. Fear of childbirth is reportedly increasing, which may result in further requests for C-sections (Nieminen et al., 2009).

The statistics presented above indicate that C-section prevalence is not necessarily related to medical need but is viewed as an equivalent alternative to natural birth. Presumably, the perception is that C-section is a relatively safe procedure. However, the long-term developmental effects of C-section birth are largely unknown, and so there is an urgent need to study these effects.

As a consequence, hundreds of recent studies have been conducted into the potential long-term health consequences of C-sections. Research has shown, for example, that adolescents who were born via C-section are more likely to experience metabolism issues such as obesity (Bar-Meir et al., 2019) and diabetes (Vehik & Dabelea, 2012). Medical researchers have also suggested that people born via C-section experience long-term health issues because they are not exposed to critical maternal bacteria at birth, such as common lactobacilli (Stinson et al., 2018). Consequently, since C-section infants are not exposed to these bacteria in the same way as vaginally delivered (V-delivered) infants, they are more prone to chronic illnesses such as asthma, allergies, obesity, and diabetes (Stinson et al., 2018). Other research suggests that C-sections may trigger the expression of disorders like diabetes in people who have a genetic predisposition for the disorder (Bonifacio et al., 2011).

There is also evidence of a potential link between C-sections and various neurodevelopmental disorders in children and adults. Two of the most prevalent neurodevelopmental disorders, attention deficit/hyperactivity disorder (ADHD) (Curran et al., 2016) and autism spectrum disorder (ASD) (Langridge et al., 2013), have been associated with C-section birth; the correlations between the prevalence of these two disorders and C-section birth have been demonstrated in large-scale quantitative meta-analyses (Zhou et al., 2019; Ben-Ari, 2015).

There is still no consensus in the literature, however, as to the exact nature and extent of the relationship between C-section birth and ADHD or ASD. Much of the C-section and development research is correlational and based on cross-sectional studies that track the prevalence of these disorders in C-section born children compared to the general population, so the conclusions are limited (Xu et al., 2020). Furthermore, C-section birth is a quasi-independent variable—i.e., there is no way to independently analyze the effects of C-sections on development without the influence of other variables, both known and unknown, or independently randomly assign birth to be either C-section or vaginal. This has led to some controversy in the medical research around C-sections with some researchers claiming that there is a strong link between C-sections and long-term health effects (e.g., Curran et al., 2015; Bull-Larsen, 2019), whereas others have found through meta-analyses that the link may not exist or may depend on other variables (Xu et al., 2020). For this reason, further research is needed to make strong conclusions about C-section birth's effect on development.

Despite the challenges presented above, correlational/cross-sectional analyses have advanced an understanding of birth method's relationship with neurodevelopmental disorders. If there is a link between neurodevelopmental disorders and C-section birth, then it raises the question of how C-section birth might affect behaviour more generally. To answer this question, it is best to review experiments that use lab-controlled measures of behaviour as they can provide clarity on specific effects related to birth method better than cross-sectional or correlational analyses. For example, a cross-sectional study can determine that C-section birth is a significant predictor of the rate of ADHD diagnosis, but there is still the question of how C-section birth may be a factor with different attention processes. An experiment that controls the tasks and measures of attention can come to conclusions about how C-sections relate to performance on those tasks. Such experiments are discussed in the following section.

Attention Task Performance and Birth Method

Much of the past research on C-section births has been focused on medical issues as opposed to cognition, which has motivated neuroscientists and psychologists to investigate whether differences might also exist in neurocognitive development between C-section and V-delivery. For example, research has shown that rat pups born via C-section may develop differences in the barrel cortex, a primary sensory area responsible for tactile perception in rats, which is analogous to human primary visual cortex in both function and structure (Toda et al., 2013), although more research is needed to verify the effects of C-section on barrel cortex development. These findings were recently expanded by Cheisa et al. (2020), who found a deficit in communicative behaviours in rat pups who were born preterm by C-sections. Based on the functional similarity between rat barrel cortex and human somatosensory cortex, Adler and Wong-Kee You (2015) investigated and found behavioural differences in the allocation of visuospatial attention in human infants born via C-section when compared to V-delivered controls. Specifically, using eye tracking technology, they found that 3-month-old infants born by C-section had slower allocation of bottom-up attention than V-delivered infants, as measured by increased latency to initiate reactive eye movements (saccades) in a Posner-like visual cueing task (Adler & Wong-Kee You, 2015). The robustness of these early experimental results in human infants has driven further exploration into the impact of C-section on neurocognitive development.

Consistent with the previous findings (Adler & Wong-Kee You, 2015), subsequent research using a different visuospatial attention task, namely visual search, identified differences in allocating attention in both infants and adults born via C-section relative to vaginally delivered individuals (Rahimi & Adler, 2019). That is, infants and adults born via C-section exhibited delayed initiation of saccadic eye movements to localize a feature-present search target (i.e., an R among an array of Ps) across all set sizes relative to those delivered vaginally. In addition to confirming the effect of birth mode on visuospatial attention, this finding demonstrates the validity of using visual search tasks to investigate potential neurodevelopmental effects of C-section birth. The current study builds on this work by having both C-section and V-delivery adult participants complete a battery of attention and memory tasks to examine a wider range of potential neurocognitive differences as a function of birth mode.

Neurophysiology and Birth Method

Based on the results of Toda et al. (2013) and Adler and Wong-Kee You (2015), analyses were conducted into neurophysiological differences by Solomon-Harris et al. (2020). Using resting-state fMRI (rs-fMRI) to investigate differences in brain functional connectivity in adults born via C-section relative to those born vaginally, they found a significant difference between the functional connectivity of the default mode network (DMN) –a neural network associated with resting state—and visual regions. Notably, these differences are found with visual regions involved in bottom-up attention (left primary visual cortex (V1) and bilateral superior colliculi) (Solomon-Harris et al., 2020). These results shed light on the relationship between C-section birth and the development of neural attention networks. Furthermore, they suggest that for C-section adults, there is aberrant functional connectivity of regions primarily associated with bottom-up attention—automatically orienting to a stimulus—which is consistent with past behavioral findings (Adler & Wong-Kee-You, 2015; Rahimi & Adler, 2019). Given that the DMN is associated with a resting state, stronger connectivity in DMN regions suggests that it would take longer to shift from a resting state to an active state. Bottom-up attention, therefore, would therefore take longer to activate in C-section born adults with stronger DMN connectivity than in people with average DMN connectivity.

Current Research

As yet unpublished analyses conducted by Stevens and colleagues (in preparation) have established that there are behavioural differences in visual attention between C-section vs. V-delivered young adults. Specifically, this study found that C-section born participants exhibit slower response times on a flanker task compared with V-delivered participants. Unlike the findings of Rahimi and Adler (2019), which presented a deficit of bottom-up attention, the results of the flanker task suggest a deficit of top-down attention into adulthood. That study also established that there are functional brain network differences as function of delivery mode in regions involved in attention. Specifically, they found that V1 has a stronger connectivity with default network regions in C-section participants when compared with V-delivered participants. The objectives of this study were to further investigate these findings in neurophysiology and behaviour related to attention in adults born via C-section vs. vaginally. Specifically, the aims were to 1) verify and further elucidate the nature and extent of visual attention deficits associated with C-section birth (Solomon-Harris et al., 2020; Rahimi and Adler, 2019) by collecting data from a new sample of participants, and 2) identify potential structural brain differences in adults born via C-section relative to vaginal birth by analyzing data originally collected as part of a different project.

This project conducted an online experiment that tested participants on a series of behavioural tasks—the Attention Network Test (ANT) (Posner & Peterson, 1990), the Sustained Attention to Response Task (SART) (Robertson et al., 1997), the Trail Making Test (Rogers & Monsell, 1995), the Stroop Colour and Word Task (Stroop, 1935), an *n*-back working memory task, and a visual search task. These tests assessed both top-down and bottom-up attention, as well as working memory and task switching. The primary goal of these behavioural measures was to validate and expand on the infant findings of Adler and Wong Kee You (2015), and the adult findings of Rahimi and Adler (2019), Solomon-Harris et al. (2020) and Stevens et al. (in preparation).

In the recent unpublished results of an analysis by Stevens and colleagues, though a significant difference between C-section participants and controls on the visual flanker task was found, the sample and effect sizes were small, and participants were only asked whether they were born via C-section or vaginally, so other information on delivery (e.g., whether participants were born full-term) was unknown. The present study collected data on several new behavioural measures—as well as an expanded birth experience questionnaire—to bolster the conclusions made by prior analyses.

Finally, the present project complimented evidence recently obtained by Solomon-Harris et al. (2020) that there are differences in brain functional connectivity related to birth method. While Solomon-Harris et al. examined functional differences, no analysis had been conducted on differences in brain structure—i.e., how grey-matter integrity differed in C-section delivered brains compared to V-delivered brains. Therefore, the present research sought to identify potential structural differences between C-section and V-delivered young adults. Since there has been no prior analysis of this nature, it was not possible to use literature priors to determine seed regions of interest for this analysis. Instead, a data-driven approach was used—i.e., differences were identified using the sample of participants and whole brain analysis that compared the complete cortical surfaces of the groups instead of individual ROIs.

Hypotheses

Hypotheses for this study were based on the findings of Adler and Wong-Kee You (2015), Rahimi and Adler (2019), Solomon-Harris et al. (2020), and Stevens et al. (in preparation). However, behavioural studies prior to the current study had only been conducted on a visual search task and a flanker task, so hypotheses for many of the behavioural tasks—namely the SART, the Stroop, the trail making test, and the n-back task were mainly exploratory. Each task is briefly described below with its corresponding hypotheses.[1]

Visual Search

The present study used a conjunction search paradigm based on feature integration theory (Treisman, 1986). The version of the search task used in this experiment was developed from Motter and Simoni (2008). In some conditions, the target stimulus (either L or T) is present on the screen among an array of non-target, incongruent stimuli (e.g., red and green L's and Ts of different orientations from the target), and in some cases, it is absent from the array with only the non-target stimuli present. Participants were required to respond whether the target is present or absent by pressing corresponding buttons on a keyboard. This task was used in this experiment to assess bottom-up and top-down attention as the time it takes for a participant to detect the stimulus is a measure of their faster and unconscious feature-detection, or bottom-up processing, efficiency. Alternatively, the ability to decide that the target is absent is an effective measure of a slower, serial search approach, or top-down processing (Treisman & Gormican, 1986).

Given that Rahimi and Adler (2019) found an effect for bottom-up attention on a similar visual search task, it was hypothesized that C-section born participants would exhibit slower response times on target present trials of the visual search task. Furthermore, since Stevens et al.

[1] More detailed task descriptions are found in the methods section.

(in preparation) found a deficit of top-down attention in C-section born participants, it was hypothesized that those participants would exhibit slower response times on target absent trials compared with V-delivered controls—i.e., they would take longer to complete a serial search and verify that the target was absent from the array.

The Attention Network Task

The ANT is a task paradigm based on the attention theory presented by Posner and colleagues (1980). Posner's theory suggests that attention can be divided into alerting, orienting, and executive control functions. Briefly, alerting refers to the state of arousal triggered in an individual by an external cue, orienting refers to the stimulus-driven shifting of attention to select information in an individual's environment, and executive attention is the process of voluntarily selecting relevant information to attend to while limiting attention to non-relevant information (Amso & Scerif, 2015). The target stimulus for the ANT is an arrow pointing in either the left or right direction. The target arrow is flanked by two arrows on the left and right side (known as the flankers). The flankers can either be congruent (i.e., facing the same direction as the target) or incongruent (i.e., facing in the opposite direction of the target).

The ANT's flanker condition is similar to other flanker tasks previously used to assess attention and birth method. The recent study conducted by Stevens and colleagues (in preparation) indicated that birth method interacted with flanker task conditions such that adult participants born via C-section demonstrated longer response times for incongruent trials (i.e., trials where flankers were not facing the same direction as the target arrow), but not congruent trials (i.e., trials where flankers were facing the same direction as the target), compared to V-delivered participants. Therefore, it was concluded that C-section participants exhibited a top-down visual attention deficit on this task.

It was hypothesized that C-section born participants would exhibit a similar deficit of top-down attention such that they would take longer to complete incongruent flanker trials on the ANT compared with V-delivered controls. Additionally, it was hypothesized that C-section born participants would show a deficit on alerting and orienting trials, such that they would take longer to complete these trials compared with V-delivered controls.

Sustained Attention to Response Task

The SART is a go/no-go task originally developed by Robertson et al. (1996) to measure the effects of traumatic brain injury on sustaining attention over periods of time. Participants are told to watch for a target numeral presented on screen among varying non-target numerals. The task requires participants to press a key on frequent occasions when non-target stimuli are presented and to withhold key presses on infrequent occasions when the target is presented on screen. Researchers found that errors—i.e., failing to withhold a key press—were significantly correlated with faster reaction times on previous trials (Robertson et al., 1996). They concluded that correlation means that participants were shifting from controlled attention to automatic responding, hence the tendency to respond faster and less accurately. This task was chosen for the present study, therefore, because it would identify any differences in sustained attention between C-section born and V-delivered participants. It was hypothesized that participants born via C-section would be unable to sustain their attention for as long as V-delivered participants. This means faster reaction times from C-section participants on the SART overall, and specifically on trials where C-section born participants pressed “go” before a failed “no-go”, as was exhibited in Robertson et al. (1996).

The Stroop Task

The Stroop task (Stroop, 1935) was originally designed to measure the interference of conflicting stimulus components on response accuracy and timing. Stroop found that participants took longer to name the colour a word was printed in (i.e., font colour) when that word was the name of a conflicting colour (e.g., when the word "red" was presented in green font). The conclusion from Stoop's study was that longer response times are due to suppressing a conflicting response (Stroop, 1935), which is similar to the effect found in incongruent flanker conditions of the ANT when assessing top-down, executive function. Therefore, the Stroop task was chosen to compliment the analysis of top-down attention intrinsic in the ANT's flanker conditions. It was hypothesized that C-section born participants would respond slower than V-delivered participants on incongruent trials—trials where the font colour did not match the word.

The Trail Making Test

The Trail Making Test was an adaptation of the pen-and-paper version created by Reitan (1958) to test the effects of traumatic brain injury on task switching. The test measures the time it takes to complete a connect-the-dots task where the participant must sequentially switch between connecting letters and connecting numerals in ascending order. Performance is scored based on the difference in time it takes to complete an easier, numerals-only, version of the task, and a more challenging, numerals and letters version. It was hypothesized that C-section born participants would exhibit delayed task switching performance, which means they would take longer to complete the trail that required participants to switch between connecting numerals and connecting letters.

N-Back Task

The letter n-back task was designed by Jaeggi et al. (2010) to test working memory performance by requiring participants to maintain information about stimuli from *n* number of trials earlier. Participants must then respond when the stimulus reappears after a certain number of trials. The n-back varies in difficulty as a function of the number of trials a participant must maintain in their working memory (e.g., a 1-back requires a response when the stimulus is immediately repeated one trial later, and a 2-back requires a response when the stimulus is repeated after two trials, etc.).

Working memory has not been investigated in the C-section literature, however, visual attention and working memory are closely linked to working memory (Craik & Lockhart, 1972). Most notably for the present research: studies have shown a relationship between top-down attention and working memory (Majerus et al., 2018). The more demanding a task is on working memory, the more top-down attentional control is needed to remain focused on the task (Majerus et al., 2018). If C-section participants show a deficit of top-down attention, then there is a possibility they may be less accurate on a working memory task, especially as the task demands more working memory capacity. It was hypothesized that C-section born participants would exhibit weaker working memory performance which means a higher proportion of incorrect responses (i.e., indicating that the letter was repeated from *n* trials earlier when it was not, or failing to identify a repeated letter).

Structural MRI Hypothesis

Finally, the proposed study took a data-driven approach to structural MRI analysis, because there are no theoretical priors from the literature to inform a region of interest analysis for the impact of birth method on human neural structure. No other study has reviewed anatomical data relating to birth method, so hypotheses for this portion of the study are limited. However, there is evidence to suggest that functional neural networks correlate with brain structure (Damoiseaux & Greicius, 2009). Therefore, recent studies into the functional connectivity of C-section born adults can inform hypotheses. I hypothesized that C-section anatomical scans would show lesser grey-matter integrity in regions associated with visual attention and the DMN (e.g., V1, superior colliculus) when compared to V-delivered participants.

Methods

Participants

Participants for the behavioural study were recruited online via email, virtual advertisement campaigns, and the York University research participant pool (URPP). Participants were 65 adults aged 18-35 (M = 23.11, SD = 4.64; 46 females, 19 males) with normal or corrected-to-normal vision, self-reported typical colour-vision (which was necessary for successful completion of the Stroop test), and no history of serious mental illness, as self-reported in a demographics questionnaire. Information was collected about participants' birth experience through a comprehensive questionnaire – born via C-section or not, premature/full-term, if C-section was voluntary/emergency, as well as parental age at the time of birth, birth country, whether there were any complications in the procedure, and whether the mother was sedated for delivery. The demographics questionnaire is presented in Appendix A.

Of the 65 participants, 21 were born via C-section (16 female, 5 male), 41 were born vaginally (29 female, 12 male), and the remaining 4 were unsure (2 female, 2 male); the latter 4 participants (2 female, 2 male) were not analyzed in this study. The ethnicities of participants were: South Asian (n = 19), White (n = 17), East Asian (n = 7), Black (n = 9), Middle Eastern (n

= 6), Hispanic (*n* = 2), and Other (*n* = 5). Fifty-eight participants were born at full-term and 7 were unsure.

The highest educational level achieved by the participants was high school (n = 39), technical college (n = 5), undergraduate degree (n = 15), or post-graduate degree (n = 5). All participants spoke English, with 15 being monolingual and the other 50 being multilingual. Information was not collected on which participants were native English speakers.

Table 1. Demographic Information

Participants	Sex		Ethnicity		Birth Country		Education	
C-Section			South Asian	5			Highschool	14
			White	3				
	male	5	East Asian	2	Canada	9	College	2
			Black	2				
			Middle Eastern	2	India	4	Undergrad	4
	female	16	Hispanic	1				
			Other	6	Other	8	Post-Graduate	0
V-Delivered			South Asian	13			Highschool	23
			White	12				
	male	12	East Asian	5	Canada	19	College	3
			Black	6				
			Middle Eastern	4	India	4	Undergrad	11
	female	29	Hispanic	1				
			Other	0	other	18	Post-Graduate	4
Total			South Asian	18			Highschool	37
			White	15				
	male	17	East Asian	7	Canada	28	College	5
			Black	8				
			Middle Eastern	6	India	8	Undergrad	15
	female	45	Hispanic	2				
			Other	6	Other	26	Post-Graduate	4

Table 1. Continued.

Participants	Language	
C-Section	Monolingual	2
	Multilingual	19
V-Delivered	Monolingual	12
	Multilingual	29
Total	Monolingual	14
	Multilingual	48

MRI Data

For the MRI analysis, 81 adult participants (61 V-delivered, 20 C-section born) were drawn from a larger sample of data collected as part of a multisite study conducted at York University and Cornell University. Participants who consented to be contacted after the initial data collection were approached for research conducted by Solomon-Harris et al. (2020) via email. Those who responded were asked whether they were born by C-section or born vaginally. Therefore, this was the only demographic information available for this thesis.

Apparatus and Stimuli

Participants for the behavioural experiment completed the tasks on their personal laptops (n = 61) or desktop computers (n = 4). If applicable, participants were instructed to avoid using touchscreens and instead use a physical keyboard to respond to stimuli. Given the nature of online experimentation, it was impossible to control for screen size, angle, or participant distance from the screen. Stimuli sizes for the visual search task, ANT, and SART were measured based on percentage of total screen size to accommodate for variations in screens. Participants completed the experiments at home and were asked to work in a quiet place free from distractions.

Visual Search Stimuli

Target stimuli for this task were T's and L's, that were either red or green depending on the trial and varied in orientation randomly around a 360-degree axis (e.g., a target could be a green T that was angled 45 degrees from its usual position). Targets were sized to be 10% of the total height of the screen. Targets were presented in a cloud (array) of both T's and L's that were both green and red oriented randomly around a 360-degree axis. Array size varied such that each trial presented an array of either 6 letters, 12 letters, 24 letters, or 48 letters, including the target (on target-present trials) and the distractors. Example stimuli are presented in Figure 1, and procedure is presented in Figure 2.

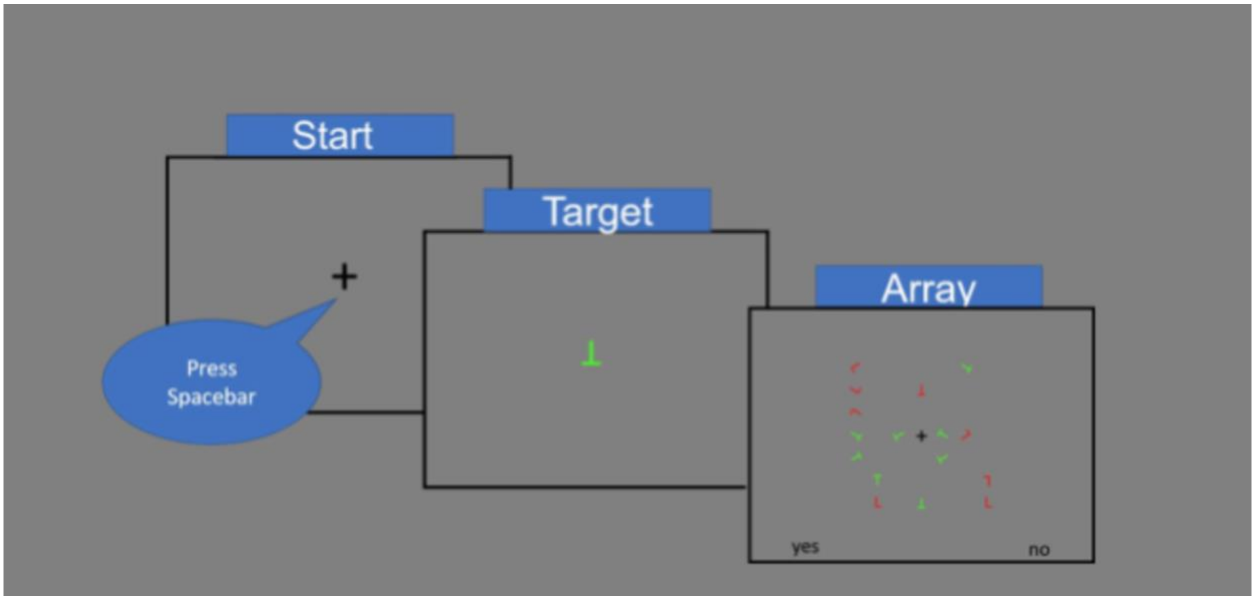

Figure 1. Example trial from the visual search task.

ANT Stimuli[2]

Stimuli consisted of 5 black arrows – a central target arrow facing right or left, and 4 flanking arrows (2 on each side of the central arrow) all facing in either the same direction as the central arrow (congruent trials) or in the opposite direction (incongruent trials), presented on either the top, or bottom of a black fixation cross. The fixation cross was present in the centre of the screen. On orientation trials, a star (spatial cue) was presented, either for 400 ms, or 800 ms ahead of the arrows, in the section of the screen that the arrows were subsequently presented on valid cue trials, or on the opposite side of the screen in invalid cue trials. Half of all trials were valid cue trials. On alerting trials, two stars were presented (double cue) for 100ms ahead of the arrows on the top and bottom of the fixation cross. On other trials, no cue was presented before the spatial cue or arrows. Arrows/flankers were sized to be 6% the total height of the screen and were spaced 7% of the screen height apart; cues were sized to be 5% of the screen height. Examples of stimuli and procedure are presented in Figure 3.

SART Stimuli

The target (no-go) stimulus for the SART was the number ’3’, presented in the centre of the screen for 250 ms, preceded and proceeded by a mask, comprising a larger circle with an ’X’ through it, which was presented for 900 ms. The other stimuli (go) were other numerals from 1-9, excluding the numeral 3, also presented for 250 ms between presentations of the mask. The

[2] Since data for this project was collected as part of a broader laboratory effort to collect detailed behavioural data for other projects, a revised version of the ANT was used that expands on the original ANT with conditions to assess the relationship between alerting, orienting, and executive attention. This version is described below, however, due to the nature and scope of this project, only analysis on scores from the three main measures were reported on here. For more information, refer to Fan et al. (2009).

mask was sized to be 20% of total screen size, and numerals were presented in 5 different font sizes. Examples of stimuli and procedure are presented in Figure 4.

Stroop Stimuli

Stimuli were the words “red”, “blue”, “green”, and “black”, presented in one of those font-colours. On congruent trials, words were presented in their respective font-colour (e.g., “red” was presented in the font-colour red), and on incongruent trials, words were presented in an opposing font-colour (e.g., “red” was presented in the font-colour blue). Control stimuli were coloured squares of the same colours as the words (i.e., red, blue, green, or black). Participants were required to indicate the correct colour of the font of colour-words (i.e., red, blue, green, or black) or squares of these same colours. Coloured squares were presented in separate blocks from coloured words. The stimuli stayed on screen until a response was recorded with an interval of 200 ms between trials. Examples of stimuli and procedure are presented in Figure 5.

Trail Making Test Stimuli

The trail making test consisted of two separate connect-the-dots style tasks. In the first, Trail A, participants were presented with a screen of numerals ranging from 1 to 25 in a non-sequential pattern (e.g., numeral 1 was presented in the centre of the screen, and numeral 2 may not have been directly next to it). In the second, Trail B, participants were presented with a screen of numerals ranging from 1 to 13 and letters ranging from ’A’ to ’L’. Again, these characters were presented in a non-sequential cloud pattern around the entire screen. For this test, participants used their mouse to draw a black line from character to character sequentially. Examples of stimuli and figures are presented in Figure 6.

n-Back Task Stimuli

The stimuli for the n-back task were a set of 20 consonants from the Latin alphabet, presented in sequence, one at a time. In each block of the n-back task, a random selection of 10 of these consonants were presented (non-response trials), and 5 of these 10 consonants were presented a second time (response trials), for a total of 15 trials (e.g., for a 1-back trial, a response would be required if the letter "M" was immediately preceded by "M", and on a 2-back trial, a response would be required if the letter "F" was preceded by the letter "F" two trials earlier, etc.). All consonants in a block of trials had an equal chance of being repeated. In each trial, the letter was presented for 500 ms. There was an interstimulus interval of 2000 ms between trials. Participants were able to respond anytime within 2500 ms after stimulus onset. Examples of stimuli and figures are presented in Figure 7.

Procedure

Given the limitations of the COVID-19 pandemic and related public health measures, data were collected remotely, using Zoom (https://zoom.us) and the online data collection software, Inquisit (https://www.millisecond.com). Web links to questionnaires and behavioural tasks were sent to participants using the chat function in the web call. First, participants were sent a link to complete the demographic questionnaire using the online survey software, Qualtrics (https://www.qualtrics.com). This survey contained questions about participants' age, sex, sexual orientation, ethnicity, birth history, education history, neurodevelopmental status, and whether there was a history of head trauma. The questionnaires took approximately 15 minutes to complete. A copy of the questionnaire can be found in the Appendix.

Next, participants who were deemed eligible based on the questionnaire were then sent links to complete the battery of tasks online using the Inquisit software. These tasks assessed

Posner's (1980) attention networks test (ANT), visual working memory (*n*-back task), visual search (conjunction search task), sustained attention in the presence of distracting stimuli (SART) (Robertson et al., 1997), task switching (Trail Making Task) (Rogers & Monsell, 1995), and cognitive flexibility (Stroop Task, Stroop, 1935).

Given that the session was long, and online connections were unpredictable, the tasks were presented in order of importance for the research question. That way, if the experiment finished before all the tasks could be completed, the most important data would be recorded. This order was: the conjunction visual search task, the ANT, the SART, the Stroop Task, the trail making test, and the *n*-back task. Information on the number of participants included in analyses for each task can be found in Table 2.

The visual search task implemented a basic conjunction search paradigm (Motter & Simoni, 2008). Participants were presented with an array of letters and instructed to search for a target with a specific colour and orientation within the array of letters (e.g., a green 'T' in an array of green and red 'L's). The target could be either present or absent within the array. Participants indicated whether the target was present or absent with a corresponding keyboard press. The task was a full, mixed design with 192 trials—2 target colours (green vs. red) × 2 target letters (L vs. T) × 4 array sizes (6, 12, 24, 48) × 2 target conditions (present vs. absent) × 6 repetitions. For each trial, a fixation cross appeared on the screen until the participant pressed the spacebar. Next, a fixation cross was presented on the screen for 1000 ms, followed by presentation of the array until either the participant made a response (indicating whether the target was present or absent) or 7000 ms had elapsed (i.e., no response was made, and the trial was not recorded). Before testing, participants completed a practice block of 24 trials—12 with the target stimulus present, and 12 with the target stimulus absent, 6 trials per target colour (red

& green), and 6 trials per letter (‘L’ & ‘T’). During the practice block, participants were given feedback about their accuracy. Performance was measured based on accuracy of responses (i.e., the percentages of times the participant accurately indicated that the target was present when it was present, and the percentage of times the participants accurately indicated the target was absent when it was absent). Response time was also recorded and analyzed (i.e., how long it took participants to respond to the trial).

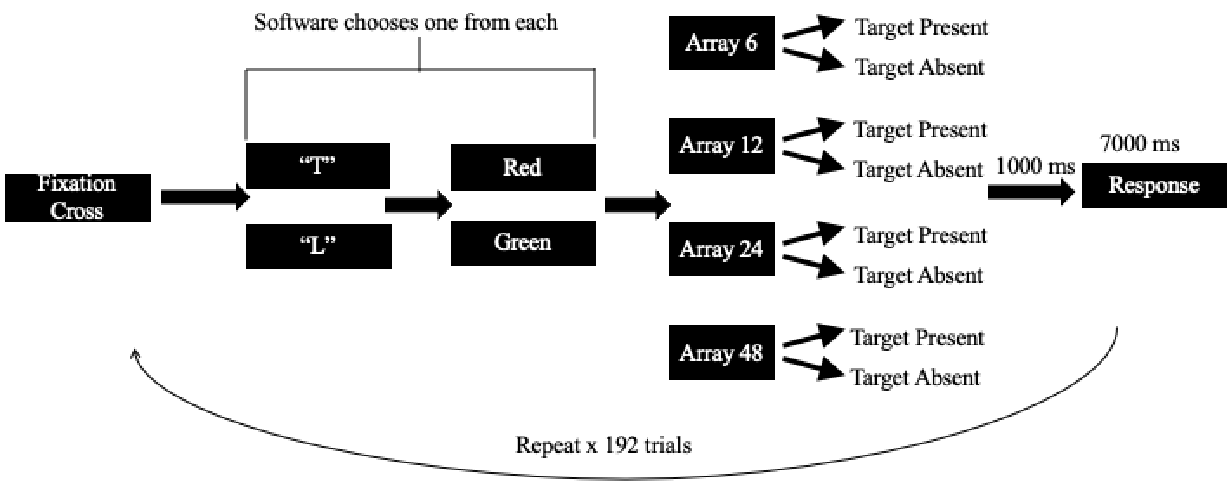

Figure 2. Example sequence for the visual search task.

In the ANT (Fan et al., 2009), participants were required to indicate the direction of a target (either a left or right facing arrow) as quickly and accurately as possible while ignoring distractors (i.e., flanking arrows facing in the congruent or incongruent direction). Preceding some of the target stimuli was an alerting cue (informing participants that the stimulus was about to appear) 100 ms before trial onset. An orienting cue (informing the participants whether the target would appear on the top or bottom of the screen, either 400 ms or 800 ms before trial onset, was presented in other trials. Alternatively, on some trials no cue (neither alerting nor orienting) was presented before trial onset. Scores for alerting were calculated based on the difference in reaction time between correct trials where participants were alerted, and correct trials where they were not. Scores for orienting were determined based on the difference in reaction time on correct trials when oriented 400 ms before the trial and 800 ms before the trial. Scores for executive attention were based on reaction time for correct trials between congruent and incongruent trials. On some trials, participants were not given any cue before the target stimulus. Participants were presented with 4 blocks of 72 trials each. Each block contained: 5 cue conditions (no cue, double cue, invalid spatial cue, valid spatial cue), 3 cue times (no cue, 400 ms, 800 ms), and 2 flanker congruence conditions (congruent vs. incongruent). For each trial sequence, either an alerting cue was presented for 100 ms or the screen was blank for 100 ms, a cue was presented for either 0 ms, 400 ms, or 800 ms, and the target was presented (with either congruent or incongruent flankers) for a maximum of 1700 ms or until the participant responded. Participants completed a practice block of 24 trials with feedback given for each trial.

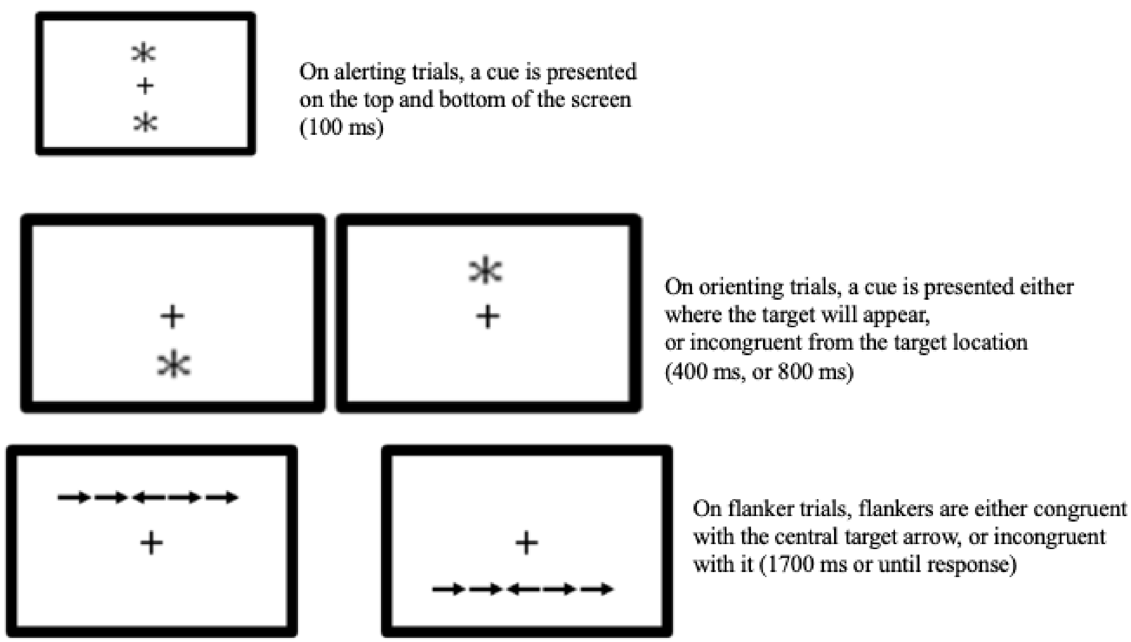

Figure 3. Description of stimuli and procedure from ANT

The SART was a go/no-go task (Cheyne et al., 2009; Robertson et al., 1997) in which participants responded to a series of stimuli (single numerals) by pressing a keyboard button but withheld the response when presented with an infrequent target (the numeral 3). The numerals 1-9 (excluding numeral 3) were presented 25 times each in random order across 225 trials. Numerals were presented for 250 ms, followed by a mask (an ‘x’ with a circle around it) presented for 900 ms. Keyboard responses were recorded from the onset of the digit, to be able to record anticipatory responses (i.e., responses made prior to stimulus presentation) through the time when the mask was presented for a total of 1150 ms.

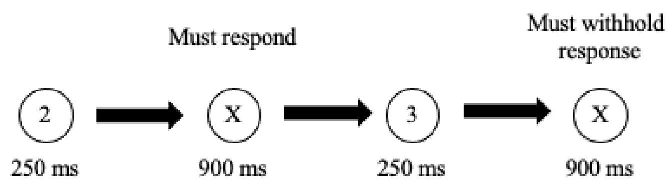

Figure 4. SART Procedure.

The Stroop task was a variation on the classic experiment conducted by Stroop (1935). Participants were required to select the correct colour of the font of colour-words (i.e., red, blue, green, or black) or squares of these same colours. There were 84 trials of the form: 4 colours (red, green, blue, black) × font-colour-word congruency (congruent, incongruent, control squares) × 7 repetitions. The stimuli stayed on screen until a response was recorded, which ended the trial, with an interval of 200 ms between trials. Given that the main measure in the Stroop Task is time to complete the task, no time limit was imposed on participant responses.

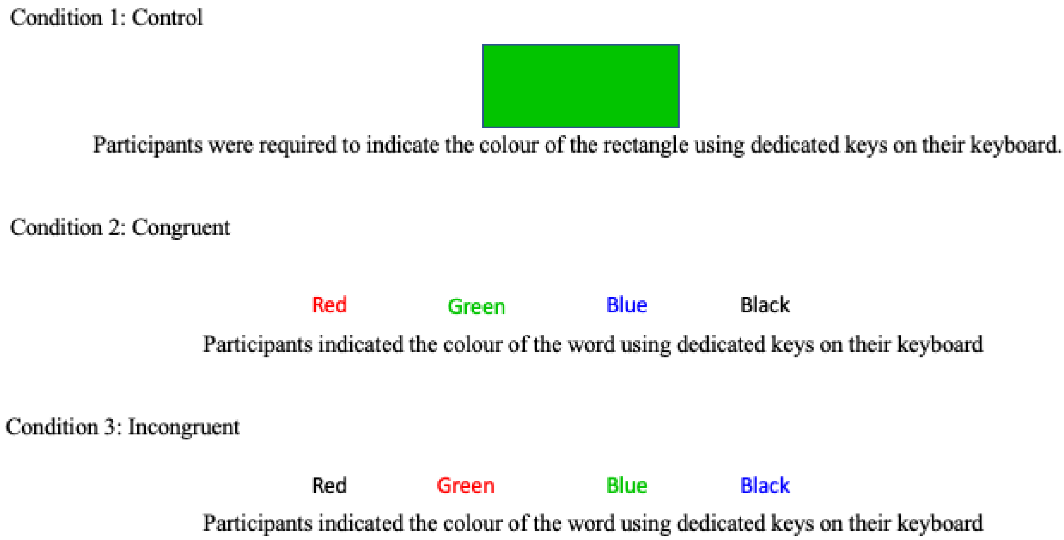

Figure 5. Description of procedure and stimuli from the Stroop task.

The trail making test required participants to draw a single line connecting numbers in ascending order that were displayed simultaneously on the screen in the first part of the test (Trail A). In the second part of the test (Trail B), participants alternated between connecting numbers and letters in ascending order (e.g., drawing a line from 1 to A, A to 2, 2 to B, B to 3, etc.). Performance was scored based on difference in time it took participants to complete Trail A and the time it took participants to complete Trail B. No time limit was imposed on the response. Errors were recorded for every time the participant failed to connect the dots in sequence.

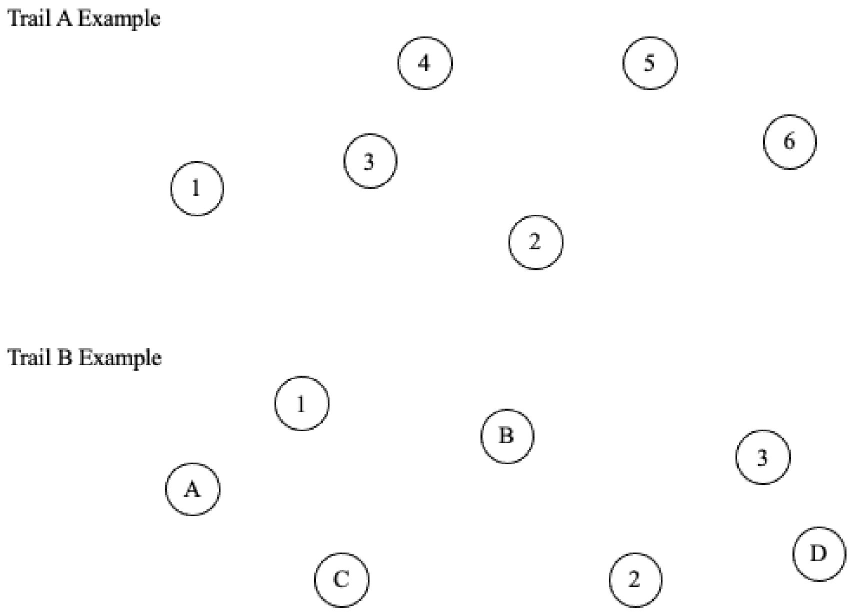

Figure 6. Example stimuli from trail making test.

Finally, in the n-back task (Ragland et al., 2002) participants were presented with a sequence of letters, one at a time, and were required to respond when the presented letter matched the letter presented *n*-trials earlier in the sequence, where *n* was a specific number of trials. For example, in a 2-back task, the participant was required to respond when the letter presented matched the letter presented 2 trials before. 1-back, 2-back, and 3-back levels were analyzed. Each n-back level contained 3 blocks, and each block contained 15 trials. In 10 of those trials, consonants did not repeat, and 5 trials showed a repeating consonant. On each trial, the letter was presented for 500 ms. An interstimulus interval of 2000 ms preceded the presentation of the next letter. Participants were able to respond anytime during the 2500-ms trial. Participants completed 9 practice trials per *n*-level presented. Performance was scored as the proportion of correct responses on all 15 trials, where a correct response for a target trial would be a keypress, and a correct response for a non-target trial would be to withhold a keypress.

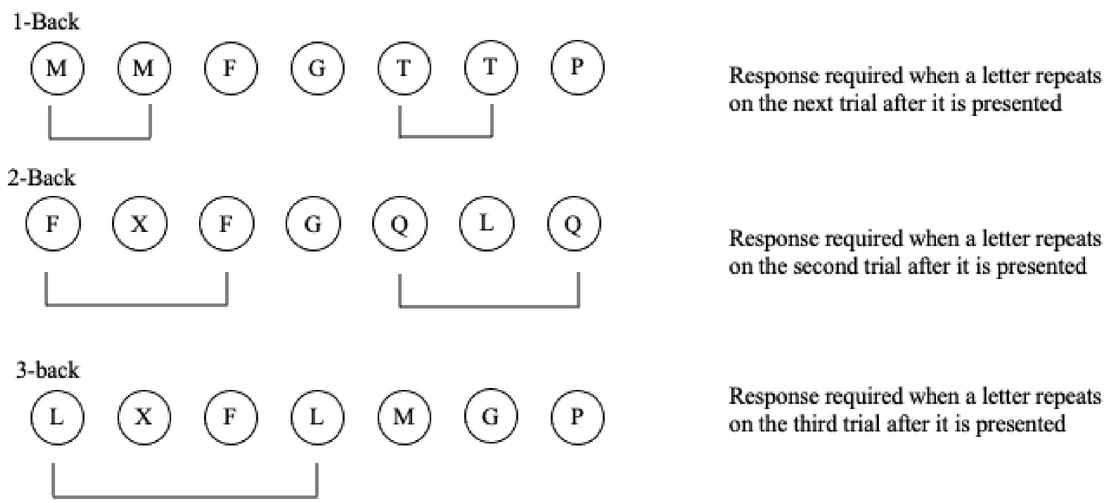

Figure 7. Example procedure from the n-back task.

MRI Acquisition

Imaging data were acquired on a 3T GE750 Discovery series MRI scanner with a 32-channel head coil at the Cornell Magnetic Resonance Imaging Facility and on a 3T Siemens Tim Trio MRI scanner with a 32-channel head coil at the York University Neuroimaging Center in Toronto. Scanning protocols were closely matched across sites. Anatomical scans at Cornell were acquired using a T1-weighted volumetric magnetization prepared rapid gradient echo sequence (TR=2530ms; TE=3.4ms; 7° flip angle; 1mm isotropic voxels, 176 slices, 5m25s) with 2x acceleration with sensitivity encoding. At York, anatomical scans were acquired using a T1-weighted volumetric magnetization prepared rapid gradient echo sequence (TR=1900ms; TE=2.52ms; 9° flip angle; 1mm isotropic voxels, 192 slices, 4m26s) with 2x acceleration and generalized auto calibrating partially parallel acquisition (GRAPPA) encoding at an iPAT acceleration factor of 2.

Analysis

MRI Analysis

Preprocessing

Structural MRI data were preprocessed using the Computational Anatomy Toolbox (CAT12) within SPM12 (https://www.fil.ion.ucl.ac.uk/spm/). First, MRI data were segmented into grey matter (GM), white matter (WM), and cerebrospinal fluid using the default settings. Data were then smoothed using a Gaussian kernel of 8mm full width at half maximum. After the images were preprocessed, a two-sample *t*-test was conducted to determine the differences between the structure of C-section born brains and V-delivered brains.

Voxel Based Morphometry

Once the images had undergone a BET extraction and skull stripping, the GM volume was analyzed using the voxel-based morphometry (VBM) toolbox in SPM12. VBM is a method of tissue-segmentation that separates GM from WM by combining the techniques of tissue-classification—assigning voxels a tissue class based on their intensity—and registration—matching a template brain to the volume being segmented (Ashburner & Friston, 2005). VBM was used to compare the GM of C-section born participants with the GM of V-delivered participants. The VBM was coded as a two-sample *t*-test (C-section – Vaginal), using the 3dttest function in AFNI, to identify any voxels in the brain showing a statistically significant difference, at the $p = .05$ level, between groups in terms of GM integrity. The results of this analyses were then corrected for multiple comparisons using the 3DClustSim function in AFNI (https://afni.nimh.nih.gov). This technique identifies the minimum number of contiguous statistically significant voxels that a cluster must comprise to be statistically significant at the cluster level, corrected for multiple comparisons.

Behavioural Data Analysis

Behavioural data were analyzed using univariate statistical methods with the statistical processing programs JASP (https://jasp-stats.org), and R (https://www.r-project.org). Main effects of birth method on task performance were explored, as were interaction effects between birth method and other demographic factors (e.g., birth country, weekly alcohol consumption etc.) and effects of covariance between task performance variables. A summary of each behavioural task and the corresponding analysis conducted is presented in Table 2.

Results

Behavioural Experiment

Sex-Based Analysis

It is noted that participants for the behavioural experiment were disproportionately female. Given the constraints of time and the pandemic, the experiment included as many participants as could be recruited to participate online. It was therefore not possible to control the proportion of males and females in the study.

Furthermore, since group sizes were small, it was not possible to run a meaningful analysis on the interaction between sex and birth method. Given that there were few males in both birth method groups, it is unlikely that any sex-based differences on the behavioural tasks affected the results differentially across the two groups. However, since the ratio of males to females was unequal in both groups, a Chi-Square test was run to rule out a group confound by ensuring that the male to female ratio in the C-section group did not differ significantly from that in the V-delivered group. Results showed that the ratio of males to females was not significantly different between the C-section group (males = 24%, females = 76%) and the V-delivered group (males = 29%, females = 71%), $\chi^2 = .31$, $p = .58$. Results are presented in Table 3.

Table 2. Summary of Analyses Conducted by Task

Task	N (Csec)	N(Vag)	Analyses Run	IV	DV
n-Back	12	31	Mixed Methods Anova (2x3)	n-Levels (1-back, 2-back, 3-back) Birth Method	correct hit rate
trail-making	16	38	Mixed Methods ANOVA (2x2)	Trail Type (A vs. B) Birth Method	difference in time to complete the trails
SART	17	36	Independent Sample t-Tests	Birth Method	reaction time overall reaction time before a failed "no-go"
Stroop	16	35	Independent Sample t-Tests	Birth Method	Congruent Incongruent Control
ANT	16	42	Independent Sample t-Tests	Birth Method	orienting scores alerting scores executive control scores
Visual Search	21	37	Mixed Methods ANOVAs (2x4)	Array Size	Reaction Time (Present and Absent Target) Accuracy (Present and Absent Target)
			Post Hoc t-Tests (Array sizes 6, 12, 24, 48)	Birth Method	Accuracy (Absent Target)

Table 3. Chi-Square Test results

	method		
sex	C-section	V-delivered	total
male	5 (24%)	12 (29%)	17
female	16 (76%)	29 (71%)	45
total	21 (100%)	41 (100%)	62
	value		p-value
χ^2	0.31		0.58

Visual Search

For these analyses, a 2 (birth method; C-section vs vaginal birth) × 4 (array size; 6, 12, 24, 48) mixed methods ANOVA, where birth method was a between-subjects factor and array size was a within-subjects factor, was conducted for both reaction time and accuracy scores when the target stimulus was present in the array and when it was absent from the array.

Target Present Accuracy Analysis.

From the analysis of accuracy when the target was present, a main effect was found for set size such that participants showed decreasing accuracy as set size increased from the size 6 array (M = .92, SD = .11) to size 12 (M = .88, SD = .11), size 24 (M = .84, SD = .13), and size 48 arrays (M = .72, SD = .15), F (3, 168) = 51.38, p < .001, partial η^2 = .48. No main effect was found for birth method such that accuracy scores were not significantly different between C-section (M = .82, SD = .07) and V-delivered (M = .84, SD = .09) participants, F (1, 56) = .81, p = .37. Finally, there was no significant interaction between birth method and array size; C-section participants did not score significantly different across array sizes 6 (M = .88, SD = .16), 12 (M = .85, SD = .13), 24 (M = .82, SD = .16), and 48 (M = .73, SD = .17) when compared to V-delivered participants at array sizes 6 (M = .93, SD = .09), 12 (M = .89, SD = .09), 24 (M = .83, SD = .12), and 48 (M = .72, SD = .12), F (3, 168) = 1.63, p = 0.18. Results are shown in Table 4 and Figure 8.

Table 4. Target Present Accuracy Mixed ANOVA Results

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Array Size	0.96	3	0.32	51.37	<.001	0.48
Array Size * Birth Method	0.03	3	0.01	1.64	0.18	0.02
Residuals	1.04	168	0.006			

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Birth Method	0.04	1	0.04	0.81	0.37	0.01
Residuals	2.39	56	0.04			

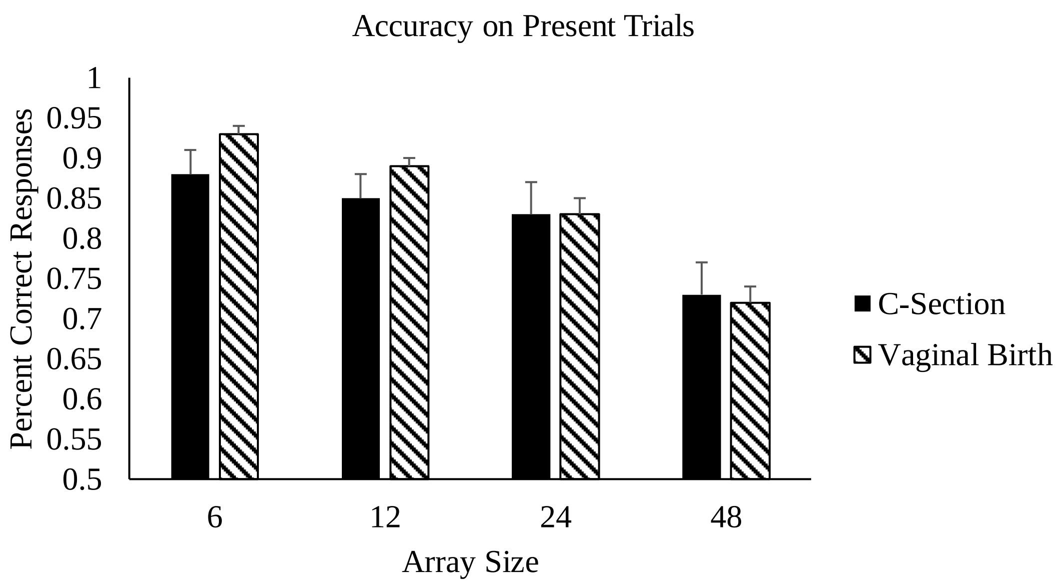

Figure 8. Accuracy on target present trials of the visual search task based on birth method. Error bars represent standard error of the mean.

Target Present Reaction Time Analysis.

From the analysis of reaction time when the target was present, a main effect was found for set size suggesting that reaction time decreased overall as set size increased from the size 6 array (M = 1.18, SD = .28) to size 12 array (M = 1.46, SD = .32), size 24 array (M = 1.76, SD = .37), and size 48 array (M = 2.40, SD = .55), $F(3, 168) = 210.95$, $p < .001$, partial $\eta^2 = .79$. No main effect was found for birth method such that reaction time scores were not significantly different between C-section (M = 1.75, SD = 0.48) and V-delivered (M = 1.70, SD = .47) participants, F (1, 56) = 0.14, p = 0.71. Finally, there was no significant interaction between birth method and array size such that C-section participants did not score significantly different across array sizes 6 (M = 1.29, SD = .48), 12 (M = 1.45, SD = .45), 24 (M = 1.81, SD = .51), and 48 (M = 2.40, SD = .79) compared to V-delivered participants across array sizes 6 (M = 1.17, SD = .20), 12 (M = 1.46, SD = .26), 24 (M = 1.77, SD = .31), . and 48 (M = 2.40, SD = .45), F (3, 168) = 0.63, p = 0.60. Results are shown in Table 5 and Figure 9.

Table 5. Target Present RT Mixed ANOVA Results

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Array Size	3737	3	1426	215.54	<.001	0.80
Array Size * Birth Method	27.96	3	9.32	1.14	0.92	0.80
Residuals	918.80	159	57.79			

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Birth Method	339.73	1	0.01	0.75	0.39	0.01
Residuals	2406	53	0.04			

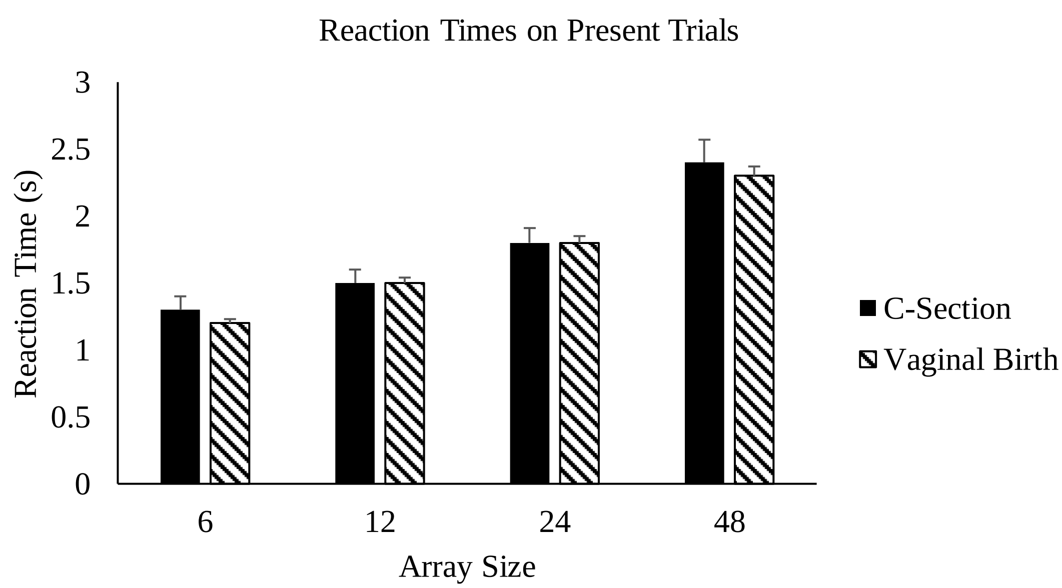

Figure 9. Bar plot of reaction time on trials where the target was present in the array. Error bars indicate the standard error of the mean.

***Target Absent Accuracy Analysis*.**

Accuracy scores were analyzed on trials when the target was absent. A main effect was found for set size such that accuracy decreased overall as set size increased from the size 6 array (M = .93, SD = .14), size 12 array (M = .93, SD = .15), size 24 array (M = .92, SD = .15), and size 48 array (M = .89, SD = .16), F (3, 168) = 5.99, p < .001, partial η^2 = .10. A main effect was also found for birth method; accuracy scores were significantly different between C-section (M = .86, SD = .02) and V-delivered (M = .96, SD = .02) participants, F (1, 56) = 5.83, p = .02, partial η^2 = .10. However, no interaction effect was found between birth method and array size indicating that C-section participants did not score significantly different across array sizes 6 (M = .87, SD = .22), 12 (M = .86, SD = .24), 24 (M = .87, SD = .23), and 48 (M = .83, SD = .24) when compared to V-delivered participants across arrays 6 (M = .97, SD = .04), 12 (M = .97, SD = .06), 24 (M = .95, SD = .08), and 48 (M = .94, SD = .08) F (3, 168) = 1.20, p = .31, partial η^2 = .02. Results are shown in Table 6 and Figure 10.

Table 6. Target Absent Accuracy Mixed ANOVA Results

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Array Size	0.05	3	0.015	5.87	<.001	0.09
Array Size * Birth Method	0.01	3	0.003	1.30	0.26	ns
Residuals	0.44	174	0.003			

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Birth Method	0.53	1	0.53	6.98	0.01	0.107
Residuals	4.39	58	0.08			

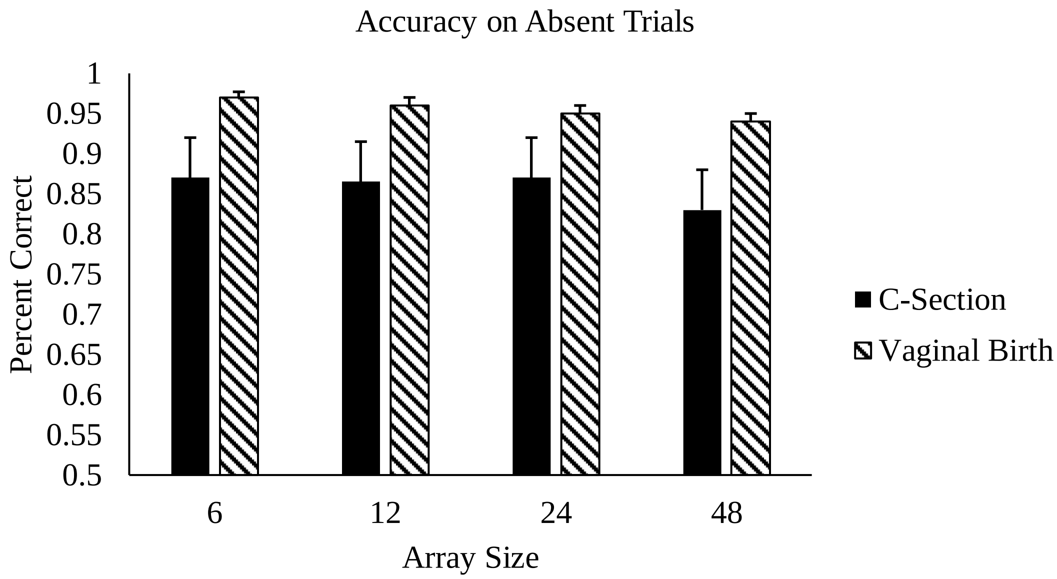

Figure 10. Bar plot of accuracy scores when the target was absent from the array. Error bars indicate the standard error of the mean.

Given that the main effect of birth method was significant for accuracy on target absent trials of the visual search, a post hoc analysis was conducted to determine which arrays showed significance differences between birth methods. A series of *t*-tests were conducted with accuracy as the dependent variable and birth method as the independent variable. Accuracy score was significantly different between C-section and V-delivered participants at array size 6, t (56) = -2.45, p = .02, Cohen's d = 0.68; size 12, t (56) = -2.51, p = .02, Cohen's d = 0.68; and size 48, t (58) = -2.82, p = .02, Cohen's d = 0.68. However, significance did not hold for array size 24, t (56) = -1.77, p = .08; Results for these analyses can be found in Table 7 and are visualized in Figure 10.

Table 7. Post-Hoc Results

Independent Samples t-Tests				
	t	df	*p*	Cohen's *d*
Array 6	-2.45	56	.02	0.68
Array 12	-2.50	56	.01	0.68
Array 24	-1.77	56	.08	ns
Array 48	-2.49	56	.02	0.68

***Normalized RT Scores*.**

Given that results were significant for accuracy on target absent trials and graphs appeared to show some differences for reaction time score based on birth method, reaction times were normalized using the formula [(Target Present – Target Absent) / Target Absent]. Since reaction times were coded in milliseconds, reaction times within birth method groups could differ by hundreds between participants. By normalizing RT scores, the natural within-group variance could be reduced to represent the average RTs more accurately between birth method groups. Each array size was compared using independent samples t–test with birth method as the independent variable and normalized RT as the dependent variable. Results were not significant for any array size comparison, size 6 t (57) = 1.58, p = .12; size 12 t (57) = .24, p = .81; size 24 t (57) = 1.72, p = .09; and size 48 t (57) = 1.19, p = .24.

***Target Absent Reaction Time Analysis*.**

Finally, from the analysis of reaction time when the target was absent, a main effect was found for set size such that reaction time decreased overall as set size increased from the size 6 array (M = 1.51, SD = .41) to size 12 array (M = 2.12, SD = .55), size 24 array (M = 2.81, SD = .78), and size 48 array (M = 3.83, SD = .11), F (3, 165) = 303.15, p < .001, partial η^2 = .85. No main effect was found for birth method; reaction times were not significantly different between C-section (M = 2.50, SD = 0.94) and V-delivered (M = 2.56, SD = 1.03) participants, F (1, 55) = .19, p = .66. Finally, there was no significant interaction between birth method and array size; C-section participants did not score significantly different across array sizes 6 (M = 1.50, SD = .56), 12 (M = 2.09, SD = .70), 24 (M = 2.69, SD = 1.01), and 48 (M = 3.65, SD = 1.48) when compared to V-delivered participants across array sizes 6 (M = 1.49, SD = .33), 12 (M = 2.09, SD = .46), 24 (M = 2.81, SD = .62), and 48 (M = 3.87, SD = .85) F (1, 165) = .95, p = .42.

Results are shown in Table 8 and Figure 11.

Table 8. Target Absent RT Mixed ANOVA

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Array Size	13330	3	4445	264.79	<.001	0.84
Array Size * Birth Method	24.96	3	8.32	0.05	0.99	*ns*
Residuals	2619	156	1678			

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Birth Method	574.95	1	574.95	0.31	0.58	0.006
Residuals	9663	52	185.20			

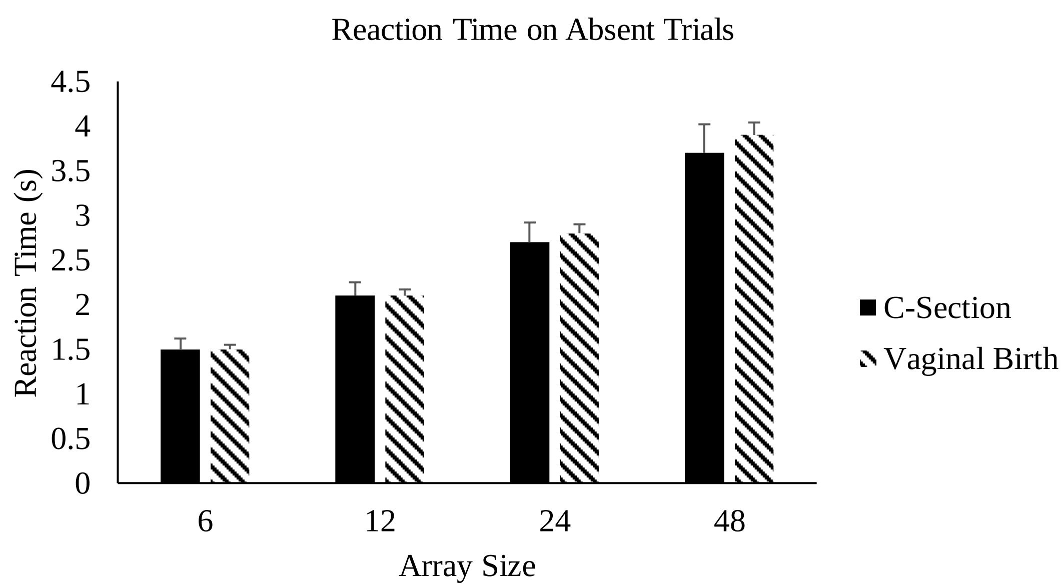

Figure 11. Bar plot of birth method and array size on the reaction time when the target was absent from the array. Error bars indicate the standard error of the mean.

Attention Networks

Independent samples t-tests were conducted for alerting, orienting, and executive control scores. Orienting scores were calculated by finding the difference of reaction time in the valid cue condition with 0 ms time between cue and target and with 800 ms between cue and target. On orienting scores, participants born via C-section (*M* = 27.68, *SD* = 29.90) did not score significantly different from V-delivered participants (*M* = 17.25, *SD* = 27.35), *t* (56) = 1.26, *p* = .15. Alerting scores were calculated for each participant by finding the difference between reaction time in the no-cue condition and in the condition where participants were alerted, but not oriented to the stimulus location (i.e., the stars were on either side of the central fixation cross). On alerting scores, C-section participants (*M* = 79.70, *SD* = 36.26) did differ significantly from V-delivered participants (*M* = 60.91, *SD* = 38.46), *t* (56) = 1.68, *p* = .10, indicating that …. Finally, executive attention scores were calculated based on the difference in reaction time when the flanker was incongruent and when the flanker was congruent. On executive attention scores, participants born via C-section (*M* = 66.21, *SD* = 47.86) did not differ significantly from V-delivered participants (*M* = 84.64, *SD* = 40.64), *t* (54) = -1.46, *p* = .21. Results are illustrated in Table 9 and Figure *12*.

Table 9. Attention Network t-Test

	t	df	p
orienting	1.26	56	0.15
alerting	1.68	56	0.10
executive control	-1.46	54	0.21

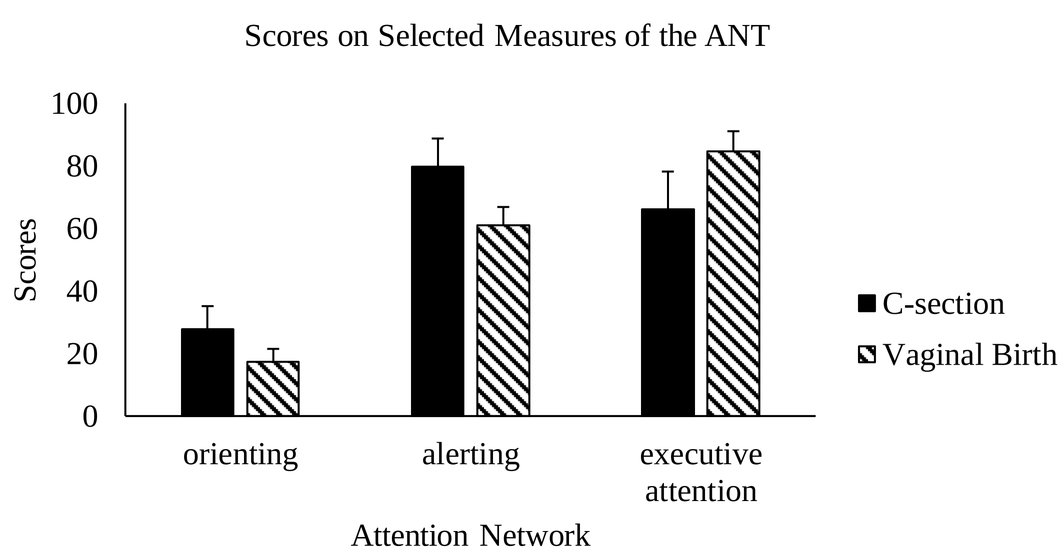

Figure 12. Scores on measures of the ANT based on birth method. Error bars represent standard error of the mean.

Sustained Attention

To test the hypothesis, reaction time scores both overall and on a “go” trial before a failed “no-go” trial—because failing to withhold a response indicates that participants were no longer sustaining attention and instead were responding automatically—were tested using independent samples t-tests. For overall reaction time, C-section participants (*M* = 407.67, *SD* = 92.22) did not differ significantly from V-delivered participants (*M* = 395.89, *SD* = 14.81), *t* (51) = .45, *p* = .66. On reaction time on “go” trials before a failed no-go trial, C-section participants (*M* = 335.28, *SD* = 74.83) did not differ significantly from V-delivered participants (*M* = 337.18, *SD* = 89.37), *t* (47) = -.08, *p* = .94. Results are presented in the Table 10 and Figure 13.

Table 10. SART t-Tests

	t	df	p
RT Overall	0.45	51	0.66
RT “Go” before Failed “No Go”	-0.08	47	0.94

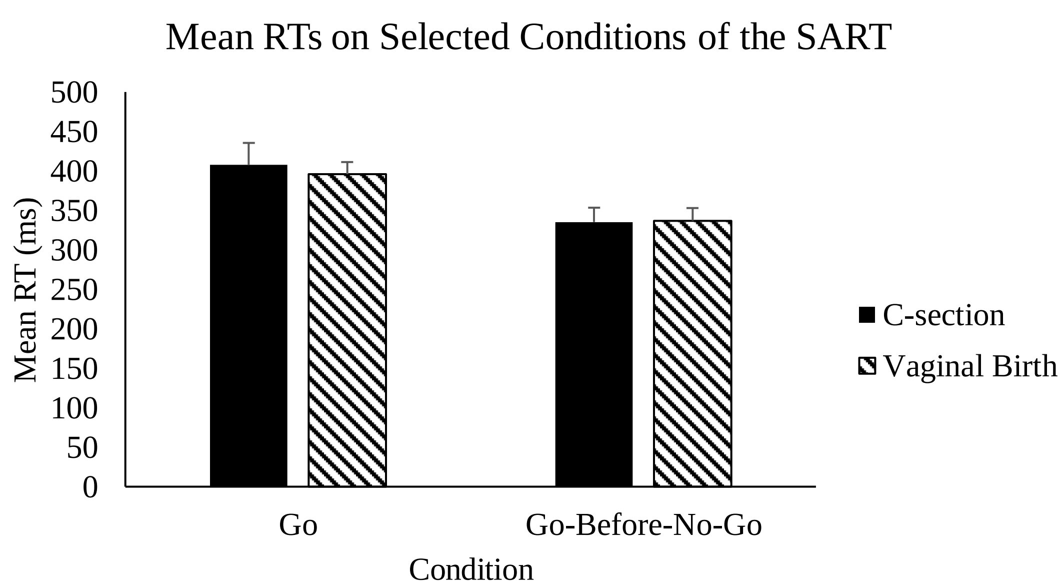

Figure 13. Mean reaction time on Go trials and on Go trials before a no-go trial. Error bars represent standard error of the mean.

The Stroop Task

Two-sample *t*-tests were conducted for reaction time (in seconds) of correct responses in all three conditions: control, congruent, and incongruent. In the control condition, C-section participants (*M* = 1.04, *SD* = .33) did not differ significantly from V-delivered participants (*M* = 1.00, *SD* = .25), *t* (49) = .46, *p* = .65. Similarly on congruent trials, C-section scores (*M* = 1.05, *SD* = .40) did not differ significantly from V-delivered scores (*M* = 1.00, *SD* = .25), *t* (49) = .47, *p* = .64. Finally, scores also did not differ between C-section (*M* = 1.45, *SD* = .67), and V-delivered (*M* = 1.23, *SD* = .36) on incongruent trials, *t* (49) = 1.54, *p* = .13. Results are presented in Table 11 and Figure 14 below.

Table 11. Stroop t-Tests

	t	df	p
control	0.46	49	0.65
congruent	0.47	49	0.64
incongruent	1.54	49	0.13

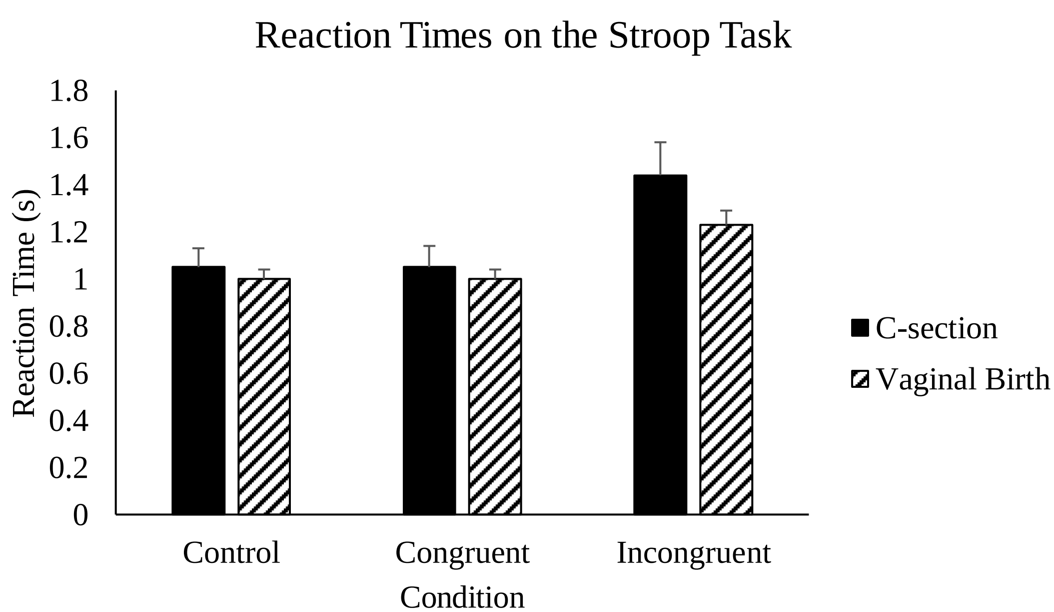

Figure 14. Mean reaction times on conditions of the Stroop task. Error bars represent standard error of the mean.

Task Switching

For this analysis, a 2-sample *t*-test was conducted with birth method as the independent variable and the difference in time taken to complete Trail B and Trail A was the dependent variable. The analysis was not significant as C-section born participants (*M* = 11.11, *SD* = 12.61) did not show a stronger effect for task switching on Trail B when compared with V-delivered participants (*M* = 9.26, *SD* = 13.72), *t* (52) = 0.46, *p* = .64. Results are visualized in Figure 15.

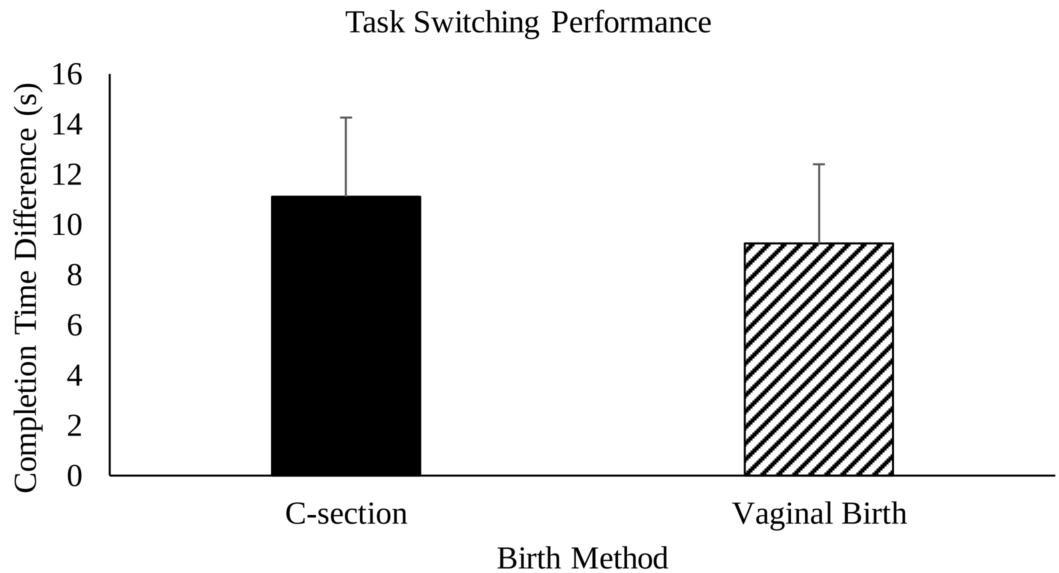

Figure 15. Results of a 2-sample *t*-test on task switching. Error bars represent standard error of the mean.

Working Memory

A 2 (Birth Method: C-section vs. Vaginal) × 3 (n: 1-back vs. 2-back vs. 3-back) mixed methods analysis of variance (ANOVA) with method as the between-subjects variable and the *n*-back level (eg. 1-back) as the within-subjects variable was conducted on the hit-rate (i.e., the proportion of correct responses). A significant main effect for n-back level was found indicating participants scored differently across trials of the 1-back (*M* = .88, *SD* = .22), the 2-back (*M* = .78, *SD* = .25), and the 3-back (*M* = .65, *SD* = .22), *F* (2, 82) = 14.11, *p* < .001, partial η^2 = .26.

The main effect of birth method was not significant such that participants born via C-section did not score differently than V-delivered participants regardless of n-back level, *F* (2, 52) = 2.91, *p* = .09.

Finally, the interaction of birth method and n-back level was not significant such that birth method was not a factor in the difference in hit rate between C-section n-back trials (1-back (*M* = .74, *SD* = .37), 2-back (*M* = .70, *SD* = .29), and 3-back (*M* = .62, *SD* = .22)), compared to V-delivered *n*-back trials (1-back (*M* = .93, *SD* = .09), 2-back (*M* = .81, *SD* = .23), and 3-back trials (*M* = .62, *SD* = .66)), *F* (2, 80) = 3.35, *p* = .04. Birth method was not a significant factor in the rate to which accuracy decreased across trials of the *n*-back. Results are presented in Table 12 and Figure 16.

Table 12. N-Back Mixed ANOVA

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
n-Back	0.66	2	0.33	14.11	<.001	0.26
n-back * Birth Method	0.11	2	0.05	2.26	0.11	ns
Residuals	1.92	82	0.02			

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	partial η^2
Birth Method	0.32	1	0.32	2.95	0.09	ns
Residuals	0.11	41	0.11			

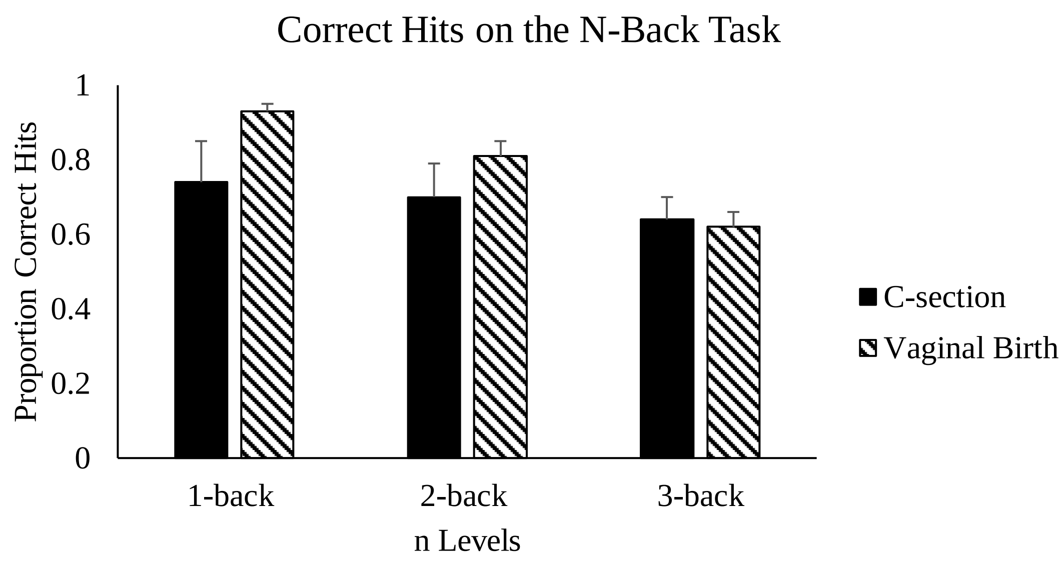

Figure 16. Proportion of correct responses on trials of the n-back. Error bars represent standard error of the mean.

Voxel-Based Morphometry

A whole brain analysis was used that did not limit search to specific ROIs. First, a p = .005 was chosen to inspect the results without cluster correction. The cortical map indicated that there were differences in the parietal lobe, near the posterior cingulate cortex (PCC), at the p threshold chosen, t (79) = 2.91, p = .005. This suggests that C-section participants showed greater grey-matter integrity in those regions. However, at the more conservative p = .001 threshold, the cortical maps of C-section adults were not significantly different from those of V-delivered adults. Finally, a bi-sided, NN = 3 cluster correction indicated that clusters would need to be at least 343 voxels to be significant at the p = .05 level. No cluster in the initial t-test survived this correction. Results are presented in Figure 17.

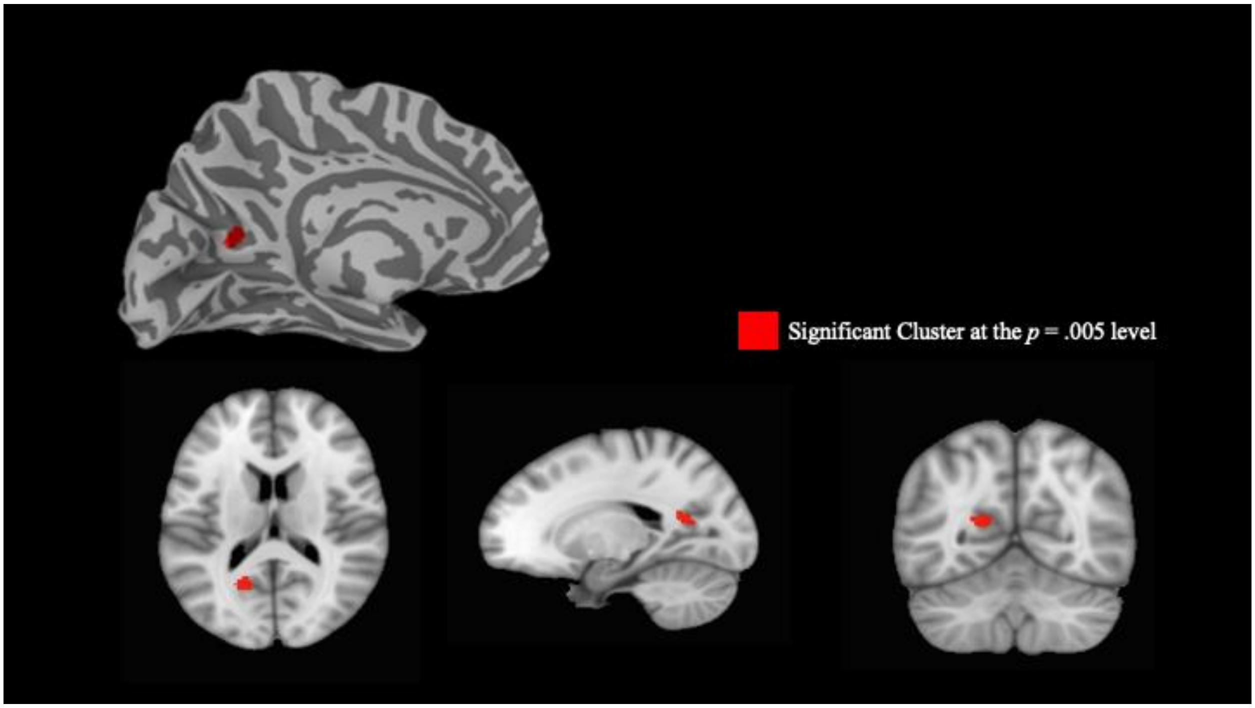

Figure 17. Results of structural analysis on C-section vs. V-delivered at the p = .005 level without cluster correct. Red indicates C-section exhibit greater grey-matter integrity in the region compared with V-delivered participants.

Discussion

This study sought to expand on findings from Adler & Wong-Kee You (2015), Rahimi and Adler (2019), and Stevens et al. (in preparation) that suggest C-section birth is related to a deficit in visual attention performance. Additionally, anatomical MRI scans were analyzed to expand on the findings of Solomon-Harris et al. (2020). For the behavioural experiment, a new sample of participants was asked to complete an online battery of visual attention, executive function, and working memory tests. It was predicted that, generally, C-section participants would show deficits in performance on these tasks when compared to V-delivered controls. Specifically, it was hypothesized that C-section participants would exhibit slower performance on top-down and bottom-up attention tasks.

Additionally, since there is recent evidence suggesting a relationship between C-section birth and intrinsic functional neural networks (Solomon-Harris, 2020), this study sought to determine whether a structural difference existed between C-section adults and V-delivered controls. Structural brain images of C-section born adults compared to vaginally born adults were analyzed using a VBM segmentation approach and two samples *t*-test. It was predicted that C-section born participants would exhibit less cortical grey-matter integrity in visual attention regions of the brain. The findings are discussed below.

Behavioural Results

Similar to the structural MRI analysis, results on most of the behavioural tasks suggest that C-section and V-delivered participants did not perform significantly different from each other. As with the structural MRI analysis, many of these tasks were not chosen based on literature priors but as a way of filling the gaps in the C-section and attention literature for future studies. So, this is not an unexpected outcome. However, it provides further evidence that the effect of C-sections is uniquely a bottom-up/top-down processing effect, and not generalized to other aspects of attention or cognitive function. Previous research with infants (Adler & Wong-Kee-You, 2015) and adults (Rahimi & Adler, 2019) demonstrated that individuals born by C-section are slower to initiate eye movements in spatial cueing and visual search tasks suggesting a deficit in their attentional mechanisms. Notably, these studies argue that slowed eye movements indicate a deficit in bottom-up processing. In contrast, Stevens and colleagues (in preparation) found a top-down processing deficit in a manual-response flanker task experiment. Findings from the current study seem to indicate that the visual attention deficit is most pronounced on a visual search task—consistent with Rahimi and Adler (2019)—where participants must search an array for the target stimulus. However, the results suggest a top-down processing deficit on trials where C-section born participants had to serially search the array for a missing target, which is consistent with Stevens et al. (in preparation). Therefore, the result of the present study complicates the findings referenced above. While no difference was found between groups on the flanker-style task conducted here, a top-down attention deficit is consistent with Stevens et al. (in preparation). Conversely, while the study supports the conclusion that birth method influences visual search performance, it is the opposite effect observed in Rahimi and Adler (2019).

There are several possibilities for why these results might be inconsistent. In Rahimi and Adler (2019), participants were not instructed on the task before completing it. Instead, participants were left to implicitly determine the identity of the target stimulus and that it may not always be present in the array. In contrast, the task used for the current experiment may have influenced the bottom-up process with a top-down stimulus set. In other words, given that participants were trained on the task before completing the experimental set and explicitly instructed as to the identity of the search target, participants would be able to compare a top-down stimulus set to current stimulus parameters as they actively scanned each array and determined none of the stimuli were the target. If this is the case, no conclusion can be made on the nature of C-sections on bottom-up processing from this experiment, only that there is a link between C-sections and top-down processing.

Alternatively, the conclusion that C-section birth influences top-down processing is complicated by the fact that the results showed no significance for the flanker portion of the ANT. If top-down attention is affected by birth method, this effect should be present on any top-down attention task. This raises the question as to what is unique in a visual search task opposed to other tasks in this study. By concluding that C-section participants were less accurate on target-absent trials of the visual search task, it means that C-section participants were more likely to indicate that a target was present in the array when it was not. Given that there was no significant difference for response time on target-absent trials, it is not the case that C-section born participants had a delayed top-down response, but that they saw the target when it was not there. Whereas the flanker task requires conflict resolution in that participants must ignore conflicting stimuli to respond accurately, on target-absent visual search trials participants must observe that none of the stimuli match the target quickly. Specifically, the target-absent results suggest C-section born adults exhibit a deficit in stimulus discrimination. Even though many processes can be defined as top-down attention, the effect observed here may be different from the one observed in the flanker task.

There are other possibilities for why the top-down attention effect was not observed on the flanker task. Limitations to the experiment, discussed in detail in the proceeding section, meant that the sample size was small, and often subtle effects may turn up as insignificant in the analysis. The design of this experiment is also different from that of Stevens et al. (in preparation). It could be the case that task order had a training effect on participants, such that C-section born participants were better able to engage top-down attention on the ANT after completing the visual search task. In any case, these results indicate a need for further research on the relationship between C-section birth and top-down/bottom-up attention processing.

VBM Results

The results of a t-test comparing the anatomical brain images of C-section born adults and V-delivered adults indicate that there was no significant difference in the grey matter density between these groups. While there was the suggestion of greater grey matter integrity for C-section participants in an area of parietal lobe and posterior cingulate cortex, even under a conservative *p*-value of .005, this significant cluster did not survive the threshold necessary for significance.

Given that the VBM analysis was mainly exploratory, it is not surprising that the results were insignificant. However, it is worth noting that the cluster flagged in the initial *t*-test is from a region associated with the DMN, an area which prior research suggests that C-section born adults will show altered development. Deoni et al. (2019) found that there may be differences in white matter development in C-section children, leading to reduced functional connectivity within the DMN. However, this is likely the only study of its kind on the topic, so much remains unknown. The result presented here seems to contradict Deoni et al.'s finding, but this may be because the present analysis was low on power and requires a larger sample size to find the same effect as Deoni et al.

However, since Solomon-Harris et al. (2020) found functional differences in the same sample used for this project, it could also be the case that C-section adults show altered functional connectivity but not structural differences. Functional connectivity refers to the temporal connection of two neural regions (Honey et al., 2009). In other words, regions of the brain are considered functionally connected when they are active simultaneously or sequentially in a given scenario (e.g., while the person is at rest). Given that stronger functional connections are often related to an increased rate of neuron firing and denser neuronal fibers between regions, there is good reason to assume that neural structure correlates with function (Rykhlevskaia, 2008). A similar line of reasoning can be made by extending the Hebbian rule that temporally related neurons become structurally connected over time (Sompolinsky, 2006). Conversely, it follows that weaker connectivity would relate to reduced cortical integrity. However, studies have shown that structure does not necessarily relate to functional connectivity. While structural differences account for some of the variance in functional connectivity, it is often the case that two regions have a functional relationship but no structural connections (Honey et al., 2009). Even though C-section participants show weaker functional connectivity within visual regions, cortical structure may only account for a portion of that variance and failed to show significant results in a structural analysis of this scope and complexity. However, it is worth exploring the possibility that there is a portion of variance accounted for by the structure of C-section brains in the brains' altered functional connectivity. If structure accounts for even a small proportion of variance in network connectivity, then it is valuable to conduct further structural analyses with tests more sensitive to that variance.

Limitations

Beyond the general limitations that come with human experimentation, this study was faced with unique challenges related to running an experiment online coupled with the quasi-experimental nature of birth method research. The following section will highlight some of these limitations, beginning with a discussion on the challenges with online experimentation and finishing with a discussion on potential limitations with the research project overall.

Online Experiment Limitations

The behavioural experiment for this study was conducted online via video chat and virtual software. It was not possible to control the apparatus used by participants or the environment in which participants completed the tasks. Participants completed the attention tasks in their own space, so the environment was inconsistent. Although participants were instructed to find a quiet space to complete the study, it was impossible to control the sounds of people living with them, lighting, temperature, or other possible distractors. Additionally, there was no way to ensure consistency about screen size, participant distance from the screen, or consistency about keyboard size. All these factors may play a role in participant performance and could increase variance between participants. For example, a study by Coutte et al. (2014) found that preparing to press a key on a keyboard in a visual search task resulted in latency in the first saccade. This suggests that keyboard design is a factor in visual search performance, and it would have been ideal to control for keyboards in this experiment as well as screen distance, head position, and hand position to be comparable to other experiments of attention. However, the data was found to be reliable and valid between participants. Reaction times and scores remained consistent across tests, suggesting that any confounding variables did not significantly impact results within this experiment.

Online experimentation is uniquely problematic for the trail making test. Traditionally, the trail making test is conducted in-person with a pen and paper. Instead, the virtual trail making test required participants to use a mouse to draw a line on a screen. Given that almost every participant worked on a laptop, it is reasonable to assume they were using a trackpad to complete this task instead of a physical mouse. Practically, this means participants would have to use two hands—one to press the left cursor down to start drawing a line, and the other to draw the line—to complete the experiment. Not only is this a less intuitive way to draw a line than using a pencil, but it is more technically demanding as it requires two hands coordinated to a virtual plane. As a result, participants in this study took significantly longer to complete the trails than is documented in the original instructions for the test. Since the online trail making test required a significantly different motor function than the original test design, it is difficult to draw conclusions about the results of the test. While this study can conclude that C-section participants took no longer to complete the trail making test compared with V-delivered participants, it is unclear whether this result is reflective of task switching or another skill.

Another concern when using online software to record responses is the possible delay between when a participant presses a button on the keyboard and when the response is recorded into the software's system. There is a concern that this delay would be caused by varying internet strength across participants and would increase variability across participants and mask any variability related to group effects. However, unlike the previous limitations raised about online experimentation, this is not likely a confound to the results presented here because data is recorded on the local computer before being uploaded to the online server. By recording the data locally, delays caused by internet lag are not a factor. Since the task software is downloaded to the local computer prior to running the experiment, the task is not dependent on internet stability either.

Visual Search Outliers

In addition to the confounds created by online experimentation, it also important to note the problem outliers may cause for interpretation of results. A couple of C-section born participants scored well below the mean (38% in one case) on accuracy in the target-absent condition of the visual search task. These participants were not removed from the analysis and may have contributed to the significant result in the target-absent mixed methods ANOVA by skewing the C-section group accuracy mean downwards. Since C-section group size is small, a couple of participants scores that are significantly off the mean could have a major effect on the overall group mean. This would make it appear that C-section born participants score worse on the visual search task compared with V-delivered participants when most of them score equally.

The question of whether to retain or remove outliers is not a simple one. Removing outliers from an analysis post-hoc is considered a questionable research practice, as it is often used to manipulate results (Bakker & Wicherts, 2014). Since the question of how to determine an outlier and what to do with them is still up for debate, researchers are more likely to make a type I and/or II error by removing outliers without reasonable cause (Bakker & Wicherts, 2014). However, there are cases where it is best to remove outliers, such as when the reported result has been altered by human error or something may have affected reasonable performance on the task (Osborne & Overbay, 2004). While it is important to note the possibility of outlier effects on the visual search conclusion, there are good reasons to leave the outliers in the analysis.

Roughly 5 of 21 participants in the C-section birth group were flagged as potential outliers on the target-absent condition. This means that 25% of participants would be removed from analysis, which raises the question of whether these participants are truly outliers or if the C-section group naturally has a high degree of variability. Removing 25% of subjects from an analysis would have a significant effect on the results and would significantly increase the possibility of making a type II error. Furthermore, while it is recommended to remove outliers when there is suspicion that they are unrepresentative of the population due to human error or other confounding variables, it is questionable to remove outliers based on their deviation from the mean alone (Bakker & Wicherts, 2014). Since there is no reason to believe that the 5 data points flagged were misreported or caused by another confounding variable more so than any other data point and given that removing them would have a deleterious effect on the results, the decision was made to leave them in the analysis. Future studies into C-section birth should note the possibility of outliers at the outset and consider either recording or controlling for them before analysis to avoid type I or II errors (Bakker & Wicherts, 2014).

Future Directions

Despite the potential effects of limitations, and that the findings from most of the behavioural tasks and the MRI analysis did not indicate any systematic differences between C-section and vaginal birth adults, the research has turned up interesting questions about C-sections and attention that would be worth exploring in future studies.

First, for many of the tasks used in this experiment, this is the first-time birth method has been studied as a factor affecting performance. Much is unknown about how the experimental paradigm developed for this thesis is affected by C-sections and more data will need to be collected before detailed conclusions can be made. The natural next step for this project will be to collect more data with a focus on collecting detailed information on birth and demographics and improving the C-section sample size to make analyses more powerful. The immediate goal is to continue data collection until the sample size is big enough and with appropriate power to run more complete analyses. Despite the concerns raised above, the online data collection has been an efficient and effective way to collect behavioural data. While the results of the current study failed to show clear differences as function of birth mode, there is still compelling evidence in other literature to suggest that there may be differences in attention task performance. A larger and more diverse sample size will stand a better chance of replicating past studies, as often subtle effects are detected in larger analyses (Sudlow et al., 2015).

Further, database analyses should shift to using large-scale database projects such as the Human Connectome Project (http://www.humanconnectomeproject.org) and the UK Biobank (https://www.ukbiobank.ac.uk). Samples such as these often contain thousands of participants tested on a variety of behavioural tasks and with detailed demographic data (Sudlow et al., 2015). Additionally, many databases come with brain data which would allow for deeper analysis into the connection between birth method, attention-task performance, and neural structure and function. Large sample sizes that can only be found in databanks will allow for detailed analysis and the ability to detect subtle differences in attention between birth method groups.

Beyond the scope of this research, more work should be done to explore the relationship between development and birth method. As mentioned earlier in this paper, there are a few widely accepted theories as to the cause of developmental differences and birth method. Many researchers posit that exposure to certain bacteria in the birth canal is necessary for regular development (Stinson et al., 2018). However, this theory can be hard to verify given the quasi-experimental nature of the birth method condition. Researchers are not able to control for variables related to pregnancy, birth, and early childhood development in human samples.

Given that birth method research is difficult to control for, there is still much debate in the literature as to birth method's effect on development. For example, some research into rat pups has shown that removing the pup from its mother via C-section and preventing exposure to these bacteria can lead to asocial behaviour in the rat pup and an early death (Chiesa et al., 2020). However, even more controlled experiments such as these can yield contradictory results. A year prior, Chiesa et al. (2019) found that C-sections did not affect long-term development in rat pups. At the same time, some researchers have found that exposing a human infant delivered via C-section to the birth canal bacterium has shown no significant differences in neural development relative to C-section infants not exposed to these bacteria (Stinson et al., 2018). These researchers argue that, while there are clear neurodevelopmental differences between C-section and V-delivery, it is not clear what factors related to birth method cause these differences.

Conclusion

The research on C-section birth and visual attention is new and much is still unknown about the topic. This study developed a new experimental paradigm that compared C-section born adults to vaginally born adults on a variety of visual attention and working memory tasks. The findings have provided further evidence that suggests C-section birth is related to a deficit in top-down attention, though that is contrary to some findings of other infant and adult studies (Adler & Wong-Kee You, 2015; Rahimi & Adler, 2019). While the results of the VBM were largely nonsignificant, future research into birth method effects on neural structure is a valuable pursuit. As knowledge on this topic expands, it is the hope that experiments like the one presented here will be valuable in designing future paradigms and developing hypotheses.

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Appendix A

VAC Questionnaire

Survey Flow

Block: Basic Demographic Questions (12 Questions)
Standard: Sensory perception (12 Questions)
Standard: Medical Info (14 Questions)
Standard: Handedness (1 Question)
Standard: Education (6 Questions)
Standard: Language (1 Question)
Standard: Birth (16 Questions)
Standard: Permission to contact (1 Question)
Standard: Debriefing (1 Question)

Page Break

Start of Block: Basic Demographic Questions

Thank you for taking the time to participate in this study. Please read through the following consent form and, should you choose to consent, indicate so at the end of the document.

Please enter your 6-digit participant ID:

____

The following section will ask you questions about who you are. Please answer all questions to the best of your ability and with as much detail as you feel comfortable giving.

JS

Please enter your date of birth.

	Month	Day	Year
Please Select: (1)	▼ January (1 ... December (12)	▼ 1 (1 ... 31 (31)	▼ 1900 (1 ... 2049 (150)

What is your biological sex?

- ○ Male (1)
- ○ Female (2)
- ○ Prefer not to say (5)

What is your sexual orientation?

- ○ Heterosexual (1)
- ○ Homosexual (2)
- ○ Bisexual/Pansexual (3)
- ○ Other (4)
- ○ Prefer not to say (5)

What is your ethnicity

- ○ White (11)
- ○ Black (12)
- ○ Canadian Indigenous (13)
- ○ East Asian (14)
- ○ Hispanic (15)
- ○ South Asian (16)
- ○ Other (please specify) (17) ____
- ○ Prefer not to say (18)

What is your marital status?

- ◯ Single (1)
- ◯ Dating (6)
- ◯ Living with partner (3)
- ◯ Married (2)
- ◯ Divorced (4)
- ◯ Widowed (5)
- ◯ Prefer not to say (7)

What is your estimated annual household income?

____

Do you currently take contraceptive pills?

- ◯ Yes (1)
- ◯ No (2)

Have you ingested cannabis (through any method) in the past three months?

- ◯ Yes (1)
- ◯ No (2)

According to Health Canada guidelines, a standard alcoholic drink is equivalent to:

-341 ml (12 oz.) bottle of 5% beer, cider, or cooler
-142 ml (5 oz.) glass of 12% wine
-43 ml (1.5 oz.) serving of 40% distilled alcohol (e.g., rye, gin, rum)

With this in mind, on average, how many drinks do you consume per week?

	0 2 4 6 8 10 12 14 16 18 20
Number of drinks per week. ()	

End of Block: Basic Demographic Questions

Start of Block: Sensory perception

Do you play first-person shooting/action video games?

- Yes (1)
- No (2)

If yes, how many HOURS do you play per week?

▼ 1-10 (1) ... 20+ (3)

Do you have hearing problems?

- Yes (1)
- No (2)

Do you wear a hearing aid?

- ○ Yes (1)
- ○ No (2)

Do you have vision problems (e.g., nearsightedness, colour blindness)?

- ○ Yes (1)
- ○ No (2)

Which of the following do you wear to correct your vision?

- ○ Glasses (1)
- ○ Contacts (2)
- ○ Both glasses and contacts (3)
- ○ I do not wear either (4)

Is your vision corrected to normal with glasses or contacts?

- ○ Yes (1)
- ○ No (2)

Are you colour blind?

- Yes (1)
- No (2)
- Unsure (3)

Which type of colour blindness are you affected by?

- Red, Green (1)
- Blue, Yellow (2)
- Unsure/Prefer not to say. (4)

Have you ever had a head injury (e.g., concussion)?

- Yes (1)
- No (2)

Did you seek medical attention for this injury?

- Yes (1)
- No (2)
- Unsure (3)

Please provide details of your injury (e.g., age, recovery period):

____

____

____

____

____

End of Block: Sensory perception

Start of Block: Medical Info

Have you been diagnosed with COVID-19?

- Yes (1)
- No (2)
- Unsure/Prefer not to say (3)

Have you been vaccinated against COVID-19?

- Yes (1)
- No (2)

Have you received a full dose of the vaccine (2 shots in most cases) or just a partial dose (e.g., 1 shot)?

- ◯ I am partially vaccinated (1)
- ◯ I am fully vaccinated (2)
- ◯ Unsure/Choose not to answer (3)

Which vaccine did you receive?

- ◯ Pfizer (1)
- ◯ Moderna (2)
- ◯ Astra-Zeneca (3)
- ◯ Johnson-Johnson (5)
- ◯ Unsure/Other (6)

Was your case mild (e.g., the equivalent of the common cold or seasonal flu symptoms) or severe (e.g., required extended hospital stay or time in the ICU)?

- ◯ Mild (1)
- ◯ Severe (2)

For your mild case, please provide any details of the illness you feel comfortable sharing (e.g., how long were you sick, are you still experience symptoms, what sort of symptoms etc.)

____

For your severe case, please provide any details of the illness you feel comfortable sharing (e.g., how long have you been sick, are you still experiencing symptoms, did you have to go to the hospital etc.)

____

If you had to go to the hospital for COVID-19, please provide any details you feel comfortable sharing about your hospital stay (e.g., were you on oxygen, how long were you there for etc.)

____

Have you ever been diagnosed with any of the following (select all that apply)?

- ▢ Attention Deficit Hyperactive Disorder (ADHD) (1)
- ▢ Obsessive Compulsive Disorder (OCD) (2)
- ▢ Autism Spectrum Disorder (ASD) (3)
- ▢ Generalized Anxiety Disorder (GAD) (4)
- ▢ Major Depressive Disorder (MDD) or bipolar disorder (5)

Are you actively taking medication for any of the above neurological diagnoses?

- ○ Yes (1)
- ○ No (2)
- ○ Unsure (3)

At what age were you diagnosed with the above?

____

Are there any other details we should know about your diagnosis?

____

Please list the medications you are taking for the above diagnoses

____

If you are currently taking any other medications, please list them here:

____

End of Block: Medical Info

Start of Block: Handedness

The following questions are from a short form of the Edinburgh Handedness Inventory (Oldfield, 1971; Veale, 2014). These questions will assess to what degree you are right or left-handed.

Each question will present an activity, and a sliding scale from "Always left" to "Always right". Please indicate to what degree you use either hand in that activity.

Always Left	Usually Left	Both equally	Usually, right	Always Right
-100	-50	0	50	100

Writing ()	
Throwing ()	
Using a toothbrush ()	
Using a spoon ()	

End of Block: Handedness

Start of Block: Education

The following questions will ask you about your education history.

What is the highest level of education you received?

- ◯ High school diploma (1)
- ◯ College certificate (2)
- ◯ Undergraduate degree (3)
- ◯ Master's degree or post-graduate certificate (4)
- ◯ Doctoral degree or higher (5)

In which country did you attend elementary school? (If you moved during elementary school, list all countries you attended school in)

____

What language was your elementary school primarily taught in?

○ English (1)

○ French (2)

○ Other (3) ____

In which country did you attend high school? (As above, if more than one country, please indicate)

____

What language was your high school primarily taught in?

○ English (1)

○ French (2)

○ Other (please indicate) (3) ____

End of Block: Education

Start of Block: Language

Please list all languages you have learned from birth.

____

____

____

____

____

End of Block: Language

Start of Block: Birth

The following questions will ask you about your birth history. Some of these questions are quite specific, and you are encouraged to seek answers from someone who may have information on your birth (such as a family member or close family friend).
While all questions allow you to select that you are unsure, we ask that you try to be as detailed as possible in your answers. As always, you can choose not to answer any question for any reason.

X→

Which country where you born in?

▼ Afghanistan (1) ... Zimbabwe (1357)

Were you born via C-section or natural vaginal birth?

◯ C-section (1)

◯ Vaginal (2)

◯ Unsure (3)

Were you born at full term, or pre-term?

◯ Full-Term (1)

◯ Pre-Term (2)

◯ Unsure (3)

At how many weeks where you born?

▼ 42+ weeks (6) ... Unknown (7)

Was your C-section planned, or was it an emergency procedure?

○ Planned (1)

○ Emergency (2)

○ Unsure (3)

What was the reason for your emergency procedure?

____

What was the reason for the planned C-section?

____

Were any drugs administered during your birth?

○ No (1)

○ Yes (please list) (2) ____

○ Unsure (3)

What was your biological mother's age at your birth?

▼ Under 18 (1) ... 85 or older (9)

What was your biological father's age at your birth?

▼ Under 18 (1) ... 85 or older (9)

Did you spend any time in the neonatal intensive care unit (NICU) after your birth? (If yes, please indicate how long)

- ○ Yes (1) ____
- ○ No (2)
- ○ Unsure (3)

Did your biological mother experience any health complications during pregnancy or delivery?

- ○ Yes (1)
- ○ No (2)
- ○ Unsure (3)

What were the complications?

____

Did you experience any health complications during pregnancy or delivery?

○ Yes (1)

○ No (2)

○ Unsure (3)

What were the complications?

____

End of Block: Birth

Start of Block: Permission to contact

Please enter your email in the text box below if you would like to be contacted about future experiments in the Cognition & Aging Neuroscience Laboratory (e.g., name@host.ca).
By entering your email you are not committing to participate in any future study.

____

End of Block: Permission to contact

Start of Block: Debriefing

Thank you for taking the time to complete this questionnaire. A member of the research team will contact you soon to schedule your testing session. The answers you gave today will aid in research that aims to better understand the relationship between visual attention, cognition, and birth methods.

We'd like to remind you that, while we encourage you to continue participating, you may choose to withdraw your consent at any time.
If you have any further questions about this study, your participation, or the questions you were asked today, please do not hesitate to contact one of the members of the lab listed below.

We wish you all the best for the rest of your day.

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End of Block: Debriefing