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Applying gaze-contingent training within community settings to infants from diverse SES backgrounds☆,☆☆

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A B S T R A C T

Even in infancy children from low-SES backgrounds differ in frontal cortex functioning and, by the start of preschool, they frequently show poor performance on executive functions including attention control. These differences may causally mediate later difficulties in academic learning. Here, we present a study to assess the feasibility of using computerized paradigms to train attention control in infants, delivered weekly over five sessions in early intervention centres for low-SES families. Thirty-three 12-month-old infants were recruited, of whom 23 completed the training. Our results showed the feasibility of repeat-visit cognitive training within community settings. Training-related improvements were found, relative to active controls, on tasks assessing visual sustained attention, saccadic reaction time, and rule learning, whereas trend improvements were found on assessments of short-term memory. No significant improvements were found in task switching. These results warrant further investigation into the potential of this method for targeting 'at-risk' infants in community settings.

Research suggests that, by the time children from low socioeconomic status (SES) backgrounds start school, they can show poor performance on a variety of measures of executive functions (EF). These include attention control, which can be defined as 'the capacity to choose what to pay attention to and what to ignore' (Blair & Razza, 2007; Razza, Martin, & Brooks-Gunn, 2010). It has been suggested that attention control can mediate learning and subsequent cognitive development across a range of domains (Cornish, Scerif, & Karmiloff-Smith, 2007; Karmiloff-Smith, 1998), including language acquisition (Rose, Feldman, & Jankowski, 2009), initiating and maintaining social interactions (Mundy, Sullivan, & Mastergeorge, 2009) and learning in academic settings (Welsh, Nix, Blair, Bierman, & Nelson, 2010; see also Scerif, 2010; Wass, 2014). It has even been suggested that EFs may play a protective role in development, such that children with good EFs are better able to compensate for atypicalities in other areas, making them less likely to receive a clinical diagnosis later in development (Johnson, 2012).

Research suggests that, in cases where we want to improve attention control, the earlier the intervention, the greater the potential to effect change (Wass, Scerif, & Johnson, 2012). Neural plasticity is thought to be greatest at very early stages of postnatal development (Huttenlocher, 2002; Spencer-Smith et al., 2011), consistent with how functional patterns of brain activation change with increasing age (Johnson, 2010). In terms of behaviour, Heckman similarly argued that plasticity is greater earlier in development (Heckman, 2006). He maintained that the mastery of skills needed for economic success follows hierarchical rules, with later attainments building on earlier ones (Karmiloff-Smith, 1998; Karmiloff-Smith et al., 2012; Sonuga-Barke, Koerting, Smith, McCann, & Thompson, 2011).

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There is evidence that children from low-SES backgrounds, who often experience impoverished early environments or *in utero* exposure to toxic substances (e.g., drugs, alcohol), show reduced sustained attention and poor attentional control (Hackman & Farah, 2009; Tomalski & Johnson, 2010), and that these difficulties may increase the likelihood of later negative outcomes such as ADHD (Noble, Norman, & Farah, 2005). In particular, being raised in a low-SES context contributes to poor performance in visual attention and novelty detection tasks, accompanied by reduced prefrontal brain activity (Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009). Disparities in SES have also been linked to differences in selective attention to speech, with children from low-SES families showing reduced ability to filter out irrelevant sound streams as well as a reduced response to attended sounds (D'Angiulli, Herdman, Stapells, & Hertzman, 2008; Kaldy & Blaser, 2013). SES-related differences in frontal gamma power have also been identified in infants as young as 6 months of age (Tomalski et al., 2013).

These findings suggest that it may be desirable to investigate the effect of early interventions to strengthen the early development of executive functions within low-SES populations during infancy. Although a variety of parent- and teacher-mediated interventions are available for children of pre-school age and upwards (Thompson et al., 2009), no behavioural techniques have yet been devised for providing training that is directly targeted at infants. In this case, our focus was on computer-mediated interventions, because these have a variety of potential practical advantages over parent- and teacher-mediated interventions. First, if found effective, they can potentially be run with minimal supervision, and in home settings, and therefore can be scaled up at a much lower cost than is possible with clinician-mediated interventions. Second, it is much easier to ensure that paradigms can be administered consistently across multiple sites. Third, more sensitive and rapid criteria can be devised to change task difficulty contingent on performance than is possible with human-mediated interventions. Computerised training techniques also have the long-term potential for integration with human-mediated interventions as part of a multi-component training battery.

A recent review evaluating computerised studies that trained EF across the lifespan reported that very little previous work has attempted to directly target these cognitive functions during infancy – whether in low-SES or other populations; these researchers did note, however, that those studies targeting younger participants tended to report more widespread transfer of training effects, suggesting the possible usefulness of targeting this age range (Wass et al., 2012; see also Diamond, Barnett, Thomas, & Munro, 2007; Wass, 2014). The absence of previous work targeting infant populations is partly due to the methodological challenges involved in recruiting and repeatedly testing children of this age range, and partly due to methodological difficulties in applying training.

Researchers working with infants face the problem of identifying a means by which the individual can interact with a computerised training paradigm, because fine motor skills and action planning are obviously poor at this age (Aslin, 2007). One solution is to use eye-gaze contingent control as the means by which the infant interacts with the training – by using eye-trackers to design training stimuli that change contingent upon where on the screen the infant looks. Using this interface in a lab-based context, Wass and colleagues administered a battery of tasks to typically developing 11-month-olds targeting interference resolution, inhibition, task switching, and working memory for objects embedded in scenes of varying complexity (Wass, Porayska-Pomsta, & Johnson, 2011). An average of 77 min of training was administered over four visits spread over 2 weeks, with the effects of training assessed relative to an active control group. Immediately post-training, increased cognitive control and sustained attention were observed (Wass et al., 2011); attentional disengagement latencies and saccadic reaction time latencies were reduced following training, and a trend emerged in changes in looking behaviour during free play. No changes were found in working memory.

Thus, it seems that the practical problems of delivering a form of training that can engage infants in contingent training can be overcome by using eye-tracking and has clear potential. However, another problem in effectively applying this approach is that laboratory-based studies tend to recruit less diverse and less representative samples, consisting predominantly of infants from families with higher SES (Henrich, Heine, & Norenzayan, 2010). To surmount this, one potentially fruitful approach is to take eye-tracking equipment out of the lab and into child care centres that enrol primarily low-SES infants. In the UK, early intervention centres are called Sure Start Children's Centres (CCs), which were created for this purpose in 1998 in recognition of the importance of investing in universal early education, particularly for low-SES populations (Guidance, S. S. C. s. C. S., 2013). CCs are mostly found in low-income areas, with high indices of multiple deprivations (Government, D. f. C. a. L., 2010; Noble, Mclennan, & Wilkinson, 2010). They are closely linked with their communities, and specifically tasked with helping parents with children under five. The Sure Start programme is comparable to the American Head Start programme and, for example, to the Ontario Early Years Plan approach in Canada, the recently created Biztos Kezdeta in Hungary, and to approaches recently created in Australia. CC environments, although not as controlled as lab-based testing settings, are likely to be better controlled than the home, with the researcher able to set up in a dedicated room in advance of testing, and to test in a single day a cluster of infants, under similar conditions.

In this study, we assessed whether training paradigms previously employed in lab settings could be successfully administered in CCs, within community settings. We had two goals:

1. To explore whether working in CCs facilitated recruitment of participants from diverse backgrounds, and whether weekly scheduling of training proved manageable for these parents and infants.
2. To test whether training effects observed in the lab could also be demonstrated in a community setting.

The study design was closely based on that used by Wass and colleagues (Wass et al., 2011). The training stimuli used, and three of four pre–post assessments, were identical to those used in this lab-based study. Participating parents and infants attended sessions once a week as part of a scheduled weekly drop-in. As with the previous lab-based study, approximately half of the infants in the current study underwent training. The other half was assigned to an active control group, who attended an equal number and duration of sessions, but instead of training watched infant-appropriate animations and TV clips on the eye-tracker monitor. Assessment of training effects was analysed in-task. Transfer of training effects was also assessed using pre–post assessments involving non-trained tasks examining aspects of attention control – namely visual sustained attention, saccadic reaction time latencies, attentional disengagement latencies, anticipatory saccades during rule learning, and short-term memory. Although these tasks differ in task paradigm, their unifying feature is that they all require infants to exercise endogenous (effortful) control over the focus of their visual attention (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; see also Colombo & Cheatham, 2006). We predicted that, as in the previous lab-based study, training attention control would lead to an improvement in performance on these non-trained attention control tasks from pre- to post-training periods.

Methods

Participants

Infants were recruited by CC staff through phone calls, flyers, and advertisement of our 'Learn about your baby' sessions in their quarterly calendars. Parents were either contacted by CC staff, or contacted the Centre or researcher directly, to book an appointment (further details on the set-up and recruitment in CCs are given in Ballieux et al., in