Visual Filtering in Children with Fetal Alcohol Spectrum Disorder

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Abstract

Fetal alcohol spectrum disorder (FASD) refers to a spectrum of effects resulting from prenatal exposure to alcohol (PEA). Attention problems are considered common among children with PEA. In this study, a specific aspect of visual attending, filtering, was examined among children with FASD with both an experimental flanker task and clinical subtests. On the flanker task, the participants responded to centrally presented arrows while ignoring distracter arrows that sometimes appeared to the left and right of the target. These distracters were either congruent or incongruent with the target. The attentional demands of the task were manipulated in this study, as an increase in attentional demand decreased developmental differences in filtering efficiency in previous studies. Immature cognitive control, as a potential explanation for inefficient filtering, was also explored among children with FASD. The methodological issues of differing levels of prenatal alcohol exposure and lower developmental level were considered. The 14 children with FASD were diagnosed with an alcohol-related disorder based on the Canadian Diagnostic Guidelines (Chudley et al., 2005), and matched on mental age, as assessed with the Leiter International Performance Scale – Revised, with typically developing (TD) children. The group of children with FASD displayed behavioural symptoms of attention-deficit hyperactivity disorder, but did not demonstrate visual filtering difficulties in general. The findings suggest that difficulties in filtering may be evident for children with FASD later in development. An increase in both the attentional demands of the task and the flanker distance appeared to be helpful. The children with FASD demonstrated difficulties with cognitive control, specifically with attention switching and working memory. They demonstrated a larger increase in reaction time (RT) to target-only displays when they were presented within a block of trials with flanker and no-flanker displays. The RT to these target-only displays was similar to the RT to incongruent distracter displays. These findings support cognitive control deficits. The possibility that unexpected visual displays are particularly disruptive for children with FASD is also discussed.

Résumé

L’ensemble des troubles causés par l'alcoolisation foetale (ETCAF) fait référence à un éventail d'effets résultant de l'exposition prénatale à l'alcool (EPA). Les problèmes d'attention sont considérés communs chez les enfants avec une EPA. Dans cette étude, le filtrage visuel a été examiné chez les enfants atteints de l’ETCAF avec une tâche expérimentale conçue pour mesurer l'efficacité de filtrage et des sous-tests cliniques. À la tâche expérimentale, les participants ont répondu aux flèches présentées de manière centralisée tout en ignorant les stimuli de distraction (SD) apparaissant parfois à gauche ou à droite de la cible. Ces SD étaient conciliables ou inconciliables avec la cible. Les exigences attentionnelles de la tâche ont été manipulées dans cette étude, car une augmentation de la demande attentionnelle diminuait les différences de développement dans le filtrage, selon des études antérieures. Un contrôle cognitif immature, étant une explication potentielle pour le filtrage inefficace, a aussi été exploré chez les enfants atteints de l'ETCAF. Les questions méthodologiques de niveaux différents d'EPA et de développement de niveau inférieur ont été examinées. Les 14 enfants atteints de l'ETCAF ont été diagnostiqués selon les lignes directrices canadiennes concernant le diagnostic (Chudley et coll., 2005) et correspondant à l'âge mental avec des enfants ayant un développement typique (DT). Le groupe d’enfants atteints de l'ETCAF démontre des symptômes de comportements THADA, mais ne démontre pas de difficultés de filtrage visuel en général. Les conclusions préliminaires suggèrent que les difficultés de filtrage peuvent être évidentes chez les enfants atteints de l'ETCAF plus tard dans leur développement. Une augmentation dans les exigences de la tâche et de la distance des SD semblait être utile. Les enfants atteints de l'ETCAF ont démontré des difficultés avec le contrôle cognitif, spécialement avec la commutation de l'attention et la mémoire de travail. Le temps de réaction (TR) aux écrans avec la cible était beaucoup plus lent que ceux présentés dans un bloc d'essais avec et sans SD. Le TR à ces écrans était semblable au TR aux écrans avec SD inconciliables. Ces conclusions peuvent refléter un déficit dans les mécanismes de contrôle cognitif. La possibilité que des informations visuelles inattendues soient particulièrement dérangeantes pour les enfants atteints de l'ETCAF est également discutée.

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Visual Filtering in Children with Fetal Alcohol Spectrum Disorder

In the present study, the visual filtering abilities of children with FASD were examined. Visual filtering refers to the ability to respond to task relevant visual information while simultaneously ignoring task irrelevant visual information (e.g., Brodeur, Trick, & Enns, 1997) and has implications for effective functioning in many areas of daily living. For example, for school-aged children, visual filtering is particularly relevant to classroom environments in which the need for filtering is high and the impact of deficits is great. In classrooms, there are countless visual stimuli that need to be ignored in order to focus on the class lesson, and reacting to irrelevant stimuli would interfere with the student's ability to complete their schoolwork and learn new information.

The presence of general attention problems for children with FASD is well established (Streissguth, 2007). For example, the majority of children with relatively high levels of prenatal exposure to alcohol (PEA) present with behavioural symptoms consistent with a diagnosis of ADHD (e.g., Fryer, McGee, Matt, Riley, & Mattson, 2007). These children also tend to perform poorly for their age on tasks that measure attention in comparison to same-age peers (e.g., Kooistra et al., 2010; Lee et al., 2004). Still, there are inconsistencies in the literature with regard to the specific areas of attention that may be affected by PEA. Some of these inconsistencies are likely due to various factors relevant to the study of children with FASD, two of which will be addressed in this study. For example, the participants included in previous studies varied in terms of the level of the PEA that they experienced or the diagnostic p rocedures that were used to identify them. In the present study, the children with FASD were all diagnosed with an alcohol-related disorder based on the Canadian diagnostic guidelines (Chudley et al., 2005). A diagnosis of an alcohol-related disorder using these guidelines means that the child is *alcohol affected*, and considered to have brain dysfunction as a result of the PEA that was experienced. The other factor that is addressed in this study is the impact of developmental differences between groups. Children with PEA or FASD are typically compared to same age peers who function at a higher developmental level, and therefore group differences can be misleading and difficult to interpret, especially in the area of attention where developmental improvements are evident (e.g., Pasto & Burack, 1997). The children with FASD were matched with TD children on mental age, as opposed to chronological age, to control for the impact of developmental level on attentional functioning (Burack, Iarocci, Flanagan, & Bowler, 2004).

In this study of visual filtering, children with mental ages between 7 and 12 years diagnosed with an alcohol-related disorder based on the Canadian diagnostic guidelines (Chudley et al., 2005) were administered an experimental task designed to measure filtering efficiency, along with relevant subtests from the Test of Everyday Attention for Children (TEA-Ch). In order to effectively filter out distractions, cognitive control mechanisms such as working memory are needed to keep the task requirements in mind (Lavie, Hirst, de Fockert, & Viding, 2004), therefore measures of cognitive control were also administered in this study. Children with FASD tend to have difficulties with working memory (e.g., Burden, Jacobson, Sokol, & Jacobson, 2005), and these difficulties could be related to reported increases in distractibility for children with PEA (Graefe, 2004; Nulman et al., 2004).

Fetal Alcohol Spectrum Disorder

Fetal alcohol spectrum disorder (FASD) is a non-diagnostic umbrella term that refers to a spectrum of effects resulting from prenatal exposure to alcohol (PEA). In general, there is a dose-response relationship between PEA and impairment, but the degree and type of impairment varies depending on a number of factors such as the dosage and timing of the PEA and a variety of maternal and environmental factors (Chudley et al., 2005; Stratton, Howe, & Battaglia, 1996). On one end of the spectrum of effects is fetal alcohol syndrome (FAS), a specific pattern of birth defects associated with excessive maternal alcohol consumption during pregnancy. These birth defects, which historically included growth deficiency, a pattern of facial anomalies, and central nervous system dysfunction, were first described in the North American medical literature in the early 1970s (Jones & Smith, 1973; Jones, Smith, Ulleland, & Streissguth, 1973). The criteria for FAS have remained largely the same over the years, but are now more clearly defined through the development of diagnostic procedures in the United States and Canada (e.g., Astley, 2004; Chudley et al., 2005). These procedures also include diagnostic criteria for other alcohol-related disorders, reflecting the fact that PEA can lead to clinically significant neurobehavioral impairment in the absence of growth deficiency or the characteristic facial features of FAS (e.g., Stratton et al., 1996).

Recommendations for the diagnosis of FAS were published by the Institute of Medicine (IOM) in 1996 following extensive review of the research and consultation with experts in the field (see Stratton et al., 1996). These recommendations included the criteria for fetal alcohol syndrome, as well as criteria for three other alcohol-related disorders (partial fetal alcohol syndrome, alcohol-related birth defects and alcohol-related neurodevelopmental disorder). A few years later, a diagnostic procedure was developed at the University of Washington (Astley & Clarren, 1999; Astley & Clarren, 2000). Astley and Clarren created the 4-Digit Diagnostic Code, which ranks the degree to which each of the key diagnostic features of FAS (growth deficiency, FAS facial features, central nervous system damage or dysfunction, and PEA) is present in an individual (see Astley, 2004 for an updated version). The criteria are clearly defined, involving quantitative measurement, and the entire range of effects, from none to severe, can be described.

In 2005, the Canadian diagnostic guidelines were published (Chudley et al., 2005). A subcommittee of the Public Health Agency of Canada's National Advisory Committee on FASD created these guidelines in consultation with experts in the diagnosis of FAS from Canada and the United States. This was undertaken to reach an agreement on a standard for diagnosis in Canada, and resulted in the integration of the two diagnostic approaches described above; the subcommittee recommended that the 4-Digit Diagnostic Code should be used to describe and measure the presence of the key diagnostic features for each individual, and that the terminology described by the IOM should be used to describe the diagnosis.

According to the Canadian guidelines for the diagnosis of alcohol-related disorders (Chudley et al., 2005), the term FASD refers to the three diagnoses of fetal alcohol syndrome (FAS), partial fetal alcohol syndrome (pFAS), and alcohol-related neurodevelopmental disorder (ARND). The diagnostic criteria for all three include prenatal exposure to alcohol and significant brain dysfunction. A diagnosis of FAS also requires the presence of growth deficiency (i.e., weight and/or height $< 10^{th}$ percentile) and certain characteristic facial features (i.e., short palpebral fissures, flat philtrum and thin upper lip) along with prenatal exposure to alcohol and significant brain dysfunction. Partial FAS is diagnosed when only two of the three characteristic facial features are present with or without growth deficiency. A diagnosis of ARND is provided when significant brain dysfunction has occurred as a result of PEA. Within this diagnostic framework, confirmed maternal alcohol use during pregnancy is necessary but not sufficient for an alcohol-related diagnosis, as brain dysfunction must also be evident.

Brain dysfunction is conceptualized as *significant* impairment (i.e., ≥ 2 standard deviations from the mean) in three or more domains of function, including sensory/motor functioning, cognition, communication, academic achievement, executive functioning, memory, attention/activity level, and adaptive behaviour. It is assessed through a combination of medical, speech-language, and neuropsychological testing (see Chudley et al., 2005 for examples of tests commonly used in the assessment). All individuals diagnosed with an alcohol-related disorder based on the Canadian guidelines, are impacted by prenatal exposure to alcohol (as opposed to simply exposed) and considered to have static encephalopathy (i.e., non-progressive brain damage) as a result.

Although all children with FASD present with broad deficits (i.e., significant impairment in three or more domains of brain functioning), a specific profile of brain dysfunction unique to FASD has not been identified (Chudley et al., 2005). A wide range of deficits have been reported for individuals with PEA, including cognitive delays (Coles et al., 1991), learning and language difficulties (Mattson & Riley, 1998), executive functioning deficits (Rasmussen, 2005), visual-spatial difficulties (Olsen, Feldman, Streissguth, Sampson, & Bookstein, 1998), memory problems (Coles, Lynch, Kable, Johnson, & Goldstein, 2010), attention problems (Lee, Mattson, & Riley, 2004), and adaptive skills deficits (Crocker, Vaurio, Riley, & Mattson, 2009). The numerous findings from the 25 year longitudinal study on the effects of PEA in a primarily middle-class Seattle sample indicated that problems with attention, arithmetic, visual-spatial memory, speed of information processing, and lower IQ were associated with PEA throughout childhood (Streissguth, 2007).

From a review of the literature, Kodituwakku (2007) concluded that persons with FASD display a ‘generalized deficit in processing complex information' (p.199). This was supported by Aragón et al.'s (2008) examination of the performance of 7 to 17 year old American Indian children with FAS or pFAS (identified by dysmorphologists, using the Institute of Medicine criteria; Stratton et al., 1996), on simple versus complex neuropsychological tests. Similarly, Korman, Kettunen, and Autti-Rämö (2003) found that children with PEA display widespread and generalized deficits, and noted that adolescents performed most poorly on subtests with increased complexity, as well as increased demands on working memory and attention.

Attention difficulties are commonly reported for children with PEA (Aronson, Hagberg, & Gillberg, 1997; Coles et al., 1997; Lee et al., 2004; Nanson & Hiscock, 1990; Streissguth, Barr, Kogan, & Bookstein, 1996), and these deficits were thought to result from exposure to prenatal alcohol, and underlie many of the difficulties that are reported in individuals with PEA as they develop (Kopera-Frye, Carmichael-Olson, & Streissguth, 1997).

FASD and Attention

The extent of the attention problems among children with FASD (e.g., Malbin, 2002; Nanson & Hiscock, 1990; Oesterheld & Wilson, 1997), led some to consider attention problems as a core deficit (Kopera-Frye et al., 1997). Findings from animal models support a direct link between PEA and attention deficits, as disruptions in attentional functioning occur in animals following PEA (Driscoll, Streissguth, & Riley, 1990). For example, infant monkeys with moderate PEA, the equivalent to one or two drinks daily, demonstrate poorer visual orienting and following and have shorter attention spans than non-exposed infant monkeys (Schneider, Roughton, & Lubach, 1997). Rats also display disruptions in attention following PEA, demonstrating more variable reaction time (RT) on choice RT tasks than rats without PEA (Hausknecht et al., 2005).

Disruption in attentional functioning as a consequence of PEA also appears to be evident among humans from an early age (Streissguth, 2007). For example, prenatal exposure to alcohol was significantly related to poor habituation to light in exposed human infants one or two days after birth (Streissguth, Barr, & Martin, 1983). Habituation referred to the number of trials until the infant no longer responded to a redundant stimulus, and was thought to reflect the ability of the infant to 'tune out' environmental stimuli (Streissguth et al., 1983). Jacobson, Jacobson, and Sokol (1994) studied the RTs of 6.5 month old infants drawn from a larger longitudinal study of the effects of PEA on infant cognition. Prenatal alcohol exposure was associated with an increased latency to shift eye gaze to a visual stimuli after the stimulus was presented, which was thought to reflect speed of information processing. Kable and Coles (2004) assessed the attentional regulation of 6 month old infants with varying levels of PEA using cardiac-orienting responses in response to the presentation of auditory (tones) and visual (faces) stimuli. They found that high-risk infants (i.e., those with mothers who scored high on the Maternal Substance Abuse Checklist) took longer to reach the heart rate deceleration criteria following the onset of a new event, than low-risk infants, those who scored low on the Maternal Substance

Abuse Checklist. This finding was thought to reflect difficulties in the initiation of attention, and suggested a decrease in the speed with which information is encoded. Kable and Coles noted that the high-risk infants evidenced an accelerated heart rate at stimulus onset, and suggested that slower processing speed may in fact result from difficulties with arousal regulation. The findings of these studies on infants with PEA suggest that PEA leads to difficulties in the regulation of arousal that in turn may disrupt an infant's ability to attend to and process new information in the environment, which has significant implications for development and learning.

Attention difficulties resulting from PEA continue into childhood and there is a general consensus that children with PEA often exhibit attention problems (e.g., Kooistra, Crawford, Gibbard, Ramage, & Kaplan, 2010; Lee et al., 2004; Mattson, Calarco, & Lang, 2006; Streissguth, 2007). For example, children with PEA often meet criteria for ADHD based on clinical interviews (Fryer et al., 2007; Kooistra et al., 2010; Koren, Nulman, Chudley, & Loocke, 2003), score higher than same-aged peers on behavioural questionnaires that assess attention problems (Astley et al., 2009; Brown et al., 1991; Coles et al., 1997; Lee et al., 2004; Nanson & Hiscock, 1990; Nash et al., 2006), and children whose mothers drank alcohol throughout pregnancy are rated as more inattentive at school than children of mothers who did not (Brown et al., 1991).

Relevant Methodological Issues

There are a number of methodological issues that are relevant to the study of children with FASD. The majority of studies include children with PEA, and the level of PEA is often averaged across weeks or days (e.g., one drink per day). Measuring PEA in this way does not account for infrequent heavy doses of PEA (e.g., seven drinks on one occasion per week), known as binges, which are associated with an increased risk for cognitive and behavioural problems (Streissguth, Barr, Bookstein, Sampson, & Carmichael Olson, 1999). As a result, sensitivity to the effects of PEA may be reduced. A related issue that can reduce sensitivity to group differences is that beyond the dose-response relationship between PEA and various cognitive and behavioural outcomes, several factors, such as the timing of the exposure and individual or maternal factors, are involved in determining whether or not a particular child exposed to alcohol prenatally will have FASD (Stratton et al., 1996). Consequently, a group of children with PEA in any given study may include children both with and without significant impairment, thereby reducing the ability to detect meaningful group profiles.

Comparisons between TD children and children diagnosed with an alcohol-related disorder can be used to address the issue of measurement of PEA because the level of prenatal alcohol exposure they experienced was sufficient to produce brain dysfunction. These comparisons, however, raise the methodological issue of differences between the groups in developmental level. Because individuals with PEA tend to have lower IQs than typically developing persons (e.g., Coles et al., 1991; Kodituwakku, 2007; Streissguth, Barr, Sampson, & Bookstein, 1994), their developmental levels are lower than their chronologically aged TD peers. As a result, group differences may simply reflect general developmental differences (McGee et al., 2008) rather than a specific problem in attention. Differences between children with FASD and TD children of the same chronological age are therefore difficult to interpret.

Another way children with FASD often differ from TD children is the environmental circumstances within which they live (e.g., Victor, Wozniak, & Chang, 2008). For example, many children with FASD live in foster or adoptive homes (Coles, 2003). Fuchs, Burnside, Marchenski, and Mudry (2005) found that 17% of children in the foster care system in Manitoba had, or were suspected of having, an FASD diagnosis. In a group of 14 children with FASD recruited from a larger study on the integration of health and social service for young children with special needs in Alberta, 79% were living with a foster parent in contrast to 13% of the children with ADHD (Mills, McLennan, & Caza, 2006).

Children in the foster care system may have experienced abuse and/or neglect prior to being placed in care, and these experiences can impact cognitive development (Bellis, Hooper, Spratt, & Woolley, 2009; Crozier & Barth, 2005). Striessguth et al. (1996) found that 72% of individuals with FAS/FAE in their sample of 415 had experienced violence, and only 49% reportedly lived in a stable and nurturing household for the majority (i.e., 72% – 100%) of their life. Many children lived with alcohol or drug abusing caregivers for a substantial amount of their life (Streissguth et al., 1996). With respect to attentional functioning, Brown et al. (1991) found that the sustained attention deficits for children with PEA were no longer significant when current maternal drinking was taken into account. Victor et al. (2008) found that children with FASD living in foster care had better outcomes, in terms of verbal IQ, rates of impulsivity (i.e., commission errors on a CPT) and internalizing behaviour, than children with FASD living with their birth parents. There were no differences between groups in terms of nonverbal (performance) IQ or omission errors on a CPT, errors that were particularly problematic for all children with FASD (Victor et al., 2008). Although environmental circumstances within which children live are certainly not the underlying cause of deficits in children with FASD, these experiences may have an effect on their development and explain some of the variability in the literature.

The Attentional Functioning of Children with PEA

Given the methodological issues presented above, the inconsistencies in the literature on FASD and attention are not surprising. Children with PEA consistently present with behavioural symptoms of inattention (e.g., Fryer et al., 2007), but do not always demonstrate deficits on experimental or clinical measures of attentional functioning (e.g., Coles et al., 1997). The contradiction between some experimental studies and clinical observation may reflect the fact that not all children exposed to prenatal alcohol are equally impacted by the exposure. Certain aspects of visual attentional functioning, including sustained attention, attention shifting, and focused attention have been studied in children with PEA, and a review of that literature follows, taking into account the methodological issues of PEA measurement and developmental level.

Sustained attention. A continuous performance paradigm was designed to measure sustained attention, or the ability to maintain focus over time (e.g., Mirsky, Pascualvaca, Duncan, & French, 1999), and this type of task is commonly used in the study of attention among children with prenatal exposure to alcohol. In typical versions of the task, participants are required to press a button in response to the appearance of a target stimulus (e.g., the letter X) on a computer screen, and withhold a response to any other stimuli that are presented. Stimuli are presented one at a time over a period of time, and errors of omission (failing to respond when the target appears) and commission (responding to non-target stimuli) are recorded. Errors of omission are thought to indicate inattention or lapses in attentional focus, while errors of commission, impulsivity or difficulties with response inhibition.

Based on the performance of children with PEA on various versions of continuous performance tasks (CPT), there is evidence both for (e.g., Kooistra et al., 2010; Lee et al., 2004; Nanson & Hiscock, 1990), and against (e.g., Brown et al., 1991; Burden et al., 2005; Coles et al., 1997; Richardson, Ryan, Willford, Day, & Goldschmidt, 2002) sustained attention deficits. The way in which PEA is measured appears to be relevant to the interpretation of these findings, as the degree of PEA, in terms of average amount of alcohol per day or week, does not predict sustained attention difficulties (Boyd, Ernhart, Greene, Sokol, & Martier, 1991; Fried, Watkinson, & Gray, 1992; Leech, Richardson, Goldschmidt, & Day, 1999), whereas binge drinking patterns were found to be associated with sustained attention deficits in children with PEA in comparison to participants without PEA drawn from the same longitudinal sample (Streissguth, Barr, Sampson, & Parrish-Johnson, 1986; Streissguth et al., 1984; Streissguth, Sampson, Olson, & Bookstein, 1994). Using more precise measures of maternal alcohol consumption during pregnancy (e.g., measurements of frequency and dose), Streissguth et al. (1984;1986) found that PEA was significantly related to errors of omission, errors of commission, and reaction time for 4 and 7 year olds on simple CPTs, and difficulties on the CPT persisted into adolescence (Streissguth, Sampson, et al., 1994); at 14 years of age, reaction time for all CPTs administered was associated with prenatal exposure to alcohol, as were commission errors on a more complicated version of the CPT (i.e., target stimulus X preceded by A).

Level of impairment as a result of PEA also appears to be relevant to performance on sustained attention tasks. For example, sustained attention difficulties, as measured by performance on the CPT, are evident when children diagnosed with FAS (using the less delineated historical criteria) are included in the study. Lee et al. (2004) found that among children 9 to 16 years old with heavy PEA (exact levels not reported), the 40% who met criteria for FAS committed more commission and omission errors on a visual CPT. Although Coles et al. (1997) did not find evidence for sustained attention problems in their longitudinal sample at age 7 years, they (Coles et al., 2002) found that those with PEA and physical effects of their exposure (i.e., dysmorphic features and growth deficiency) demonstrated specific deficits on CPTs in adolescence, even when controlling for IQ. The adolescents committed more errors, particularly omission errors, on the visual CPT in comparison to non-exposed adolescents drawn from the same longitudinal sample. Overall sensitivity to respond also appeared problematic for this group (Coles et al., 2002). The performance of the alcohol-affected children did not deteriorate any faster over time than the performance of the contrast group, and they did not perform any worse on the auditory CPT. Based on these results, Coles et al. concluded that children with PEA do not have a deficit in sustained attention per se, but suggested a deficit in some aspect of visual processing.

Sustained attention deficits on CPTs are evident with children identified as having FASD based on a clearly defined diagnostic procedure (i.e., the 4-Digit Diagnostic Code). For example, Astley et al. (2009) found that 8 to 15 year old children with FASD performed worse than TD children on a CPT, and Kooistra et al. (2010) found that the performance of children 7 to 10 years old with FASD deteriorated over time, and that they committed more errors of omission than TD children. The issue of developmental level may be relevant here, as the IQ levels of the FASD groups in both studies were significantly lower than the IQ levels of the comparison groups. This was more likely an issue in Astley et al.'s study where the mean IQ for children with FASD fell within the borderline range. In

Kooistra et al.'s study, however, the mean IQ for the FASD group fell within the average range and IQ was not related to performance on the CPT, providing evidence for sustained attention difficulties in children w ith FASD.

In summary, there appears to be some evidence that PEA is associated with sustained attention deficits, as measured by the CPT, particularly for children exposed to higher levels of alcohol and those diagnosed with an alcohol-related disorder. However, the extent to which these deficits are simply related to general developmental delays or environmental factors need to be further considered (Coles et al., 1997; Dolan, Stone, & Briggs, 2010). In a systematic review of the literature on children with PEA and performance on CPT tasks, Dolan et al. (2010) concluded that no component of performance is consistently associated with PEA, but that trends suggest an association between PEA and errors of both commission and omission.

Shifting Attention. Mirsky et al. (1991) defined the shift component of attention as the 'ability to change attentive focus in a flexible and adaptive manner' (p. 112), and performance on the Wisconsin Card Sorting Task (WCST) was used to measure this aspect of attention in their model. As a result, some researchers also used the WCST to measure attention shifting for children with PEA (e.g., Coles et al., 1997; Connor et al., 1999), even though the WCST is generally thought to measure broader executive function abilities, including for example, concept formation (McGee, Schonfeld, Roebuck-Spencer, Riley, & Mattson, 2008). On the WCST, participants are required to shift their attention from one visual stimulus dimension to another; for example, from sorting based on colour to sorting based on shape. However, they are required to shift based on feedback ('right' or 'wrong') from the examiner, which they must use to identify the new sorting rule. Performance deficits on the WCST among children with PEA in comparison to non-exposed typically developing children are widely cited (e.g., Kodituwakku, May, Clericuzio, & Weers, 2001; McGee et al., 2008; Vaurio, Riley, & Mattson, 2008), although Burden et al. (2005) and Richardson et al. (2002) did not find an association between PEA and performance on the WCST. Participants in these latter studies included those with lower levels of PEA, and various potential confounders were controlled, including current maternal drinking and measures of the home environment.

When children with greater amounts of PEA are studied, performance on the WCST is impaired. For example, Vaurio et al. (2008) found that children with heavy PEA (i.e., at least 4 drinks per occasion at least once per week or 14 drinks per week during pregnancy) performed significantly worse on all outcome measures on the WCST in comparison to TD children. This is consistent with the findings by McGee et al. (2008) who found that 8 to 15 year old children with heavy PEA performed worse on the WCST than non-exposed children. The children with FAS in McGee et al.'s study, identified based on traditional criteria, demonstrated more difficulties than exposed children without FAS. Coles et al. (1997) also found that 7 to 8 year old exposed children with dysmorphic features demonstrated difficulties on the WCST (i.e., less categories completed).

Similarly, Kodituwakku et al. found that children 8 to 18 years old (Kodituwakku, Handmaker, Cutler, Weathersby, & Handmaker, 1995) and children 7 to 19 years old (Kodituwakku, May, et al., 2001) with PEA, many of who met criteria for FAS (based on traditional criteria), made more perseverative errors on the WCST and completed less categories as a result.

Based on this evidence, level of impairment as a result of PEA appears to be more indicative of poor performance on the WCST than the presence of PEA alone. For example, Astley et al. (2009), using the 4-Digit Diagnostic Code, found that children with FASD (i.e., those who would be considered to have an alcohol-related disorder if the Canadian diagnostic guidelines were used) made significantly more errors on a computerized version of the WCST than both children without PEA and children with *mild ARND* (defined as PEA and significant impairment in less than three areas of brain function). In another study (Connor, Sampson, Bookstein, Barr, & Streissguth, 2000), a clinical group of diagnosed adults with PEA consistently demonstrated extreme deficits on the WCST, but adults with lower levels of PEA from a longitudinal study did not.

Developmental level issues complicate the interpretation of the findings on the WCST as children with higher levels of PEA and those with FASD tend to have lower IQs (e.g., Astley et al., 2009; Streissguth et al., 1996), and both age (Burden et al., 2005) and IQ (Kodituwakku et al., 1995) were found to be related to performance on the WCST. Both McGee et al. (2008) and Vaurio et al. (2008) found that children with heavy PEA performed poorly on the WCST, although they performed better than expected based on their IQ. Further analyses by McGee et al. indicated that this result appeared to reflect regression to the mean rather than a particular strength, as children with lower IQs tended to have higher WCST scores and children with higher IQs tended to have lower WCST scores. In their study on adults with PEA, Connor et al. (2000) concluded that PEA had a direct effect on the deficits measured by the WCST, and this relationship was not mediated by IQ.

The WCST may not be a good measure of attention shifting for children with FASD, as it is a complex task that relies on broader abilities than attention, such as problem solving and concept formation (McGee et al., 2008). The WCST is regularly used as a measure of executive function in adults (Eling, Derckx, & Maes, 2008), and executive functioning appears to be an area that is impaired for individuals with PEA or FASD (Connor et al., 2000; Kodituwakku, Kalberg, & May, 2001; Rasmussen, 2005). Connor et al. (2000) suggested that the WCST was not particularly sensitive to the subtle effects of PAE on executive function at lower levels of exposure.

Mattson, Calarco, and Lang (2006) administered a less complex computerized experimental task designed to measure attention shifting across visual and auditory modalities to 9 – 14 years old children with heavy PEA (exact levels not reported; children born to mothers who abused alcohol during pregnancy). Stimuli (red square, green square, high tone, low tone) were presented one at a time with varying interstimulus time intervals, and the children exposed to high levels of prenatal alcohol were slower than the TD children when required to switch back and forth between auditory and visual stimuli. They were not less accurate than the TD children when full scale IQ was used as a covariate, and therefore Mattson et al. suggested that children with FASD were capable of switching between modalities, but that it required more cognitive effort for them to do so.

Difficulties in shifting attention are supported by the performance of children with heavy PEA on other measures that involve an aspect of switching. For example, Vaurio et al. (2008) found that the children with PEA in their study (who also met criteria for ADHD) demonstrated significant difficulties in comparison to both TD children and children with ADHD on the Trail Making Test - Part B (e.g., Reitan & Wolfson, 1993) which requires switching between sequencing a set of numbers and letters. These findings are consistent with the performance of children diagnosed with an alcohol-related disorder. For example, Rasmussen and Bisanz (2009) and Astley et al. (2009) found that the children with FASD demonstrated significant difficulties switching between letters and numbers on the Trail Making Test from the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001). Connor et al. (2000) concluded that PAE was related to performance deficits on the Trail-Making Test for diagnosed adults, and not mediated by IQ.

The evidence about attention switching is ambiguous. Although children with higher levels of PEA or FASD demonstrate deficits on the WCST, performance deficits may reflect a lower developmental level. Findings from a study with adult participants (Connor et al., 2000) suggest that the deficits measured on the WCST may be present above and beyond general cognitive ability. Regardless, performance on this task may not reflect the ability to shift attentional focus, as broader abilities are measured. Performance on trail making tasks supports difficulties with attention shifting, but could similarly reflect developmental level. Based on Mattson et al.'s (2006) findings, children exposed to high levels of prenatal alcohol may have some difficulties switching attentional focus, above and beyond what would be expected based on IQ.

Focused attention. Focused attention refers to the ability to direct attentional resources to a task and filter out distracting stimuli (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991). Children (Burden et al., 2005), adolescents (Streissguth, Sampson, et al., 1994), and adults (Connor, Streissguth, Sampson, Bookstein, & Barr, 1999) with PEA demonstrate difficulties on digit cancellation tasks. The attention shifting task administered by Mattson, Calarco, and Lang (2006) also included visual and auditory focused attention conditions that required the participants to maintain focused attention to stimuli in one modality while ignoring visual and auditory distracters. The stimuli (red square, green square, high tone, low tone) were presented one at a time with varying interstimulus time intervals. Mattson et al. found that the children with PEA were less accurate in the focused attention conditions and consistently responded slower to visual stimuli than typically developing children, indicating a ‘consistent and significant deficit in visual focused attention” (p. 366).

Summary. A review of the literature on PEA and attention reveals some inconsistencies, which is in contrast to the common descriptions of inattention and distractibility in children with FASD. These inconsistent findings may be explained by methodological issues that arise when studying children with PEA. Despite these inconsistencies, there is evidence to support a link between PEA and attention problems, as well as ongoing attention deficits in children with PEA. Perhaps not all children with PEA display attention problems, but those with higher levels of exposure or alcohol-related diagnoses appear to have difficulty remaining focused and inhibiting responses to task-irrelevant information in comparison to TD peers, and demonstrate a particular deficit in visual focused attention. Further research is needed to determine if these difficulties are consistent with generalized delays or represent specific areas of deficit.

Visual Filtering

Visual focused attention appears to be impaired in children with FASD (Mattson et al., 2006). The ability to focus attention in the visual modality involves the ability to ignore irrelevant stimuli that appear within the same visual field (Brodeur et al., 1997; Mirsky et al., 1991). Visual focused attention allows for the selection of certain information in the visual field to process in greater detail than other, less relevant information, and ignore irrelevant stimuli within the same visual field (Brodeur et al., 1997; Enns & Trick, 2006) so that purposeful behaviour can occur. The ability to selectively process visual information (attend discriminately) allows individuals to respond, rather than simply react, to their environment. The mechanism that allows irrelevant information to be ignored is referred to as *filtering* (Brodeur et al., 1997).

The effect of PEA on visual filtering has not been specifically examined. Children with FASD may have difficulties ignoring visual distraction based on early difficulties with habituation to redundant visual stimuli among infants with PEA (Streissguth et al., 1983), behavioural descriptions of distractibility (e.g., Graefe, 2004), performance on clinical and experimental tasks (e.g., Burden et al., 2005; Mattson et al., 2006; Streissguth, Sampson, et al., 1994), and recommendations to reduce visual distractions for children with FASD (e.g., Blaschke, Maltaverne, & Struck, 2009; Malbin, 2002).

Measuring visual filtering: The flanker task. Versions of the flanker task (Eriksen & Eriksen, 1974) are frequently used to study visual filtering, as this task was designed to measure the ability to ignore task irrelevant information. In this paradigm, a target stimulus appears in the centre of the visual field with distracting stimuli flanking the target on each side. Participants are required to manually respond to a centre target with one of two manual responses. Flankers are either the same as the target, different from the target, correspond to the same manual response as the target (e.g., press the right button), or correspond to the opposite manual response as the target (e.g., press the left button). Performance is measured by speed of response and, sometimes, by error rates.

Using this paradigm with typical adults, Eriksen and Eriksen (1974) found that distractions that appear on the screen cannot be completely ignored. They found that filtering is less efficient (based on reaction time differences) when flankers are present than when they are not, and when the flankers are in close proximity to the target than when they are farther. Flankers that are different from the target produce more interference than flankers that are the same, and flankers associated with an opposite manual response to the target (e.g., target associated with a right button response and flankers associated with a left button response) produce more interference than those that require the same response as the target (e.g., both target and flanker are associated with a right button response). Ignored stimuli are processed to the level of response since stimuli associated with an opposite response produce more interference than stimuli associated with the same response. Eriksen and Eriksen also found that reaction time to a single target arrow with no flankers was slower on trials presented in a block of trials that were mixed, in that they included both no-flanker and flanker conditions, than on trials presented in a block of only no-flanker trials. Enns and Akhtar (1989) named this effect *attentional set* and found that it was the largest source of interference for adults. The slower RT may reflect the effort or attention involved in mentally preparing for inhibition.

Developmental improvements. Developmental improvements are evident on the flanker task. For example, Enns and Akhtar (1989) found that attentional set was also the largest source of interference for children, and produced significantly more interference for children than for adults, which may indicate that preparation for inhibition, or switching between attentional sets, is more effortful for young children. Younger children also respond more slowly on flanker tasks, and are more distracted by flankers than older children and adults (Enns & Girgus, 1985; Huang-Pollock, Carr, & Nigg, 2002; Pasto & Burack, 1997; Porporino, 2006; Ridderinkhof & van der Molen, 1995). For example, Ridderingkhof and van der Molen (1995) found that the effect of incongruent flankers on filtering was significantly greater for children 5 to 9 years of age than for children 10 to 12 years of age and adults on a version of the flanker task using arrows as stimuli. These findings indicate that both the ability to maintain an attentional set or switch between attentional sets, and filtering efficiency increase with development.

Developmental improvements in visual filtering can be explained by developmental changes in the ability to inhibit responses to irrelevant stimuli (Porporino, 2006; Ridderinkhof & van der Molen, 1995). For example, Huang-Pollock et al. (2002) and Porporino (2006) found that developmental differences in filtering efficiency were only evident in conditions where inhibition of responses to flankers was required.

Increasing processing demands. The need for inhibitory control can be reduced by increasing the processing demands of a task (Huang-Pollock et al., 2002; Lavie, 1995; Lavie & Tsal, 1994; Porporino, 2006). Attention is a limited capacity resource, and therefore attentional resources can be exhausted under certain conditions. When attentional resources are exhausted by processing task relevant stimuli, additional resources are not available to process distracters. Because distracters are not processed, inhibiting a response to the distracters is not required (Huang-Pollock et al., 2002; Lavie, 1995; Lavie & Tsal, 1994; Porporino, 2006). Porporino (2006) manipulated the level of attentional demands involved in a flanker task by asking TD children between the ages of 5 and 12 years and adults to respond to a centre target arrow in the opposite direction indicated by the arrow. For example, in the high attentional demand condition (incompatible response condition), the participants were asked to press the right button in response to an arrow pointing left. This manipulation increased the processing involved in responding to the target arrow, thereby increasing the level of attention required to complete the task. The target arrow was flanked by congruent or incongruent distracter arrows and the flanker compatibility effect (FCE), or reaction time difference on congruent versus incongruent trials, was used as the measure of distraction. Porporino found that this manipulation was not any harder for young children than it was for adults, as indicated by similar reaction time differences between corresponding and opposite response trials for both groups. Developmental differences in the FCE were only evident in the compatible response conditions, where fewer attentional resources were involved in processing the target arrow. When the target processing demands were increased, and fewer resources were available for flanker processing, there were no differences between young children aged 5 – 10 years, older children aged 11 –

12 years, and adults with regard to the effect of flankers on target processing overall, or at any flanker distance. Children as young as 5 years old filtered as efficiently as adults when their attentional resources were fully engaged in processing task-relevant information and response inhibition was not required.

Cognitive control. The process of inhibiting responses to irrelevant information in order to respond appropriately involves cognitive control mechanisms such as working memory (Huang-Pollock et al., 2002; Lavie et al., 2005; Lavie et al., 2004). Using cognitive control, information processing goals are actively maintained; for example, the distinction between task relevant and task irrelevant information, and how to respond to the information (Lavie et al., 2004). Lavie et al. demonstrated the relationship between cognitive control mechanisms and filtering efficiency in their study; increased distraction occurred in response to an increase in the working memory load involved in the task. Thus, as working memory capacity increases, so would filtering efficiency in conditions where spare attentional resources are available to process distracters.

There is evidence that cognitive control mechanisms are affected by PEA. For example, children with PEA demonstrate difficulties with executive functioning (Green et al., 2009; Kodituwakku, Kalberg, et al., 2001; Mattson, Goodman, Caine, Delis, & Riley, 1999; Rasmussen, 2005) and working memory (Burden et al., 2005; Kodituwakku, Kalberg, et al., 2001; Korkman, Kirk, & Kemp, 1998; Rasmussen, 2005), and PEA appears to have a significant impact on working memory above and beyond IQ (Burden et al., 2005). Given the relationship between filtering efficiency and working memory (Lavie et al., 2004), children with FASD may demonstrate difficulties on an experimental flanker task due to a decreased working memory capacity.

Examining Visual Filtering in Children with FASD

In this study, the filtering efficiency of MA-matched children with FASD was examined under different conditions of target-flanker distance and levels of processing demands on a flanker task. Issues both of measuring PEA and of developmental level were addressed. The issue of measuring PEA was addressed by including only those children diagnosed with an alcohol-related disorder, rather than children exposed to prenatal alcohol. Children diagnosed with an alcohol-related disorder using the Canadian guidelines (Chudley et al., 2005) were exposed to prenatal alcohol and were also *affected* by the exposure. This distinction is particularly important in the search for deficits exhibited by children with FASD, since not all children exposed to prenatal alcohol are later identified as having FASD (Stratton, Howe, & Battaglia, 1996). The dosage and timing of the prenatal alcohol experienced by children in this study, although not measured specifically, was sufficient to produce brain dysfunction.

The issue of developmental level was addressed by comparing the performance of children with FASD with the performance of TD children at the same developmental level, as measured by the Leiter International Performance Scale – Revised (Leiter-R; Roid & Miller, 1997). Due to the lower developmental levels among the children with FASD, comparing children with FASD and TD children of the same chronological age (CA) is potentially misleading, particularly on skills such as visual filtering where developmental changes occur (e.g., Enns & Girgus, 1985; Pasto & Burack, 1997). Comparisons with TD children of the same mental age (MA) allow researchers to determine whether attentional difficulties are developmentally appropriate or not (see Burack et al., 2004). Children with FASD may perform less efficiently than TD children as a result of general cognitive ability rather than factors unique to FASD. An understanding of deficits unique to FASD, in contrast to developmentally appropriate difficulties, is essential to developing effective assessment and differential diagnostic procedures. In this study, the Leiter-R (Roid & Miller, 1997), an entirely nonverbal visual measure of cognitive ability, was used to estimate developmental level. Using this measure, children with FASD were "matched" to TD children on visual ability and group differences could then be attributed to characteristics unique to the children with FASD.

Developmental differences evident between younger and older children in TD populations can be explained by developing cognitive control mechanisms (Huang-Pollock et al., 2002; Porporino, 2006). Therefore, levels of cognitive control and the relationship between that and filtering efficiency were explored for children with FASD. The improvement in filtering that occurs for TD children when the task requires increased attention was also explored for children with FASD.

Experimental approach. A paradigm developed by Porporino (2006) based on the traditional flanker task by Eriksen and Eriksen (1974) was administered in order to explore visual filtering in children with FASD. In the traditional flanker task, a target stimulus is flanked on either side by irrelevant stimuli. The main stimulus display for the paradigm used in this study included a target arrow presented in the centre of a screen and a flanker arrow that appeared on each side of the target arrow. The task included 15 conditions (see Appendix A for a list of experimental conditions) that varied with regard to the presence of flankers, the type of flanker presented with the target, the distance of the flanker from the target, and the response associated with the target. The target arrow always appeared at the centre and was presented with or without flanker arrows on either side. The flankers were either *congruent* (identical) or *incongruent* (pointing in the opposite direction) with the target arrow. The flankers appeared 1.0°, 2.8°, or 4.7° visual angle from the target arrow. Two examples of displays are presented in Figure 1. In order to manipulate the attentional demands involved in the task, the response associated with the target was either *compatible* or *incompatible*. In the compatible condition, the participants pressed the response key located in the direction the arrow was pointing. In the incompatible condition, the participants pressed the response key located in the opposite direction in which the arrow was pointing.

The efficiency of filtering was assessed by comparing performance in the flanker type conditions (congruent versus incongruent flankers). The difference between the reaction time for congruent and incongruent flankers was the measurement of the effect of flankers on target processing (the flanker congruency effect or FCE; Enns & Girgus, 1985; Porporino, 2006; Ridderinkhof & van der Molen, 1995) and was used as a measure of filtering efficiency. Attentional set was assessed by comparing performance in the blocks that include only no-flanker displays to performance on no-flanker trials that appear within mixed blocks (both no-flanker and flanker displays) in compatible conditions. The effect of flanker distance on filtering was assessed by comparing performance in the flanker distance condition (1.0°, 2.8°, and 4.7°). The effect of increasing the attentional demands was assessed by comparing performance in the response compatibility conditions (compatible and incompatible). Developmental improvement between 7 and 12 years MA was assessed.

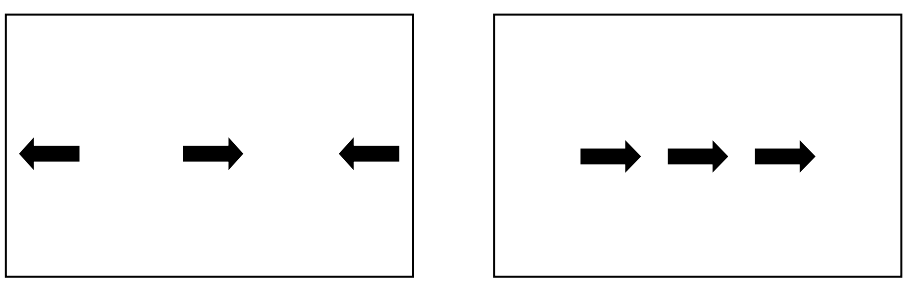

Figure 1. Examples of experimental displays: Display with congruent flankers presented at 1.0° visual angle (right), and display with incongruent flankers presented at 4.7° visual angle (left).

Clinical approach. In addition to the administration of an experimental paradigm of visual filtering, a more clinical approach to assessing attention was included in this study. Attention is one of the brain domains recommended to be assessed during the neuropsychological assessment for FASD (Chudley et al., 2005). A significant impairment in this domain could reflect a clinical diagnosis of attention-deficit/hyperactivity disorder (ADHD) and/or poor performance on clinical measures that require attention. In this study, the Conners' Rating Scale (Conners, 1997) was used to assess behavioural symptoms of ADHD, and subtests from the Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1998) were used to assess focused attention and attentional control. The TEA-Ch was considered an appropriate choice for children with FASD, as the test was designed to measure various components of attention without relying on other abilities, such as memory, verbal comprehension, or motor speed (Manly et al., 2001), any of which may be impaired in children with FASD (e.g., Stratton et al., 1996).

Predictions

General findings on the flanker task. Based on previous research using the flanker task (Enns & Akhtar, 1989; Eriksen & Eriksen, 1974; Jonkman et al., 1999), overall RT was expected to be faster when there were no flankers than when there were flankers. Reaction time was expected to be faster when the flankers were congruent with the target than when they are incongruent, and when the response was compatible than when it was incompatible. It was expected to decrease with increased developmental level (MA). Children with FASD were expected to have slower RTs than MA-matched TD children.

Attentional set. Attentional set may reflect cognitive control mechanisms, such as working memory. Children with FASD appear to have impaired working memory (e.g., Burden et al., 2005), and were therefore expected to experience greater interference due to attentional set than the MA-matched TD children. The children with FASD were expected to have larger differences in RT between no-flanker trials presented in one block and those mixed with flanker trials, than MA-matched TD children.

Conditions of low attentional demand. Based on previous evidence that children with FASD have deficits in cognitive control mechanisms (e.g., Burden et al., 2005), they were expected to show less efficient filtering of irrelevant information when the attentional demands of the task are low (Lavie et al., 2004; Porporino, 2006). The children with FASD were expected to demonstrate more difficulty ignoring the flankers than MA-matched TD children when their attention is not fully engaged in the task. This would be manifested as a larger FCE than among MA-matched TD children overall and at each flanker distance in response compatible conditions.

Conditions of high attentional demand. The children with FASD were expected to filter similarly to MA-matched TD children once the need for cognitive control mechanisms in filtering was reduced. When the attentional demands involved in the task were increased, available attentional resources would be engaged in processing the target, and fewer resources would be left to process the flankers. Thus, in response incompatible conditions, the FCE for children with FASD was not expected to differ from MA-matched TD children, and flanker distance was not expected to be related to FCE for either group.

Developmental improvements. Based on previous research (Porporino, 2006), the developmentally younger children (based on MA) were expected to display larger FCEs than developmentally older children in the response compatible conditions where less processing demands are required. These differences were not expected to be significant in response incompatible conditions when the need for inhibitory control is reduced.

Filtering efficiency and clinical measures. For the children with FASD, the FCE in response compatible conditions (low attentional demand) was expected to predict parent ratings of attention problems and performance on clinical measures of working memory, focused attention, and attentional control.

Method

Participants

The participants included 14 children with FASD (see Table 1) with a mean chronological age of 11.73 years (SD = 1.36) and range of 9.00 to 13.58 years, an average mean nonverbal IQ, based the Leiter-R brief IQ scale, of 83.07 (*SD* = 10.59) and a range of 62 to 100, and a mean mental age of 9.65 years (*SD* = 1.47) with a range of 7.75 to 12.67 years. The participants also included 14 typically developing (TD) children (see Table 1) with no history of prenatal exposure to alcohol or attention problems (based on parent report). Each child was matched within 4 months on mental age to a participant with FASD in order to make the two groups as equal as possible with respect to developmental age.

Table 1

Descriptive Statistics for the FASD and TD Groups

		CA		MA		Brief IQ		%	%
Group	***N***	***M***	***SD***	***M***	***SD***	***M***	***SD***	**Male**	**Caucasian**
FASD	14	11.73	1.36	9.65	1.47	83.07	10.59	35.7	57.1
TD	14	8.42	1.39	9.59	1.55	114.93	9.92	35.7	92.9

Note. CA = chronological age; MA = mental age; Brief IQ = brief IQ score from the Leiter-R.

The children with FASD were recruited from the Asante Centre for Fetal Alcohol Syndrome, a FASD assessment and diagnostic centre located in the Fraser Region of British Columbia (BC) that provides assessment to individuals throughout BC. A staff member from the Asante Centre contacted legal guardians of children between 8 and 13 years of age who underwent a FASD assessment through the centre, and invited them to participate. Twenty-two children were initially tested, but eight were eliminated from the study; the mental ages of 5 children fell outside of the target developmental age range for this study (i.e., 7 to 12 years), two children did not have confirmed prenatal exposure to alcohol, and a TD match was not found for one child. All the children with FASD had been assessed in accordance with the Canadian diagnostic guidelines (Chudley et al., 2005) and received one of three alcohol-related diagnoses, FAS (n = 1), pFAS (n = 3), or ARND (n = 10). Eight of the participants with FASD were rated by the diagnostic team as having significant attention problems, four were rated as having mild to moderate attention problems, and only one was rated as having no attention problems (data for one participant was missing). Nine children with FASD had a diagnosis of ADHD. The majority of the children with FASD were living with someone other than their birth parents (2 with birth fathers; 6 with foster families; 4 with adoptive families; 2 with relatives). All of the children for whom the information was available ($n = 12$) experienced postnatal risk (e.g., multiple placements; abuse/neglect). Ten of the children for whom the information was known ($n = 11$) experienced other prenatal exposures in addition to alcohol (e.g., tobacco; marijuana). Five children regularly took medication to manage their attentional difficulties and the caregivers of these children were asked to not give the medication on the day of testing. Three of these children were tested off their medication. Two were on medication during the time of the assessment (one because the caregiver forgot and one because of the type of medication the child was on). The children who were tested off their medication had taken their last dose at least 24 hours before the testing session.

The TD children were recruited from communities in British Columbia through the use of community postings, school contacts, and the distribution of flyers to acquaintances and colleagues. Only children with a parent or caregiver knowledgeable about the child's prenatal history were included in the study.

The mean mental age for the TD children was 9.59 years (*SD* = 1.55) with a range of 7.50 to 12.75 years, and did not differ from the mean mental age of participants with FASD, $t(26) = 0.115$, $p = .909$. The TD children ranged in chronological age from 6.25 to 11.75 years (*M* = 8.42, *SD* = 1.39) and were significantly younger than the children with FASD, $t(26) = 6.364$, $p = <.001$. Based on performance on the Leiter-R, they had an estimated mean nonverbal IQ of 114.93 (*SD* = 9.92), which was significantly higher than the mean IQ for children with FASD, $t(26) = -8.217$, $p = <.001$.

Measures

The Leiter International Performance Scale – Revised (Leiter-R). The Leiter-R (Roid & Miller, 1997) is a nonverbal measure of cognitive ability developed for use with individuals from 2 to 20 years of age. The Leiter-R is entirely nonverbal and performance is not timed. It is comprised of 20 subtests organized into the two major areas of Reasoning and Visualization (10 subtests), and Attention and Memory (10 subtests). Standard scores are generated for each of the composites under these major areas. The Brief IQ Composite (4 subtests) was used to estimate the developmental level or the mental age (MA) of the participants in this study.

The Conners' Rating Scale: Long Version – Parent Form (CPRS:L). The CPRS:L (Conners, 1997) is a rating scale administered to caregivers of children and adolescents to aid in the assessment of attention-deficit hyperactivity disorder (ADHD) and other comorbid issues. The CPRS:L includes three scales that correspond to the DSM-IV diagnostic criteria for ADHD (i.e., predominantly inattentive type, predominantly hyperactive-impulsive type, and combined type). The results of this rating scale were used as a measure of the degree to which each child displayed clinically significant attention problems.

The Test of Everyday Attention for Children (TEA-Ch). The TEA-Ch (Manly et al., 1998) was designed to assess various components of attention in children. The TEA-Ch is comprised of nine subtests that are used to measure focused (selective) attention, sustained attention, or attentional control/switching. The tasks are "game-like" and require little memory or verbal comprehension skills, which makes the TEA-Ch a potentially appropriate tool for use with children with disabilities such as FASD. Four of the nine subtests were administered in this study. Two of the subtests involved visual selective attention (Sky Search and Map Mission), and the other two involved attentional control/switching (Creature Counting and Opposite Worlds) and were used as potential measures of cognitive control.

1. On the *Sky Search* subtest, the children were required to quickly circle target pairs among distracters on paper. Sky Search includes a trial with no distracters in order to control for motor speed.
2. On the *Map Mission* subtest, the children were required to locate as many target stimuli as possible on a city map within a time limit.
3. On the *Creature Counting* subtest, the children were required to switch between counting forward and backwards in response to visual targets.
4. On the *Opposite Worlds* subtest, the children were first required to name aloud the numbers "1" and "2" that they saw displayed along a path on paper. In the "opposite world" they were required to say "1" when they saw a "2", and say "2" when they saw a "1".

The Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV) Integrated. The WISC-IV Integrated (Wechsler et al., 2004) provides a measure of general cognitive ability for individuals 6 through 16 years old. The digit span and spatial span subtests were used as measures of working memory.

The Experimental Paradigm

The experimental task was administered using a Mac OS X laptop computer running SuperLab Pro software (version 1.74) with a 15 inch screen that measured 32.5 cm horizontally and 21.5 cm vertically. The laptop was placed approximately 60 cm in front of the participant. A head rest was used to maintain a consistent viewing distance for all participants. The participants responded to the stimulus by pressing the right or left buttons on a Superlab RB-530 series response pad that was attached to the laptop. All the stimuli were black on a white background, and measured 3.8° of visual angle horizontally (4 cm). The target arrow appeared in the middle of the screen alone or with flanker arrows appearing to right and left of the target in a horizontal array (see Figure 2 for examples). A black fixation symbol appeared in the centre of the screen for 250ms before each trial. A presentation of the stimuli followed the fixation symbol and remained on the screen until the participant responded, or until 5 seconds had passed.

Each of the flanker and no-flanker-mixed conditions were presented with equal frequency within each response compatibility condition. The no-flanker-blocked condition was presented in a separate block, within the compatible condition only. Response compatibility was held constant within each block. The task consisted of two blocks of 8 no-flanker experimental trials followed by two blocks of 56 experimental trials requiring compatible responding, and two blocks of 56 experimental trials requiring incompatible responding. The order of the response compatibility conditions was counterbalanced among participant pairs such that half the FASD participants (and their matched counterparts) received the compatible conditions first and half received the incompatible conditions first.

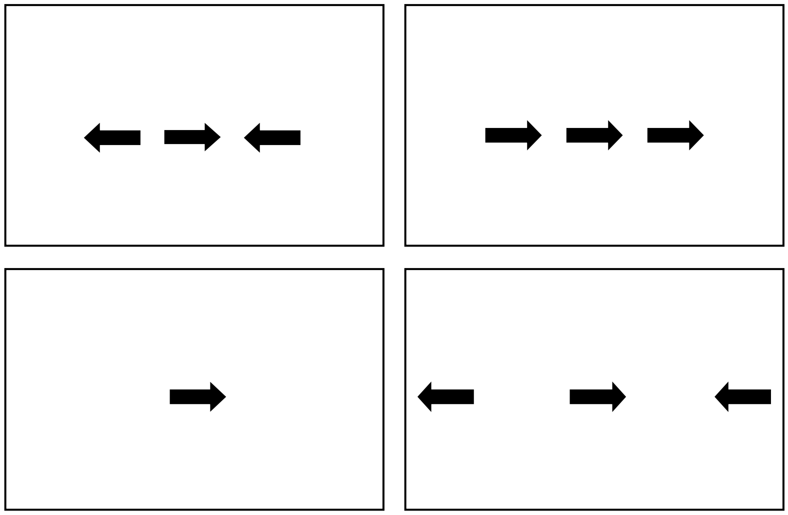

Figure 2. Examples of flanker and no-flanker displays: The close incongruent flanker display (top left), the close congruent flanker display (top right), the no-flanker display (bottom left), and the far incongruent flanker condition (bottom right).

Procedure

The legal guardians and caregivers (when different) provided signed informed consent prior to testing. Verbal assent was also obtained from the participating child. In the case of the TD participants, the child's parent completed a brief questionnaire (see Appendix B) to confirm that the child did not experience prenatal substance exposure, or have a history of learning, behaviour, or attentional problems.

The alcohol-related diagnosis, ratings for the attention-deficit hyperactivity brain domain and the postnatal risk, and other prenatal substance exposures for each of the children with FASD were obtained from the Asante Centre diagnostic assessment file.

All of the children were tested in a quiet room with limited distractions. The majority of the children with FASD were tested at the Asante Centre. One participant was tested in their home and another participant was tested at another community agency. The TD children were either tested at the Asante Centre, another community agency, or their school. All of the assessment measures were administered by an experienced clinician trained in test administration. The caregivers of the children who took stimulant medication for ADHD symptoms were asked not to administer the stimulant medication dosage on the day of testing (if appropriate).

The Leiter-R was administered first to all children. The children with FASD and some of the TD children completed the rest of the testing on the same day. The experimental task was administered first, followed by subtests from the TEA-Ch and the WISC-IV Integrated. Many TD children completed the Leiter-R alone on one day, and those that had an MA within 4 months of one of the participants with FASD completed the experimental task and additional subtests on a separate day. The testing took approximately one and an half hours in total, and the children were provided with breaks as needed. The caregivers typically completed the CPRS:L while the children were being assessed.

During the administration of the experimental task, the participants were seated at a table, 60 cm from the computer screen and told that they would play a computer game on which they have to respond to the arrows in the middle of the screen by pressing the corresponding button as fast as they can without making mistakes. Examples of the target arrows were presented to the children. The experimenter explained that other arrows may appear on the screen, but they should only pay attention to the arrow that appears in the middle of the screen and ignore any other arrows that appear on the screen. The head rest was adjusted to a comfortable height and the children were instructed to place their hands on the two response buttons and look at the middle of the screen between trials.

Before the administration of each compatibility condition, the participants were presented with one set of 21 practice trials. Prior to the administration of the no-flanker block, a set of 10 practice trials was presented. The practice trials were not included in the data analyses. Verbal feedback was given to the participants, and the instructions were repeated when necessary, during the practice trials. No feedback was provided during the experimental trials. The experimenter sat beside the participants during the administration and refrained from interacting with the children, except as required to encourage continuation or maintain rapport.

All of the participants received a small prize following the testing session. In addition, caregivers chose the option of attending an FASD workshop or receiving a $15 gift certificate to a bookstore. A $5 gift certificate was provided to the TD children who completed the Leiter-R but did not have an MA within 4 months of a participant with FASD and therefore did not participate in further testing.

Results

Visual Filtering Task

The mean RTs for each of the 15 experimental conditions, which varied in terms of response compatibility (compatible, incompatible), flanker type (none, congruent, incongruent), and flanker distance (close, intermediate, far), were calculated for each participant (see Table 2). In order to reduce the influence of potential outliers on reaction time (RT) data, RT cutoffs based on 2.5 standard deviations from the mean were calculated for each participant. The mixed blocks (i.e., contained both flanker and no flanker trials) were considered separately from the target-only block (i.e., contained only no flanker trials). A moving cutoff based on sample size (see Van Selst & Jolicoeur, 1994) was calculated for each participant for the block of no flankers as the sample size was less than 100.

A total of 6720 experimental trials were administered to the 28 participants. The participants failed to respond to 85 of those trials in the allotted time (5 seconds). Of the remaining 6635 trials, 909 were deleted from the RT analyses; 536 because of incorrect responses (7.976% of total trials presented), 52 because the RT was less than 150 ms (0.774% of total trials presented), 150 because they were the first response after a break (2.481% of total correct trials), and 171 because the RT was considered to be an outlier (2.828% of total correct trials).

Table 2

Mean Reaction Times and Standard Deviations for the 15 Experimental Conditions

Response Type	Flanker Type	Flanker Distance	FASD (n = 14)		TD (n = 14)	
			M	*SD*	*M*	*SD*
Compatible	None-Blocked	-	467.60	106.43	508.79	118.15
Compatible	None-Mixed	-	567.79	103.26	559.40	118.08
Compatible	Congruent	Close	528.57	109.81	584.15	126.60
Compatible	Congruent	Intermediate	532.30	86.16	601.68	132.13
Compatible	Congruent	Far	555.24	112.88	569.62	127.16
Compatible	Incongruent	Close	594.76	105.02	640.14	136.66
Compatible	Incongruent	Intermediate	566.03	116.94	602.57	124.77
Compatible	Incongruent	Far	538.33	118.81	622.37	145.74
Incompatible	None-Mixed	-	598.38	121.57	620.52	127.47
Incompatible	Congruent	Close	587.71	107.97	643.78	139.77
Incompatible	Congruent	Intermediate	581.26	130.04	609.39	108.05
Incompatible	Congruent	Far	572.02	103.13	614.27	132.73
Incompatible	Incongruent	Close	612.48	126.06	658.74	129.98
Incompatible	Incongruent	Intermediate	603.82	90.86	654.22	139.33
Incompatible	Incongruent	Far	611.36	124.68	642.87	137.33

The percentage of errors did not differ between the groups, $t(26) = .697$, $p = .492$, and the percentage of errors was unrelated to the mean RT for both the FASD group ($r = -.019$, $p = .950$) and the TD group ($r = .110$, $p = .709$), suggesting that a speed-accuracy trade-off was not a factor for either group. All further analyses were performed using correct RT data only. The mean correct RT, standard deviation, percentage of errors, and number of responses with RT less than 150ms are presented in Table 3 for each group.

Table 3

Reaction Times, Errors, Trials with RTs <150ms, and Outliers for Each Group on the Flanker Task

Group	M RT (SD)	% Errors	# < 150ms	# Outliers
FASD	575.02 (101.27)	8.85	2.29	6.07
TD	610.81 (130.23)	7.33	1.43	6.14

Performance on the experimental task appeared to be more closely related to developmental level than chronological age for the children with FASD as mean correct RT was associated with developmental age ($r = -.722$, $p = .004$) and not with chronological age ($r = -.502$, $p = .067$). As would be expected, the mean RT for the TD group was associated with both developmental ($r = -.778$, $p = .001$) and chronological ($r = -.815$, $p < .001$) age, which are closely linked.

In order to analyse the visual filtering abilities of children with FASD, the correct RT data was assessed with three separate mixed-model ANOVAs. The first analysis was used to examine the effect of the different types of displays on the RT of children with FASD in comparison to MA-matched TD children. The second analysis was used to examine the effect of attentional set, and the third examined the effect of various flanker conditions on RT. The alpha level for the three ANOVAs was set at .017 to account for multiple comparisons.

Flanker presence and congruency. Based on previous research with flanker tasks, the presence of distracter arrows (i.e., flankers) along with the target arrow was expected to disrupt performance. The presence of incongruent flanker arrows (i.e., those that point in the opposite direction to the target arrow) was expected to be more disruptive than the presence of congruent flanker arrows (i.e., those that point in the same direction as the target arrow). The children with FASD were expected to be more distracted than the MA-matched TD children, which would be reflected in a larger FCE for the children with FASD. The FCE is the difference in RT between trials with congruent and incongruent flankers, and is used as the measure of filtering efficiency.

In order to test the hypotheses, RT data for both the flanker and the no-flanker displays in the mixed blocks were analysed with a mixed-model ANOVA, with group (FASD, TD) as a between group variable and flanker type (none, congruent, incongruent) as a within group variable. The alpha level for the follow up *t*-tests was set at .01 to account for multiple comparisons. The analysis revealed a main effect of flanker type, $F(2,52) = 16.506$, $p < .001$, $\eta_p^2 = .388$. Consistent with expectations, the RTs were longer when the incongruent flankers were present than when there were no flankers or congruent flankers (612.31 ms vs. 586.53 and 581.67 ms). Contrary to expectations, no RT differences were found between the conditions with no flankers and the conditions with congruent flankers.

No main effect of group was found, $F(1,26) = .634$, $p = .433$, $\eta_p^2 = .024$, but an interaction of flanker type and group was found, $F(2,52) = 8.111$, $p = .001$, $\eta_p^2 = .238$ (see Figure 3). The hypothesis that the children with FASD would be more distracted by flankers was not supported, as the FCE was evident for both groups. The mean FCE for the FASD group was 28.280, $t(13) = 4.833$, $p < .001$, and the mean FCE for the TD group was 33.005, $t(13) = 5.199$, $p < .001$. Contrary to expectations, RTs were faster with the congruent flankers (559.52 ms) than with no flankers (583.09 ms), and no differences were found between RTs in conditions with incongruent flankers and conditions with no flankers (587.80 and 583.09 ms, respectively) among the children with FASD. A different pattern was evident for the TD children. As expected, the RTs were faster in the no-flanker conditions (589.96 ms) than in the incongruent flanker conditions (636.82 ms). Reaction time did not differ significantly between the congruent flanker and no-flanker conditions for either group.

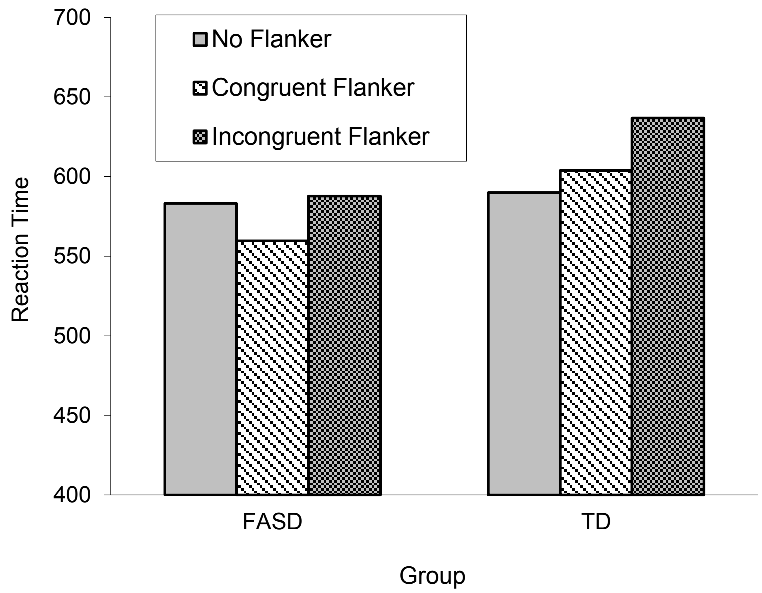

Figure 3. Mean RTs for each flanker type condition (no-flanker, congruent flanker, incongruent flanker) as a function of group. The RT difference between the no-flanker and incongruent flanker conditions were significant for the TD group, but not for the FASD group.

Attentional set. Attentional set reflects the increased time required when responding to target-only displays presented in a mixed block of trials (i.e., flanker and no-flanker displays) versus those presented in a block of target-only trials. The effect of attentional set was predicted to be greater for the children with FASD. In order to examine attentional set, only the no-flanker displays were analysed with a mixed-model ANOVA, with group (FASD, TD) as a between group variable and the block within which the target-only displays were presented (blocked, mixed) as a within group variable. As expected, the analysis revealed a main effect of attentional set, $F(1,26) = 62.254$, $p < .001$, $\eta_p^2 = .705$, indicating that the RTs were faster when the no-flanker displays were presented all together in a block of trials, than when they were presented in blocks with flanker displays (488.191 vs. 563.596 ms). No main effect of group was found, $F(1,26) = .159$, $p = .693$, $\eta_p^2 = .006$. However, an interaction effect was found between group and attentional set, $F(1,26) = 6.729$, $p = .015$, $\eta_p^2 = .206$ (see Figure 4). As hypothesized, the attentional set effect was larger for the children with FASD than for the TD children (100.195 versus 50.614, respectively), $t(26) = 2.594$, $p = .015$.

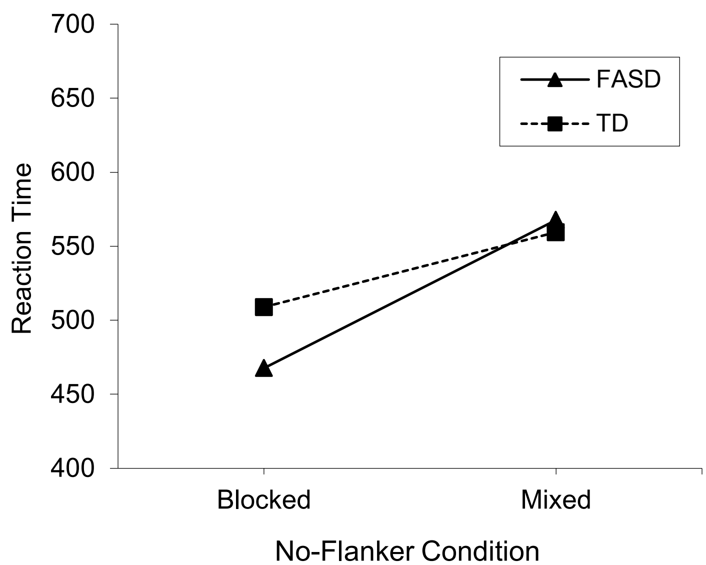

Figure 4. The reaction time (RT) for each group as a function of the block within which the no-flanker trials were presented. The children with FASD had a significantly larger increase in RT when the no-flanker condition was presented within a block of mixed flanker/no-flanker trials in comparison to a block of target-only trials.

Congruent / incongruent flanker displays. For both groups of children, the RTs were expected to be faster in the compatible response condition than in the incompatible response condition. Reaction times were also expected to increase as the distance of the flankers from the target increased. The children with FASD were predicted to have more difficulty ignoring distracters, reflected by an increased FCE, than the MA-matched TD children when their attention was not fully engaged in processing the target (i.e., during the compatible response condition when the attentional demands of the task are low). They were expected to show similar levels of filtering abilities when the attention demands of the task were higher (i.e., in the incompatible response condition).

In order to test these hypotheses, only the conditions with congruent/ incongruent flankers were examined and the conditions with no flankers were excluded. The RT data of the varied flanker displays were analysed with a mixed-model ANOVA, with group (FASD, TD) as a between group variable, and response compatibility (compatible, incompatible), flanker congruency (congruent, incongruent), and flanker distance (close, intermediate, far) as within group variables. The alpha level for the follow up *t*-tests was set at .01 to account for the multiple comparisons.

Main effects. Consistent with expectations, main effects of response compatibility, $F(1,26) = 10.755$, $p = .003$, $\eta_p^2 = .293$, flanker congruency, $F(1,26) = 50.385$, $p < .001$, $\eta_p^2 = .660$, and flanker distance, $F(1,26) = 5.828$, $p = .005$, $\eta_p^2 = .183$, were found. Reaction times were faster in the response compatible conditions than in the response incompatible conditions (577.979 vs. 615.993 ms, respectively) and when the flankers were congruent than when they were incongruent (581.665 vs. 612.307 ms, respectively). Follow-up *t*-tests revealed that RTs were longer ($p < .01$) when the flankers were presented close (1.0° visual angle) to the target arrow than when the flankers were presented far (4.7° visual angle) from the target arrow (606.291 ms vs. 590.760 ms, respectively), $t(27) = 3.37$, $p = .002$. No main effect of group was found, $F(1,26) = 1.193$, $p = .285$, $\eta_p^2 = .044$.

Interaction effects. The three-way interaction among response compatibility, flanker congruency, and flanker distance approached significance, $F(2,52) = 4.231$, $p = .020$, $\eta_p^2 = .140$. A four-way interaction (response compatibility x flanker congruency x flanker distance x group) was found, $F(2,52) = 4.470$, $p = .016$, $\eta_p^2 = .147$ (see Figure 5). As expected, filtering efficiency improved in the response incompatible condition among the TD children. The FCE was significant for the TD group at both close, $t(13) = 3.456$, $p = .004$, and far, $t(13) = 5.278$, $p < .001$, distances in the compatible condition (55.984 and 52.756, respectively), but not in the incompatible condition (14.961 and 28.603, respectively). As expected, an FCE was found at the close distance in the compatible condition for the children with FASD (66.195), $t(13) = 4.053$, $p = .001$, but contrary to expectations, not at the far distance (-16.9111), $t(13) = -1.516$, $p = .153$. Consistent with predictions, the FCE did not reach significance ($p < .01$) in the incompatible condition at either the close (24.770), $t(13) = 1.473$,

$p = .165$, or the far (39.340), $t(13) = 3.032$, $p = .010$, flanker distance for the children with FASD.

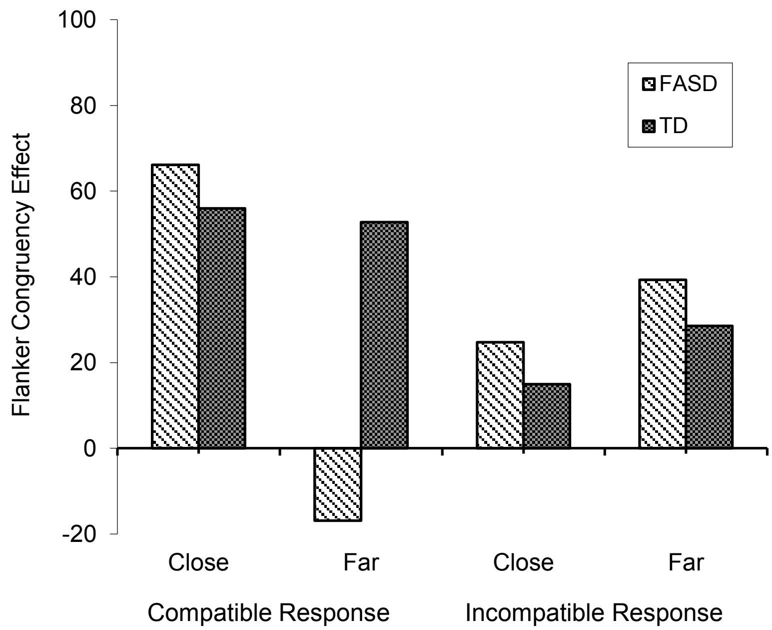

Figure 5. The FCE for each group as a function of flanker distance within each response compatibility condition. The FCE was significant for both groups in the compatible response condition at the close distance, and were no longer significant in the incompatible response condition. The children with FASD were less distracted than the TD children by flankers presented far from the target in the compatible response condition.

Developmental improvements in filtering efficiency. Developmental improvements in filtering efficiency were expected, and developmental differences were expected to be reduced when the attentional demands of the task were increased (i.e., in the incompatible response conditions). Consistent with these expectations, mental age was related to FCE in the compatible condition ($r = -.425$, $p = .024$), but not in the incompatible condition ($r = -.313$, $p = .298$). In order to analyse the developmental improvements in filtering efficiency, the participants were split into groups based on MA. The median MA for the children with FASD was 112 months (9 years, 4 months). The TD children were placed within the same developmental group as their matched counterparts. No difference between FCEs was found between the developmentally older ($n = 14$; $M = 33.280$) and younger ($n = 14$; $M = 25.076$) participants in either the response compatible condition, $t(26) = 1.576$, $p = .127$, or the response incompatible condition, $t(26) = -.770$, $p = .448$.

As children with developmental ages of 9 years were distributed across both the older and younger developmental age groups, the participants were divided into the three developmental age groups of 7 to 8 years ($n = 10$), 9 years ($n = 9$), and 10 to 12 years ($n = 9$). Developmental improvements in filtering efficiency were evident in the compatible response condition (see Figure 6), as the developmentally younger children (MA 7 - 8 years) were less efficient (FCE = 51.19) than the developmentally older children (MA 10 – 12 years; FCE = 16.64), $t(17) = 2.751$, $p = .014$. Developmental improvements between the developmentally older and younger children were no longer evident in the incompatible response condition, $t(17) = -.496$, $p = .626$, indicating that the developmental differences in filtering efficiency were reduced when the attentional demands were increased (see Figure 6).

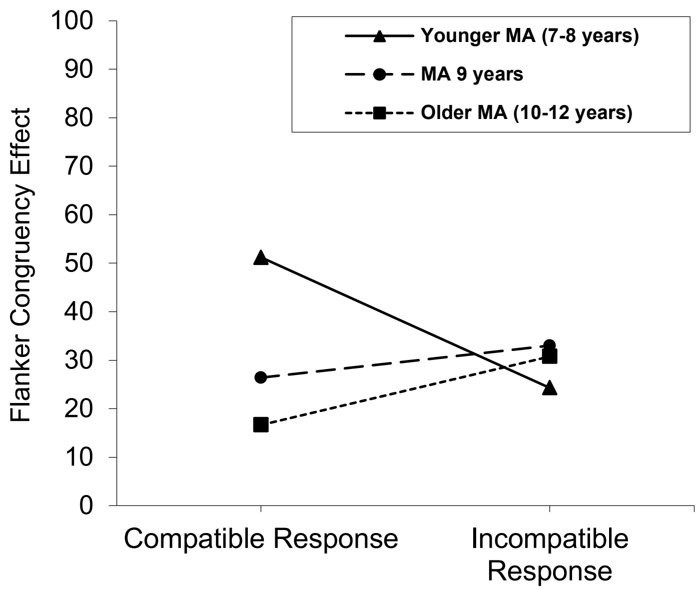

Figure 6. The FCE for the three developmental age groups as a function of response compatibility. The difference between the FCEs for the developmentally younger and older children was significantly different in the compatible response condition only. The FCE was reduced for the developmentally younger children when the processing demands were increased in the incompatible response condition.

The developmentally older group, which included both children with FASD and TD children, demonstrated an FCE that was consistent with the adult levels of visual filtering as reported in Porporino (2006). The developmentally older TD children (n = 5) similarly appeared to have adult levels of visual filtering in the compatible condition when the flankers were presented close to the target (M = 18.47), whereas the developmentally older children with FASD (n = 4) demonstrated a larger FCE (M = 47.41), which was consistent with the FCE found by Porporino for TD children between 7 and 10 years. The high attentional demand condition reduced the FCE for the children with FASD to a level that reflects efficient filtering (M = 8.79), whereas the high attentional load did not affect the minimal FCE of the TD children, who were already filtering efficiently in the low attentional demand condition. The small sample size precluded statistical analyses of this data, but the trend suggests that children with FASD experience difficulties with visual filtering in relation to their developmental level.

Caregiver Ratings of Attention Difficulties

As expected, the participants with FASD, but not the TD participants, were rated by their caregivers on the Conners' as having clinically significant attention difficulties for their developmental age. T-scores (based on MA) for several of the Conners' scales are presented in Table 4 for each group.

Based on the caregiver reports, all of the children with FASD displayed cognitive problems/inattention in relation to their MA (M = 79.08, SD = 8.78;

range: 67 - 90). None of the children with FASD scored within the average range on the diagnostic-oriented scale for attention deficit hyperactivity disorder (ADHD), inattentive type, and only two scored within the average range on the diagnostically-oriented scale for ADHD, hyperactive-impulsive type. The majority (*n* = 10; 76.9%) of the children with FASD (*n* = 13) displayed symptoms that were consistent with a diagnosis of ADHD, combined type, as measured by the Conners' (i.e., T-score of 70 or above), and an additional 15.38% had moderately elevated scores (i.e., T-score between 65 and 69). Only one child had a score within the average range. None of the TD children displayed symptoms of ADHD.

Table 4

Mean T-Scores (Standard Deviations) Based on MA for Both Groups on the Conners' Subscales

	FASD (*n* = 13)		**TD (*n* = 12)**	
Conners' Subscale	*M*	*SD*	*M*	*SD*
Cognitive Problems / Inattention	79.08	8.78	45.75	2.22
DSM-IV Index: Inattentive	77.00	9.97	45.50	2.88
DSM-IV Index: Hyperactive-Impulsive	72.92	13.20	50.92	4.34
DSM-IV Index: Total	76.77	10.66	47.75	3.31

Focused Attention and Cognitive Control

Subtests from the TEA-Ch and the WISC-IV Integrated were administered to the participants to assess focused attention (the sky search and map mission subtests), attention control (the opposite worlds and creature counting subtests), and cognitive control (the digit span and spatial span subtests). The descriptive statistics of the subtest scores on the TEA-Ch and WISC-IV Integrated subtests for each group are presented in Table 5 for scores calculated based on MA, and Table 6 for scores calculated based on CA.

Overall, the TD children demonstrated average focused attention and cognitive control for their developmental age and CA on all the subtests except for spatial span backward, on which they performed above average.

Despite their behavioural presentation, the children with FASD as a group scored within the average range for their developmental level on all but one of the standardized subtests. The finding of average levels of focused attention on the TEA-Ch subtests in relation to developmental levels is consistent with evidence from children with ADHD (Heaton et al., 2001). The children with FASD in this study also demonstrated average cognitive control for their developmental age based on their performance on the WISC-IV Integrated subtests and the opposite worlds subtest from the TEA-Ch. However, the children with FASD demonstrated difficulties on the more demanding TEA-Ch subtest of creature counting, which is used to measure attention control and requires switching between counting forward and backward. Only three children with FASD performed within the average range for their developmental level on the accuracy component of this subtest, and those three children received a subtest score of 8, which is on the low end of the average range. Only seven children with FASD accurately answered more than two of the seven trials; these children demonstrated average speed for their developmental level. As expected, the children with FASD demonstrated more difficulties with focused attention and cognitive control based on their chronological age, performing below average on the two additional subtests of opposite world and digit span.

In order to compare the two groups on their performance, *t*-tests were conducted. The results are presented in Table 5 for scores calculated based on MA and Table 6 for scores calculated based on CA. When the scores were calculated based on CA, the children with FASD performed worse ($p < .05$) than the TD children on both the attention control and cognitive control subtests. The groups did not differ on the two focused attention tasks. When the scores were calculated based on MA, the children with FASD performed worse than the TD children on the number of correct trials on the creature counting subtest, as well as two additional subtests, the digit span and spatial span backward subtests, suggesting a relative weakness in cognitive control. In contrast, the children with FASD performed better than the MA-matched TD children on the map mission subtest.

Table 5

Comparison of TEA-Ch and WISC-IV Integrated Subtest Scores (Calculated Based on Mental Age) Between FASD and TD Groups

	FASD		TD			
Subtest	***N***	***M (SD)***	***n***	***M (SD)***	***t***	***P***
Focused Attention Subtests						
TEA-Ch Sky Search						
Correct	14	10.36 (2.21)	14	8.86 (2.35)	1.742	.093
Attention	14	9.21 (2.94)	14	7.71 (2.34)	1.495	.147
TEA-Ch Map Mission	14	11.79 (3.09)	14	8.86 (3.06)	2.519	.018
Cognitive Control Subtests						
TEA-Ch Creature Counting						
Correct	14	5.64 (1.65)	13	9.62 (3.82)	-3.463[a]	.003
Timing	7	10.14 (3.08)	12	9.67 (3.80)	.281	.782
TEA-Ch Opposite Worlds						
Same World	14	9.14 (2.57)	13	9.46 (3.93)	-.251	.804
Opposite World	14	8.79 (3.22)	13	8.31 (3.52)	.369	.715
WISC-IV Integrated						
Digit Span	14	8.57 (2.47)	14	10.57 (2.31)	-2.211	.036
Digit Span Backward	14	9.14 (2.11)	14	10.29 (2.40)	-1.339	.192
Forward Span	14	8.93 (1.86)	14	9.79 (2.46)	-1.041	.307
Backward Span	14	9.21 (1.67)	14	11.93 (2.79)	-3.125	.004

Note. Scores from 8 to 12 are average.
[a] df = 16.05 (unequal variances)

Table 6

Comparison of TEA-Ch and WISC-IV Integrated Subtest Scores (Calculated Based on Chronological Age) Between FASD and TD Groups

	FASD		**TD**			
Subtest	***n***	***M (SD)***	***n***	***M (SD)***	***t***	***P***
Focused Attention Subtests						
TEA-Ch Sky Search						
Correct	14	9.93 (2.24)	14	9.36 (2.68)	.613	.545
Attention	14	7.79 (2.99)	14	8.79 (1.93)	-1.051	.303
TEA-Ch Map Mission	14	9.79 (4.08)	14	10.79 (2.16)	-.811	.425
Cognitive Control Subtests						
TEA-Ch Creature Counting						
Correct	14	5.36 (2.02)	13	10.69 (2.90)	-5.581	.000
Timing	7	7.86 (2.41)	12	11.08 (3.15)	-2.333	.032
TEA-Ch Opposite Worlds						
Same World	14	7.57 (3.11)	13	11.15 (2.67)	-3.201	.004
Opposite World	14	6.93 (3.29)	13	10.00 (2.58)	-2.682	.013
WISC-IV Integrated						
Digit Span	14	7.00 (2.60)	14	11.86 (2.03)	-5.504	.000
Digit Span Backward	14	8.14 (1.79)	14	11.64 (2.44)	-4.330	.000
Forward Span	14	7.57 (1.70)	14	11.29 (2.301)	-4.860	.000
Backward Span	14	8.21 (1.48)	14	13.14 (2.41)	-6.518	.000

Note. Scores from 8 to 12 are average.

Filtering Efficiency and Attention / Cognitive Control Measures

In order to examine the relationship between filtering efficiency and cognitive control, caregiver ratings of inattention, and performance on standardized measures that involve filtering, partial correlation coefficients were calculated, controlling for mental age. Partial correlation coefficients were calculated for the compatible conditions only and for each group separately. The coefficients were calculated between the FCE (compatible condition) on the experimental task and the raw scores obtained on the standardized measures. The results of the partial correlations are presented in Table 7.

For the children with FASD, the greater the FCE in the compatible condition (controlling for mental age), the fewer the number of correct pairs found on the TEA-Ch sky search subtest ($pr = -.670$, $p = .012$), suggesting that increased distraction on the experimental task was related to increased distraction on the TEA-Ch subtest. The FCE was not related ($p > .05$) to any of the other subtest raw scores. The partial correlation between the raw score on the Conners' ADHD, hyperactive-impulsive diagnostically oriented scale and the FCE in the compatible condition was significant ($pr = .597$, $p = .040$). The FCE was not related to the other Conners' scales. For the TD children, the FCE in the compatible condition (controlling for MA) was not related to any of the subtest scores or Conners' scales.

Table 7

Partial Correlations (Controlling for MA) between the FCE on the Experimental Task, and the Subtest and Scaled Scores on the Clinical Measures

	FASD		TD	
Subtest / Subscale	**FCE-CR**	***p***	**FCE-CR**	***p***
TEA-Ch Sky Search: Correct	-.670	.01	-.272	.37
TEA-Ch Sky Search: Attention	.275	.36	.038	.90
TEA-Ch Creature Counting: Correct	-.278	.36	.079	.80
TEA-Ch Creature Counting: Time	.188	.54	-.242	.43
TEA-Ch Map Mission	.160	.60	.267	.38
TEA-Ch Opposite Worlds: Same	.007	.98	.074	.81
TEA-Ch Opposite Worlds: Opposite	.301	.32	.074	.81
WISC-IV Integrated: Digit Span	-.201	.51	.248	.42
WISC-IV Integrated: Digit Span Backward	.006	.98	.391	.19
WISC-IV Integrated: Spatial Span Forward	-.225	.46	.063	.84
WISC-IV Integrated: Spatial Span Backward	-.324	.28	.104	.74
Conners: DSM-IV Inattentive	.192	.55	.211	.53
Conners: DSM-IV Hyperactive-Impulsive	.597	.04	.085	.81
Conners: DSM-IV Total	.472	.12	.164	.63

Note. FCE-CR = the flanker congruency effect (FCE) in the compatible response condition.

Discussion

In this study, filtering, the ability to ignore visual distractions while attending to a specified target, was examined among 14 children with FASD with MAs between 7 and 12 years as compared to 14 TD children matched on developmental level. An experimental paradigm, the flanker task, and clinical subtests of attention from the TEA-Ch (Manly et al., 1998) and the WISC-IV Integrated (Wechsler et al., 2004) were administered. The group of children with FASD included only those impacted by PEA, as assessed with the Canadian diagnostic guidelines (Chudley et al., 2005). In order to diminish the potentially confounding effects of the generally lower IQs of children with FASD the groups were matched on developmental level, assessed with the Leiter-R (Roid & Miller, 1997).

Consistent with previous research, the children with FASD presented with significant attention problems based on caregiver report, even when developmental level was considered. Sixty-four percent (n = 9) of the children with FASD (n = 14) had a diagnosis of ADHD, and 76.9% (n = 10) of the children with FASD (n = 13) were rated by their caregivers as having symptoms consistent with a diagnosis of ADHD, combined type. Despite the significant level of attention problems in this group, they performed within the average range for their developmental level on all but one of the standardized subtests and similarly to the group of MA-matched TD children in terms of overall filtering efficiency on the flanker task. As expected, a broader range of difficulties were evident for the children with FASD, whose nonverbal cognitive abilities were in the below average range, when comparisons were made based on chronological age.

Although the findings of average focused attention and high levels of caregiver reported inattention may seem contradictory, the same pattern is found for children with ADHD (Heaton et al., 2001). Children with ADHD are similarly distractible and inattentive based on behavioural observation (American Psychiatric Association, 1994; Hudziak, Copeland, Stanger, & Wadsworth, 2004), but were found to perform within the average range on the focused attention subtests of the TEA-Ch (Heaton et al., 2001) and adequately on a flanker task in comparison to TD children (Huang-Pollock, Nigg, & Carr, 2005).

Although the group of children with FASD did not demonstrate broad difficulties for their developmental level on the standardized measures, they demonstrated difficulties in working memory and cognitive control in comparison to the group of TD children, suggesting weaknesses that are consistent with previous findings in the literature (Kodituwakku, Kalberg, et al., 2001; Rasmussen, 2005). Moreover, the preliminary findings from this study suggest that the developmentally older children with FASD (i.e., MA 10 – 12 years) are less efficient in visual filtering then developmentally older TD children.

General Findings on the Flanker Task

In general, the findings in this study were consistent with previous research with flanker paradigms (e.g., Enns & Akhtar, 1989; Eriksen & Eriksen, 1974; Porporino, 2006). Overall, the RTs were faster when the response associated with the target was compatible than when it was incompatible, and RT was faster when the flankers were congruent with the target than when the flankers were incongruent. Inconsistent with previous research with flanker tasks with both different (e.g., Enns & Akhtar, 1989; Eriksen & Eriksen, 1974) and similar stimuli (e.g., Jonkman et al., 1999), the mere presence of flankers was not associated with performance that was worse than the target-only conditions, as the RTs on the conditions with the congruent flankers did not differ from the conditions with no flankers at all. One reason for the different finding in this study might be the proximity of the flankers to the target. Flankers presented closer to the target are more interfering than flankers presented further from the target (Enns & Girgus, 1985; Eriksen & Eriksen, 1974; Pasto & Burack, 1997), and the arrow flankers presented in this study were further from the target than those used elsewhere (e.g., Jonkman et al., 1999). The magnitude of the RT differences between close flanker conditions and the no-flanker conditions (compatible response) for the TD children in this study (25ms) was similar to the RT found for the TD children in the study by Jonkman et al. (22ms), suggesting that the findings from this study are consistent with previous research findings with regard to TD children.

Visual Filtering in FASD

In many ways, the children with FASD appeared to demonstrate developmentally appropriate levels of visual filtering. As a group, they performed similarly to the MA-matched TD children in terms of both overall RT and accuracy on the flanker task, and demonstrated a similar level of filtering efficiency, based on the FCE. The FCE is the difference in RT when responding to the target stimulus in the presence of incongruent flankers versus congruent flankers. The children with FASD demonstrated the ability to attend to relevant stimuli in the presence of distracters at a level that appeared to be consistent with their MA, based on nonverbal cognitive ability. This was supported by their performance on the sky search and map mission subtests on the TEA-Ch, subtests that also require the ability to attend to relevant stimuli in the presence of distracters. As a group, the children with FASD performed within the average range on these subtests, calculated based on their MA, and in comparison to the group of MA-matched TD children.

Attentional Set

Consistent with Enns and Akhtar's (1989) findings, the effect of attentional set was significant for both groups. However, this effect was almost twice as big for the children with FASD as compared to the TD children. Attentional set refers to the increased RT required to respond to target-only displays in blocks that also include flanker displays, in comparison to the RT required to respond to a series of target-only displays, and is thought to reflect the increased effort involved in maintaining an attentional set or switching between attentional sets (Enns & Akhtar, 1989).

The children with FASD may have found it more effortful than the MA-matched TD children to respond while they maintained preparedness to ignore flanker arrows. However, the children with FASD did not demonstrate increased difficulty on the opposite worlds subtest of the TEA-Ch, which also required the maintenance of an attentional set, in comparison to the MA-matched TD children.

The children with FASD may have had more difficulty than the MA-matched children when switching between the attentional sets of 'filter' and 'do not filter'. Consistent with previous evidence that individuals with FASD appear to have some difficulties with attentional shifting (e.g., Coles et al., 1997; Kerns et al., 1997; Kodituwakku et al., 2001; Mattson et al., 2006), the children with FASD performed below average for their MA, and significantly worse than the MA-matched TD children, on the creature counting subtest of the TEA-Ch, the one subtest that entails an aspect of switching, in this case, between counting forward and counting backward.

The Effect of No-Flanker Displays

Based on previous evidence, the presence of incongruent flankers along with the target was expected to disrupt performance. Thus, RTs were expected to be faster when responding to the target-only displays than to the incongruent flanker displays. This was evident for the TD children, but not for the children with FASD. For the children with FASD, performance on the trials with the incongruent flankers was the same as performance on the trials with no flankers, which is surprising. Even children for whom attention problems are especially prominent (i.e., children with ADHD) respond faster to displays with no flankers than displays with flankers (Jonkman et al., 1999). Difficulties with attentional switching may also explain these unexpected findings, since the need to switch from one attentional set (filtering) to another (no filtering) was almost always required when responding to no-flanker displays, but only sometimes required when responding to flanker displays (maximum 17% of the time) as these displays occurred much more frequently (85.7% versus 14.3%). Therefore, the impact of the attention shifting deficit would be most prominent in the target-only conditions, and may explain the significant group differences.

The relative infrequency with which the no-flanker displays appeared could have disrupted the performance of the children with FASD for another reason. As the no-flanker displays included only one stimulus, they were visually different from the flanker displays that included a three stimuli array, and occurred much less frequently. The appearance of an unexpected visual target has been found to increase reaction time. In Lane and Pearson's (1983) study, reaction time to targets was found to be slower when the target was presented in a location where it appeared less frequently, even when that location was the fixation point at the centre of the screen and no shift in attention is required. As this was more pronounced for children than for adults, Lane and Pearson suggested that the appearance of an unexpected event is more disruptive for children. The presence of novel visual stimuli has been found to be more disruptive for infants with PEA than non-exposed infants (Kable & Coles, 2004) and perhaps the visual difference between the target-only displays and the three stimuli flanker displays were unexpected and particularly disruptive for the children with FASD.

Jonkman et al. (1999) found that both TD children and children with ADHD had an increased P2 latency, which is thought to reflect visual processing (Burden et al., 2009; Jonkman et al., 1999), to target-only displays in comparison to flanker displays, with no apparent disruption in RT. In another study (Burden et al., 2009), children with FASD were generally found to have increased P2 latencies in comparison to TD children when responding to visual stimuli on a computerized task (i.e., the go/no go task). This increase in latency may indicate that children with FASD require more effort in general to process visual stimuli than TD children, which is consistent with Mattson et al.'s (2006) finding that children with heavy PEA consistently respond slower than TD children to visual, but not auditory, stimuli. Children with FASD seem to have difficulties processing visual stimuli in general, and may have particular difficulty when the visual stimuli are unexpected or deviate from the usual pattern. The idea that children with FASD are more disrupted by novel stimuli is consistent with the findings of early difficulties with habituation to redundant visual stimuli for infants with PEA (Streissguth et al., 1983), and that novel visual stimuli appear to disrupt information processing in infants with PEA (Kable & Coles, 2004). This could explain the underlying mechanism for the attentional set interference for the children with FASD as well, as the target-only flankers were expected within the blocked trials, but relatively unexpected during the mixed block trials.

Filtering Efficiency and Increased Processing Demands

Increasing the processing demands of the task improved filtering efficiency for both groups of children. The TD children were affected by the presence of distracters, regardless of the proximity of the flankers to the target under the low, but not the high, attentional demand condition. The children with FASD also demonstrated less efficient visual filtering in the low attentional demand condition when the flankers were presented close to the target, which similarly improved under the high attentional demand condition. This is consistent with the perceptual load theory of selective attention (see Lavie, 1995; Lavie & Tsal, 1994; Porporino, 2006). When the processing demands are low, fewer attentional resources are required to process the target and therefore more attentional resources are available to process distracters. Accordingly, filtering is improved when more attentional resources are used up on the target task, leaving fewer available to process irrelevant information.

The hypothesis that the children with FASD would demonstrate greater interference in the response compatible, low attentional demand, condition than the TD children was not entirely supported in this study. Whereas the filtering efficiency of the groups was similar when the flankers were presented close to the target, the groups differed with respect to filtering efficiency when the flankers were presented far from the target in the compatible response condition. Contrary to expectations, the children with FASD appeared to be particularly efficient in this condition as flanker distance appeared to be helpful in reducing the interfering effect of the flankers on performance among the children with FASD when the processing demands were low. One explanation for this finding is that the children with FASD, who were chronologically older than the TD children, were more efficient at narrowing their attentional focus in the response compatible condition. This would be consistent with the evidence of developmental improvements in narrowing the spatial range in which distracters could impede performance (Enns & Girgus, 1985; Pastò & Burack, 1997). Thus, both flanker distance and the attentional demands of the task may be important factors in the visual filtering abilities of children with FASD.

Developmental Improvements

Developmental improvements in filtering efficiency were expected based on previous research with flanker tasks, and were evident in this study. Developmental level was related to filtering efficiency in the compatible response condition but not in the incompatible response condition. This was expected as the response compatible condition presumably requires fewer attentional resources to process the target and, therefore, leaves more attentional resources available to process distracters, and younger children are less efficient than older children at ignoring distracters when the task-relevant processing demands are low (Huang-Pollock et al., 2002; Porporino, 2006). For example, the developmentally younger children in Porporino's study (MAs 7 – 8 years) had significantly larger FCEs than the developmentally older children (MA 10 – 12 years) in the response compatible conditions, indicating that children become increasingly efficient at ignoring distracters with increasing MA.

In this study, the RT on the experimental task was correlated with MA but not CA among the children with FASD, suggesting that the performance of the children with FASD was more closely related to developmental level than to CA. Developmental improvements in visual filtering are evident for TD children between 7 and 12 years of age (Huang-Pollock et al., 2002; Porporino, 2006), and the FCE for the developmentally older (MA 10 -12 years) TD children in the compatible response condition when the flankers were presented close to the target was small (M = 18.74, SD = 37.89), and consistent with the adult levels of visual filtering as reported by Porporino (2006). This FCE was much smaller than the FCE for the developmentally older children with FASD (M = 47.41, SD = 5.52), which was similar to the FCE found for the TD children between 7 and 10 years in Porporino's study. However, high attentional demand reduced the FCE for the children with FASD to a level that reflects adult levels. In contrast, the minimal FCE for the TD children remained essentially unchanged in the high attentional demand load, which would be expected as they were already filtering efficiently in the low attentional demand condition. These results suggest difficulties with visual filtering in relation to developmental level among children with FASD.

Limitations

Some limitations of this study are found with regard to the characteristics of the participant groups and to the experimental design. The former include the number of participants, demographics, the broad age range, and the difference in cognitive ability between the groups of children.

One, the number of participants in this study was small. A larger group of participants may have revealed more differences between groups, and would have allowed for additional comparisons between subgroups, for example, comparisons between (a) FASD diagnostic groups, (b) FASD groups with and without ADHD, (c) medication histories, and (d) developmental levels.

Two, the groups differed on several unavoidable demographic variables. For example, most of the children with FASD were not living with their birth parents at the time of testing, but all of the TD children were. In addition, some of the children with FASD experienced other prenatal and postnatal risk factors, aside from PEA. In addition, many of the children with FASD in this study had a co-morbid diagnosis of ADHD, and some of them were taking stimulant medication.

Three, the MA range of the children in this study was sufficiently broad that the attentional processing within each group likely varied between the MA younger and older participants, thereby possibly obscuring differences that might be observed within a more restricted range of MA.

Four, by the nature of the matching procedure used in this study, the children with FASD were chronologically older and had lower IQs than the TD children. This was expected as children with FASD tend to have lower IQs than TD children, and was the reason for choosing this matching procedure. In future studies, groups of children with FASD with IQs within the average range could be compared to groups of TD children with IQs in the average range. Children with FASD could also be matched on IQ with TD children. These procedures would be helpful in furthering the understanding of strengths and deficits for children with FASD in general, but would create more challenging recruitment procedures.

With regard to the experimental design, the decision to omit a neutral flanker condition in order to limit the number of trials diminished the ability to disentangle the effect of the mere presence of flankers from facilitation and interference effects.

Conclusions and Future Directions

The children with FASD presented with attention problems based on the behaviour observed by their caregivers. Despite this behavioural presentation, the group of children with FASD generally appeared to be able to focus their attention in the presence of visual distraction in comparison to the group of MA-matched TD children on the relatively simple tasks in this study, when clear and concrete instructions are provided one-on-one within a quiet environment.

Although the children with FASD appeared to filter efficiently for their developmental level as a group, the developmentally older children with FASD did not appear to have the adult levels of visual filtering that were evident for the developmentally older TD children. These findings suggest a specific deficit in visual filtering for children with FASD when the attentional demands of the task are low and the distracters are presented close to the target. Further studies, which include participants with developmental levels of at least 10 years, are needed to confirm this preliminary evidence.

As a group, the children with FASD demonstrated deficits in cognitive control. They appeared to have difficulty switching attentional sets in comparison to the MA-matched TD children in this study, on both the standardized subtests and the experimental task. The children with FASD also demonstrated a weakness in working memory in comparison to the MA-matched TD children, consistent with previous research with other samples of children with PEA.

The performance of the children with FASD was unexpectedly disrupted by the appearance of target-only displays within the context of a mixed block of flanker and no-flanker displays. One of the possible explanations for the increase in RT on target-only displays was that the children with FASD were more affected by the presence of relatively unexpected visual displays than the MA-matched TD children in this study. Further research is needed to investigate this possibility, and to determine if children with FASD remain effective at visual filtering when the distractions are unexpected, which is more consistent with everyday experience. Distractions that occur in the world are not entirely predictable, and if children with FASD are more affected by unpredictable visual information, they would be impacted on a regular basis. This would support the recommendations for decreased distraction and increased consistency for children with FASD (Graefe, 2004; Malbin, 2002).

Both an increase in the attentional demand of the task and an increase in flanker distance in the low attentional demand condition appeared to be helpful for the children with FASD. This may imply that when there are more distractions, as represented by the close flanker condition, an increase in the attentional demands of the task may be helpful. A decrease in the proximity of the distractions, as represented by the far flanker condition, may also be helpful when children with FASD try to focus on a less demanding task.

Nonverbal cognitive level was an important factor in the performance of children with FASD on the experimental visual filtering task in this study, whereas chronological age was not. The matching procedure used in this study appears to be relevant to the study of children with FASD, and could be used in future studies with children with FASD to control for developmental differences among children with FASD.

Original Research Contributions

This research extends the study of PEA and attentional functioning with its emphasis on visual filtering in a clinically well-defined group of children with FASD as compared to TD children carefully matched for developmental level. The children with FASD in this study ranged in MA from 7 to 12 years, and as a group, performed within the average range for their developmental level on the clinical subtests measuring visual focused attention, and similarly to the MA-matched TD children in terms of overall RT, accuracy, and filtering efficiency on the experimental task. However, the developmentally older children with FASD appeared to be less efficient in their visual filtering than the developmentally older TD children, suggesting different developmental trajectories.

Precise matching measures were used in this study to control for the potentially confounding factor of developmental level on attentional functioning. As children with PEA tend to function at a lower developmental level than TD children of the same chronological age, the findings of deficits in previous studies in which the comparison groups were matched on chronological age are difficult to interpret. Thus, the use of MA matching procedures to control for developmental differences in the attentional functioning of children with FASD was a methodological contribution of this study. For the children with FASD, developmental level was correlated with performance on the visual filtering task, whereas chronological age was not, highlighting the importance of developmental level in studying attention and other aspects of cognition among children with FASD.

The findings from this study revealed two main findings that contribute to the empirical literature and highlight further avenues of research. One, the performance of children with FASD on the flanker task was disrupted by the appearance of a target-only display within the mixed block of trials, suggesting that children with FASD are more affected by the presence of relatively unexpected visual information than TD children. Two, the developmentally older children with FASD did not attain the adult levels of visual filtering demonstrated by the developmentally older TD children on the experimental task, further highlighting the importance of developmental level and suggesting deficits in visual filtering for children with FASD. This finding is particularly significant considering the children with FASD were chronologically older than the TD children.

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Appendix A: The 15 Experimental Conditions

	Response Type	Flanker Type	Flanker Distance
1.	Compatible	None-Blocked	-
2.	Compatible	None-Mixed	-
3.	Compatible	Congruent	Close
4.	Compatible	Congruent	Intermediate
5.	Compatible	Congruent	Far
6.	Compatible	Incongruent	Close
7.	Compatible	Incongruent	Intermediate
8.	Compatible	Incongruent	Far
9.	Incompatible	None-Mixed	-
10.	Incompatible	Congruent	Close
11.	Incompatible	Congruent	Intermediate
12.	Incompatible	Congruent	Far
13.	Incompatible	Incongruent	Close
14.	Incompatible	Incongruent	Intermediate
15.	Incompatible	Incongruent	Far

Appendix B: An Example of the Information Form for Caregivers of TD Children

Child's Name: ________________________________

Research Number: ______________

MATCHING INFO ***(for researcher to complete)***

MA: __________________
year:month:day

Gender: ❑ Female ❑ Male

Handedness: ❑ Right ❑ Left

Match: ____________________ **Task Version:** ❑ Incomp ❑ Comp

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Participant Information Form

Typically Developing Children

Child's Date of Birth: ________________________________

Ethnicity: ________________________________

1. Does your child have any attention problems? ❑ Yes ❑ No
2. Does your child have any behaviour problems at home/school? ❑ Yes ❑ No
3. Does your child have any academic problems at home/school? ❑ Yes ❑ No
4. Have you or someone else ever been concerned about your child's development? ❑ Yes ❑ No
5. Was your child exposed to any substances, including alcohol, nicotine, illicit drugs, or prescription drugs/medication, before birth? ❑ Yes ❑ No ❑ Unsure