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Abstract

Older children, but not younger children, were found to look away more from the face of an interlocutor when answering difficult as opposed to easy questions. Similar results were found in earlier work with adults, who often avert their gaze during cognitively difficult tasks (A.M. Glenberg, J.L. Schroeder, & D.A. Robertson, 1998). Twenty-five 8-year-olds and 26 5-year-olds answered verbal reasoning and arithmetic questions of varying difficulty. The older children increased gaze aversion from the face of the adult questioner in response to both difficult verbal reasoning questions and difficult arithmetic questions. In contrast, younger children (5-year-olds) responded less consistently to cognitive difficulty. It is concluded that adultlike patterns of gaze aversion in response to cognitive difficulty are certainly acquired by 8 years of age. The implications of appropriate gaze aversion for children's management of cognitive resources are considered.

During difficult cognitive activity, for example remembering information, thinking of an answer to a question, planning what we are going to say, and speaking, we often close our eyes, look up at the sky, or look away from the person we are in conversation with. A number of studies, described below, report ways in which adults switch off from environmental stimulation (both live faces and other sorts of visual displays) in order to concentrate on cognitive tasks. In contrast, there has been little done on gaze aversion as a response to cognitive demands in children. This is a potentially important omission since the efficiency with which children process information influences many aspects of their development, including school progress. This article reports a study of gaze aversion in two age groups of children. In our introduction we first look at the evidence linking visual communication signals and cognitive effort. We then discuss why children might differ from adults in their strategies to deal with this cognitive effort. The final section of the introduction describes the motivations behind the current study.

Visual Communication Signals and Cognitive Effort

Considerable research effort has been expended on examining the role played by visual communication signals in human interaction. There is much evidence that visual communication signals (such as eye gaze, gesture and facial expression) are often important sources of information. Indeed many researchers propose that such signals play a facilitatory role in human communication (for example, Clark & Brennan, 1991; Goldin-Meadow, Wein, & Chang, 1992; McNeill, 1985). However, the fact that such signals are informative means that they carry a cognitive load. The processing costs of visual signals are documented. A number of researchers have linked excessive eye gaze with increased cognitive load on interlocutors (Beattie, 1981; Ellyson, Dovidio, & Corson, 1981). In addition, the cognitive difficulty of a task seems to relate to the likelihood that people avert their gaze from other people's faces and this aversion typically improves accuracy of response (Glenberg, Schroeder, & Robertson, 1998). These sorts of studies have motivated what has been called the 'cognitive load hypothesis' of gaze aversion. In other words we avert our gaze at critical points within a task or interaction to avoid processing of unnecessary, distracting or arousing visual cues from our environment.

Glenberg (1997) proposed a model of cognition in line with the cognitive load hypothesis. He suggested that the cognitive system is normally "clamped" to the environment, and so we are constantly processing environmental events. However this only accounts for part of human cognition. Engaging in other significant human cognitive activities, such as language comprehension, requires that we disengage from the flow of environmental information. Similarly, Glenberg et al. (1998) suggested that averting eye gaze helps people to disengage from environmental stimulation and thereby enhanced the efficiency of cognitive processing directed by non-environmental stimulation. Glenberg et al. (1998) proposed that while some tasks e.g., naming or object recognition tasks may be facilitated by environmental cues, conceptually driven tasks (e.g., mental imaging; remembering) will be hindered. It was proposed that visual access to one's interlocutor provides <u>one</u> source of environmental stimulation, that may interfere with the accomplishment of certain tasks. Glenberg's account of gaze aversion can therefore be seen as one version of a 'cognitive load' model of gaze aversion- we avert our gaze, in part, to control the amount of potentially distracting environmental information we are processing when cognitive resources are required for other tasks which do not involve environmental input. Furthermore, Glenberg et al. (1998) report that adults avert their gaze away from both live human faces, and from questions printed on a computer screen, when answering difficult questions. This suggests an automatic tendency to reduce the flow of any distracting environmental information during cognitively difficult activity.

So is there anything especially distracting about faces? There is evidence that faces are indeed a particularly important source of visual stimulation. A number of authors have argued that there is an innate and involuntary tendency to orient to social signals, such as faces, facial expressions and eye gaze (Langton, O'Malley, & Bruce, 1996). Furthermore, cues from faces are difficult to ignore, and when task irrelevant can interfere with performance (Langton, 2000; Langton & Bruce, 2000). One set of studies demonstrated that participants' responses to spoken directional words were affected by the presence of mismatching (to-be-ignored) pointing gestures, gaze cues, or head direction cues presented on a computer screen (Langton et al., 1996; Langton, 2000; Langton & Bruce, 2000). Other experiments have shown that a shift in another's gaze and/or head orientation triggers a reflexive shift in an observer's visual attention, even when observers are instructed to ignore the cues (Langton & Bruce, 1999; see also Driver et al., in press). Furthermore, Russell and Lavie (2001) report an advantage of faces over other visual objects when observers are trying to detect changes in visual displays in 'change blindness' paradigms. They conclude that faces have a special role when in competition for visual attention and that this supports previous claims that human faces are processed differently than stimuli of less biological significance. This literature suggests that human faces are not only a rich source of information, but also one that we are typically drawn to and that provides cues that are very difficult to ignore.

Switching off from environmental stimulation (sometimes other people's faces) is documented in real world situations. Feyereisen and Lignian (1981) investigated gaze behaviour in normal and aphasic speakers. They found evidence that gaze avoidance reflects difficulty with verbal encoding. Both Meskin and Singer (1974) and De Gennaro and Violani (1988) found that difficult memory questions produced more frequent eye movements than questions involving less extensive memory search. Similarly, the perceived importance of gaze aversion for accurate memory recall is exemplified in Fisher and Geiselman's (1992) recommendation that a witnesses' eyes should be closed as part of cognitive interviews used for eye witness testimony.

Looking away from faces may reduce cognitive load in general. There is also evidence that sometimes the reduction of processing load is more specific. One way in which visual communication signals may increase cognitive load is by increasing demands for visuospatial processing resources. Ozols and Rourke (1985) proposed a link between visuospatial processing problems and problems of processing visual-perceptual communicative information such as facial expressions and gestures etc., and suggested that the processing of visuospatial information and nonverbal communicative signals are related. It may be that these are linked by common neurological structures or perhaps by common underlying cognitive processes such as pattern recognition. Consistent with this are results described by Hanley, Young and Pearson (1991) reporting on patient ELD. From her pattern of deficits and abilities on visuospatial and verbal tasks, patient ELD illustrated the distinction between the visuospatial sketchpad (VSSP) and the phonological loop in working memory: ELD had deficits in VSSP while retaining an intact phonological loop. In addition to her impairment in VSSP, ELD was impaired on some tasks of face processing, suggesting a common substrate for social and non-social visuospatial processing. Similarly, Goldin-Meadow (2000) proposes a link between the processing of hand gestures and the visuospatial sketchpad. In addition, she proposes that while gesturing often has processing benefits (by distributing cognitive load across both verbal and visuospatial processing resources), it may in certain circumstances (e.g., if it is task irrelevant) interfere with performance on other visuospatial tasks. Thus there are different of sources of evidence that suggest that the processing of visual communication signals may be related to other types of visuospatial processing. However gaze aversion occurs in response to many types of cognitive tasks. Furthermore, we avert our gaze, not only from faces, but from any potentially distracting source of visual stimulation (Glenberg et al., 1998). Gaze aversion therefore is not related entirely to a reduction in visuospatial processing demands, and may function to reduce cognitive load in more general terms also.

It must be noted that not all researchers agree with the 'cognitive interference' hypothesis of gaze aversion. Beattie (1981) suggests that the cognitive load hypothesis is difficult to reconcile with the fact that adults are very good at dual-tasks and selectively attending to relevant stimuli. As an alternative, Beattie suggests that continuous gaze between adults interferes with task accomplishment because it produces increased physiological arousal which in turn influences cognitive processing. In other words, we gaze away from interlocutors' faces when doing demanding tasks, not because information from faces produces an increased cognitive load, but because mutual gaze between people results in physiological changes that can influence cognitive functioning negatively.

A very different approach to gaze aversion is offered by Ehrlichman (1981). He found no evidence of cognitive interference during continuous gazing at a face on a screen. He proposed that the patterns of gazing during conversation (particularly more gazing while listening than while speaking) reflect two opposing tendencies. First, gazing at an interlocutor, while speaking, is less frequent not because of the cognitive load of processing visual information from that person, but because there is a tendency to make saccadic eye movements during thinking and speaking. This tendency is opposed by the suppression of such eye movements during listening in order to monitor the other's (speaker's) facial expressions. Ehrlichman's study used a screen-based image of the interlocutor's face and it is likely that exposure to this differs in important ways compared with exposure to a live face (Beattie, 1981). Furthermore, the same pattern of aversion while speaking in comparison to listening is reported by Kendon (1967), with a very different interpretation placed upon it. He proposed that gaze aversion while speaking serves as a turn holding cue signaling the speaker's intention to continue. When a speaker looks at their listener this is interpreted as a turn yielding cue meaning that they are ready to listen. In other words patterns of gaze and gaze aversion also function as conversational cues to facilitate interaction management.

Patterns of gaze and gaze aversion in interaction therefore serve a number of different functions. The view taken in the current paper is that gaze aversion is at least partly related to control of cognitive load. Furthermore this is important for children as well as adults. One reason we have taken the cognitive load approach are the results of a number of studies where we have found cognitive interference associated with face-to-face contact in children.

Children's Strategies

While gaze aversion is reported occurring in adult interactions as a strategy for avoiding cognitive overload, no research has indicated if such phenomena occur in children. Glenberg et al. (1998) proposed that disengaging from environmental stimulation is a skill that is learned. In addition, children may be particularly dependent upon non-verbal signals in their communication. Doherty-Sneddon and Kent (1996) report that young children rely on visual communication to support their relatively poor language. This might mean that they will be less likely to avert gaze from an interlocutor. In support of this, Doherty-Sneddon (1995) found that pairs of 6- and 11-year-olds gazed at one another more than pairs of adults when doing collaborative communication tasks. In other words they averted their gaze less often. In that particular study the increased gazing seemed to reflect an greater reliance on visual signals to complete the communication task in hand and was not detrimental to performance.

In a recent study we investigated children's communication abilities in face-to-face and audio-only interaction using a communication task called the shape description task (Doherty-Sneddon et al., 2000). In the shape description task children attempted to describe and to understand descriptions of complex, abstract shapes. Such a task required that the information sender scrutinise the shapes for distinctive visual properties, and the information receiver built a visual representation of the described shape over time, sufficient to select the correct target shape from distractors. The results revealed that children performed less well when they could see one another than when they could not. Doherty-Sneddon et al. (2000) proposed that the processing demands for both partners were such that visual signals from the face-to-face communicative context interfered with performance on the task. This supported the argument that, in certain tasks, visual communication signals might interfere with task demands. If this interpretation is correct, the results suggest that the children were not 'switching off' effectively from their partner's visual signals at the appropriate times.

Furthermore, the literature on the development of attentional strategies is relevant to the question of how gaze aversion develops, since gaze aversion is an overt strategy for shifting one's attention from environmental stimulation (in this case an interlocutor). A vast literature has shown that older children are better than younger children in tasks that require the ignoring of irrelevant information (for reviews see Enns, 1990; Shepp, & Barrett, 1991). Pearson and Lane (1991) found age-related improvements between 8 years and 11 years in attention-shifting (auditory stimuli). Age-related improvements also occur in primary school-aged children in the visual domain (e.g., Enns & Girgus, 1985). We therefore expect that gaze aversion, as a strategy to shift attention, will develop with increasing age.

Introduction to Current Studies

Here we investigate whether children engage in gaze aversion in response to the cognitive difficulty of tasks they are performing. We have investigated the gaze aversion behaviour of 8- and 5-year-olds. We predicted that the younger children would not adjust their gaze aversion in response to cognitive difficulty of questions asked of them. There are a number of studies in the literature that suggest that support this prediction. These studies investigated children's social understanding of gaze and gaze aversion, and to their understanding of how gaze aversion in others relates to underlying cognitive activity (e.g., Baron-Cohen & Cross, 1992). However, certain gaze aversion behaviours develop from a very early age. Aversion behaviour in response to social stimuli is reported in infants who often break mutual gaze with their caregivers during interaction (Bruner, 1977). It has been suggested that this relates to arousal control- mutual gaze produces increased physiological arousal in infants and they break mutual gaze in order to reduce the level of arousal once it reaches a certain point (Stern, 1977; Beattie, 1981). These findings suggest that from an early age gaze aversion is a mechanism with which children control their own internal states.

In the current work a direct developmental comparison is carried between older and younger children. This is possible since they completed very similar (age appropriate) tasks. The 5-year-olds were the youngest children we could use who could do similar arithmetic and verbal tasks to those completed by the older children. We make no strong predictions regarding how the different question types we used will influence gaze aversion behaviour, except that if gaze aversion serves to reduce a particularly visuospatial cognitive load, then stronger effects will be found with arithmetic tasks compared with the verbal reasoning. There is some related literature that links type of cognitive task with gaze aversion. This has investigated whether the direction of laterality of the aversion shift changes with particular types of tasks. Initial work seemed to show that direction of eye movements tended to be contralateral to the cerebral hemisphere activated by the cognitive task. Some verbal tasks (typically left hemisphere) produced eye movements to the right, while spatial tasks (right hemisphere) produced leftwards eye movements. However the results of this literature are very mixed, the contralateral pattern is typically only found in around half the studies reported (see De Gennaro & Violani, 1988, for a review). We decided to include two different question types in order to gauge the generality of the effect of cognitive difficulty, rather than to make specific claims about differences in aversion behaviour between different task types.

The hypotheses are that:

- Older children will, like adults, increase the amount they avert their gaze as cognitive difficulty of all question types increases.
- Younger children will avert their gaze during cognitively difficult questions less consistently. This may result for a number of different reasons: they have less well developed attention shifting strategies; or because of the different social functions of gaze for young children.
- In both age groups most gaze aversion will occur while thinking, since thinking about the problem will be the most demanding part of the trial resulting in the highest amount of gaze aversion. In addition we predict there will be relatively more aversion while speaking compared with listening perhaps because of the cognitive demands of speech planning or because of the use of gaze as an interactional cue (Beattie, 1981; Kendon, 1967). This may not occur for the younger children since the use of gaze as a turn-yielding cue develops with increasing age (Levine & Sutton-Smith, 1973).

Gaze Aversion and Task Difficulty: 8- and 5-year-olds

The aim of the study was to investigate whether there would be a developmental difference between younger and older children in their use of gaze aversion as a response to increasing difficulty of questions asked of them. Five-year-olds were chosen as the younger age group since they have already begun formal school education. This meant that questions similar to those used with the 8-year-olds (although simpler) could be devised, allowing a direct developmental comparison to be made between the age groups.

Method

Participants

Twenty-five (9 males 16 females) 8-year-olds took part in the study, the mean age for the participants was 8 years 9 months (range, 7 years 10 months-8 years 10 months). Two children were taken out of the sample due to technical faults at recording and a third as English was not his first language. This left a sample of eight male and fourteen female 8-year-olds. Twenty-six 5-year-old children participated (15 girls and 11 boys). The mean age was 5 years and 8 months, ranging from 5-years and 3 months to 6 years and 4 months.

Tasks

The questions posed to the children were taken from a variety of sources. The majority of the questions were taken from the WIPPSI and BPVS IQ scales for children. Questions were also based on school books from the target age group and also 6- and 10-year-olds. The questions were either verbal or arithmetic and rated as being either easy or hard. This rating was deemed to be appropriate, through the sources used, but also from consultation with the participant's teachers, who confirmed these ratings to be fair. The verbal questions required the children to either, define words, spell words or repeat word lists. The mental arithmetic questions involved adding, subtracting and multiplication. Some differences were made to the questions given to the 5 and 8-year-olds to make the specific questions age appropriate. For example the older children did arithmetic questions involving addition, subtraction, multiplication and division. The younger ones were only asked to solve addition and subtraction problems. Items used are listed in appendix 1. At the time of testing all the youngest children had been at school for 10 months and class teachers judged the different levels of question difficulty to represent items that the children should get correct most of the time (easy) and around 30%-50% of the time (difficult).

Design

The study was a mixed design. Question difficulty was a within-subjects variable with each participant tested in the easy and difficult versions of each question type. The order of the question types and individual questions were counterbalanced across participants. Age was a between-subject variable.

Procedure

The children were taken individually to a quiet room and asked the questions. This took around ten minutes for each child. The children's faces were video recorded. The camera was positioned to get a front-on shot of the child. The camera shot was set to view the child's head and shoulders. This was consistent across conditions and age groups ensuring that image size was equivalent throughout the study. The participants were unaware that their eye contact was being recorded and were not requested to maintain gaze in a specific area. We wanted to investigate the children's spontaneous gazing behaviour when they were given no explicit instruction relating to this. The investigator maintained gaze throughout.

The dependent measures were the mean percentage of time that gaze was averted during each question type and accuracy of response. The amount of time gaze was averted was measured from when the experimenter started speaking until the child stopped speaking and included pauses, hesitations and requests for the question to be repeated. This was converted to a percentage of the time spent averting gaze during listening to the question, thinking about the response, and speaking the response.

An inter-judge reliability was performed on a random sample of the gaze aversion measurements from the video recordings. This included all of the listening, thinking and speaking aversion scores for each of the question types for 17% of the children in the sample. In total 457 episodes were coded by both judges. The original coding classified 160 (35%) of these to include gaze aversion. The second judge agreed with 92% of these classifications. Furthermore the coders' scoring for the duration of gaze aversion correlated significantly, r (456) = .847, $p < .01$.

Results

The effects of task difficulty on the percentage of time gaze was averted were analysed separately for the mathematical and verbal questions as follows.

Arithmetic Questions

More gaze aversion occurred during the hard versus easy questions. See table 1 for means. A 3-way anova was carried out with task difficulty (2 levels: easy and hard) and episode (3 levels: listening, speaking and thinking) within-subject variables. Age was a between-subject variable. Task difficulty had a significant effect on gaze aversion with more aversion occurring in response to difficult questions, F (1,46) = 20.1, $p < .001$ (mean easy = 41.4%; mean hard = 49.8%). Episode also had a significant effect on gaze behaviour with most aversion occurring while children thought of their responses (mean listening = 26%; thinking = 76%; speaking = 32%), F (2,92) = 92.8, $p < .001$. Age had a significant effect on gaze aversion, with older children averting their gaze more than younger children, F (1,46) = 10.1, $p < .01$ (mean 5 years = 39%; mean 8 years = 52%). There was a significant interaction between age and question difficulty, F (1,46) = 10.2, $p < .01$. Simple effects analyses showed that only the older children averted their gaze more during the difficult questions, F (1,21) = 19.37, $p < .001$. There was also a significant interaction between age and episode, F (2,92) = 24.0, $p < .001$. This resulted because of a higher level of aversion during speaking for the older children in comparison with the younger children (mean 8 years = 58%; mean 5 years = 14%). The effects of episode, age and task difficulty interacted, F (2,92) = 4.42, $p < .05$. Simple effects analyses on the older children's data revealed that aversion behaviour changed across task difficulty during speaking and thinking (F (1,21) = 13.65, $p < .001$; F (1,21) = 13.41, $p < .001$ respectively). No such changes occurred when children were listening to the question, during which aversion rates were low. Rates of gaze aversion did not change across task difficulty for the younger children.

Responses by the older children to easy questions were more accurate compared with difficult ones, t (21) = 11.43, $p < .001$ (mean easy = 94.5%; mean hard = 30.4%). Overall frequency of gaze aversion and response accuracy did not correlate. However there was a positive correlation between gaze aversion during listening to the easy versions of the arithmetic questions and accuracy of response, r (22) = .37, $p < .05$. Children therefore were more likely to get the answer correct if they averted their gaze while listening to the question. This was not the case for the harder arithmetic questions. In fact, there was a negative correlation between level of gaze aversion while *thinking* of a response to the hard questions and accuracy, r (22) = -.44, $p < .05$. These opposing valences of correlations make sense. When the arithmetic questions are easy, averting gaze while *listening* to the question helps the children concentrate and provides a functional benefit. When the questions are hard the children are more likely to avert their gaze while *thinking* about their response and this seems to reflect the difficulty they are having with the question, and hence they are still more likely to answer incorrectly.

The younger children were also more likely to answer the easy questions correctly than the harder ones (mean easy = 67%, mean hard = 36%), t (25) = 4.82, $p < .001$. The percentage accuracy on the difficult questions for the 5-year-olds is therefore comparable to that of the 8-year-olds. In contrast, the

5-year-olds performance on the easy questions was lower than that of the older children (95%). It might therefore be argued that gaze aversion didn't change across difficulty for the 5-year-olds because their 'easy' questions were relatively difficult resulting in correspondingly more gaze aversion in this condition. The means in table 2 show that this is not the case. Percentage aversion during easy questions is very similar in both age groups. The 5-year-olds simply do not increase this level when questions get harder. There was a negative correlation between performance on the hard questions and overall gaze aversion r (26)= -.47, $p < .01$. So the more the younger children averted their gaze on the harder questions the more likely they were to get the answer wrong.

Verbal Questions

More gaze aversion occurred during the hard questions compared with the easy ones. See table 1 for means. A 3-way anova was carried out with task difficulty (2 levels easy and hard) and episode (3 levels: listening, speaking and thinking) within-subject variables. Age was a between-subject variable. Task difficulty had a significant effect on the amount of gaze aversion that occurred with more aversion occurring during the difficult questions, F (1,46) = 22.84, $p < .001$. Age also had a significant effect on aversion behaviour with younger children averting less than the older ones, F (1,46) = 9.4, $p < .01$ (mean 5 years = 39.8%; mean 8 years = 53.4%). There was also a significant interaction between age and task difficulty, F (1,46) = 4.79, $p < .05$. Simple effects analysis revealed a much stronger influence of task difficulty for the older children, F (1,21) = 20.90, $p < .001$, compared with the younger ones, F (1,25) = 4.56, p<.05. Episode also had a significant effect with most aversion occurring while children thought of their responses, followed by speaking then listening, F (2,92) = 89.3, $p < .001$ (mean thinking = 72.2%; speaking = 40.3%; listening = 23.9. Finally there was a significant interaction between episode and age, F (2,92) = 15.12, $p < .001$, and a 3-way interaction between task difficulty, episode, and age F (2,92) = 5.26, $p < .01$. Post-hoc t-tests revealed that more gaze aversion occurred while listening to and thinking about difficult questions compared with easy questions (t (25) = 2.0, p = .06; t (25) = 2.1, $p < .05$, respectively) for the younger children. The older children averted their gaze more while thinking about and speaking their responses to harder questions compared with easier ones, (t (21) = 2.74, $p < .01$; t (21) = 4.10, $p < .001$, respectively). Patterns of change across difficulty are therefore similar between age groups for thinking, but different for listening and speaking.

For the older children responses were more accurate to easy questions compared with difficult ones, t (21) = 12.91, $p < .01$ (mean easy = 96.5%; mean hard = 58.8%). Overall levels of gaze aversion and performance score correlated negatively for the easy verbal questions, r (22) = -.536, $p < .01$. Therefore on the easy questions children gave less accurate responses when they averted their gaze more. No correlation was found for the harder questions.

The 5-year-olds also answered more easy questions correctly than difficult ones t (25) = 15.5, $p < .001$ (mean easy = 80%, mean difficult = 31%). The performance on the easy questions was high as it was for the older children. The harder questions are relatively more difficult for the 5-year-olds. No correlations between performance and levels of gaze aversion were found for the younger children.

The older children averted their gaze more frequently when answering difficult questions. This was the case for both verbal and arithmetic questions. This was particularly so when they were thinking about their responses.[1] In addition even children as young as 5-years of age increase their gaze aversion in response to cognitive difficulty, but only for certain types of questions. No significant effect of question difficulty was found for the arithmetic questions but it was for the verbal questions. This supports the second hypothesis that younger children would be less consistent in their use of gaze aversion as an overt response to cognitive difficulty. This may occur for a number of different reasons: they may have less well developed attention shifting strategies that are therefore less consistently applied; or perhaps the results were due to the different ways that gaze functions for young children combined with certain expectations they had of the adult in the questioning scenario.

Certainly gaze aversion in these age groups is a good indicator that the child is thinking. If gaze aversion does not increase during demanding questioning it may reflect that the child has simply given up and is not engaged in processing the necessary information to answer the question.[2]

Discussion

Children at 8 years of age increased the frequency with which they averted their gaze from a questioner's face as questions became harder. This was found with both verbal and arithmetic questions. It was concluded that children of this age use gaze aversion to control their cognitive load in a similar way to adults, supporting the first hypothesis. This is potentially important for the way children are seen to engage in learning situations. There is a tendency in many cultures to encourage children to 'look at me while I'm speaking to you,' and to interpret looking away as a sign of disinterest or disengagement.

What the current research clearly shows is that primary school aged children use gaze aversion to help them concentrate on difficult material. Therefore, provided the aversion is appropriately timed within the interaction, it is something to be encouraged rather than discouraged. These findings may be applied to educational settings. Preliminary work at Stirling (Longbotham, 2001) suggests that gaze aversion by 6-year-olds can be used as a cue to whether they are in their zone of proximal development (Vygotsky, 1934). If this is substantiated gaze aversion will be a useful cue that teachers and parents would be able to use to judge children's 'readiness to learn'.

The second hypothesis was also supported. The 5-year-old children were less consistent in their response to cognitive difficulty of questions. A significant effect of difficulty was only found for verbal questions with the 5-year-olds. So even by this age, children do not consistently increase gaze aversion in response to cognitive demands. In addition the effect was weaker than that found for the 8-year-olds. The 5-year-olds increased aversion while thinking of their responses to difficult verbal questions but not while speaking their responses, in the way that the 8-year-olds did. So gaze aversion in response to difficult questions is a skill that develops with age, rather than being an innate behavioural response to questions. Furthermore the younger children generally averted their gaze for a lower proportion of time than the older children. This suggests a higher reliance on visual cues at lower ages.

Therefore while certain gaze aversion behaviours appear to be innate, for example young infants break mutual gaze with their caregivers during interaction (Bruner, 1977) perhaps as an arousal control mechanism, averting gaze as an attention shifting strategy seems to be something that develops throughout early childhood. This was as expected for a number of reasons: first the age related improvements that occur in primary school-aged children in attention shifting in the visual domain (Enns & Girgus, 1985); and second, the developing understanding of eye gaze in social terms that occurs throughout infancy, pre-school and early primary school years.[3]

The third hypothesis, that gaze aversion would be higher during thinking and speaking compared with listening, is supported in the data from the older children. This suggests that the 8-year-olds attend fairly closely to the questioner while listening to the question, but then avert their gaze while preparing and delivering their response. The 5-year-olds showed a similar peak in aversion during thinking, but their aversion levels were rather low while speaking their responses. So a relatively high amount of gaze aversion is a good indication of thinking from the age of 5 years.

Another important question is whether the gaze aversion observed with the older children plays a functional role in their performance. In other words did increasing aversion allow better concentration on the task and therefore more accurate responses? The general lack of positive correlation between accuracy of responses and gaze aversion suggests that it did not. However, as Glenberg et al. (1998) argue, such correlational analyses cannot be used to judge the functional significance of gaze aversion. The reason for this is that if looking away is an index of difficulty (as we are proposing), then the children look away when questions are particularly difficult for them. Although this may help, we cannot know whether the extent that it helps supersedes the extra difficulty of the question. Other recent work that we have done gives independent evidence that gaze aversion may help children in certain tasks. For example Doherty-Sneddon, Bonner, and Bruce (2001) found that children performed better on visuospatial memory tasks when they looked at the floor, during a retention interval, compared with when they looked at an experimenter's face. This suggests that when a task involves e.g., mental imaging, looking away may be beneficial. This is in agreement with Glenberg et al. (1998) who found that adults' recall of general knowledge questions and solving of mathematics problems was more accurate when they closed their eyes than when they looked at the questioner.

This paper adds significant information to what we know about how visual communication signals function in children's cognition. Many studies have shown the informational significance of visual cues such as hand gestures, eye gaze and facial expression (Goldin-Meadow et al., 1992; McNeill, 1985). Indeed such cues provide a rich source of information to adults and children alike and often produce significant communication benefits (Boyle et al., 1994; Doherty-Sneddon & Kent, 1996). The authors' more recent work, and that of others, is now showing the importance of considering the processing *consequences* of this information. Doherty-Sneddon et al. (2001) have shown that monitoring a questioner's face can interfere with the processing of visuospatial information. Similarly Goldin-Meadow (2000) proposes that while gesturing often has processing benefits (perhaps by distributing cognitive load across both verbal and visuospatial processing resources), it may in certain circumstances (e.g., if it is task irrelevant) interfere with performance on other visuospatial tasks. The fact that gaze aversion occurs in response to both difficult verbal and arithmetic questions, suggests that it is not only related to a reduction in visuospatial demands. Instead, gaze aversion appears to function to reduce cognitive load in general.

The current studies showed that middle primary school aged children avert their gaze when asked difficult questions. This shows an overt mechanism for controlling their level of cognitive load. In contrast early primary school children show less consistent evidence of this and indeed may be more inclined to look to the questioner for help when in difficulty. Indeed, this is likely to be an important cue that helps adults provide additional help or scaffolding to young children (Wood, Bruner, & Ross, 1976). It is therefore likely that gaze aversion, as a cognitive load control mechanism, is something that develops throughout the early primary-school years. Furthermore, with older children the relative demands placed upon them across a question episode (listening, thinking and speaking) are also reflected in their gaze aversion behaviours in a way that is not as evident with younger children. As a cue to cognitive demands (both within question episodes and across task of differing difficulty), gaze aversion is therefore most reliable with older children. This may reflect different approaches older children make to problem-solving and strategies they use to cope with cognitive demands.

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Appendix

Questions used (different questions given to the 8-year-olds are in brackets)

Verbal Questions

1. Definition/vocabulary (the items listed are simulated items from WPPSI; there were 3 easy and 3 hard in the test used)

I want to see how many words you know.

	Easy	Hard
What is a/does a …… mean:	glove	telescope

2. Spelling

I want to see if you can spell the following words.

Easy	Hard
Mat (ball)	Chin (elephant)
Car	Chick (mountain)
Sat (book)	Sheep (school)

3. Word list recall

I'm going to say a few words. I want you to repeat them back to me. So try your best to remember the words I say.

Easy	Hard
Dog, car, bed	kangaroo, glue, plant, triangle
Juice, eye, hat	holiday, lion, broccoli, taxi
Girl, ball, book	cupboard, brown, grape, jelly

4. Information, similarities (the items listed are simulated items from WPPSI; there were 3 easy and 3 hard in the test used)

Easy	Hard
How many wings does a bird have?	What is pepper?
In what way are a lion and a tiger alike?	In what way are an hour and a week alike?

Arithmetic

Easy	Hard
1. Count to 10 {to 20}	Count from 10 to 20 {backwards from 20}
2. 3+2= {5+5}	2+8= {371+24}
3. 2-1= {8-4}	9-6= {(8x4)-8x3)=}
4. If you have 3 apples and Your friend gives you 1 more How many apples do you have? {If John has 8 sweets and Sarah has 9 who has more?}	If there are 4 people sitting in a room and another 5 people come in, how many people are there altogether? {How many stamps can be bought for 45p if a packet of 4 costs 5p?}
5. If you have 3 biscuits and you give 1 to your friend, how many do you have left?	There are 9 children. One of them has a bag of sweets. There are 5 sweets. How Many children will not get a sweet?
6. 2+2 =	4+6 =
7. 4-1 =	10-7 =

Table 1

Percentage Time Gaze Aversion: 8- and 5-Year-Olds

		Overall	Listening	Thinking	Speaking
Arithmetic (8-yrs)	Easy	43	23	66	47
	Hard	64	22	88	68
Arithmetic (5-yrs)	Easy	38	27	73	13
	Hard	40	30	77	14
Verbal (8-yrs)	Easy	45	23	72	51
	Hard	58	25	81	68
Verbal (5-yrs)	Easy	38	25	65	25
	Hard	41	29	72	23

Table 2

Percentage Accuracy of Responses to Different Question Types Across Age Groups

	Verbal questions		Arithmetic questions	
	Easy	difficult	Easy	Difficult
8-years	97	59	95	30
5-years	80	31	67	36

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Footnotes

1. The authors have some anecdotal evidence that when 6-year old children (not involved in the current studies) deliberately try not to avert their gaze, when thinking about questions, they still do. In one incident a 6-year old boy was posing for some publicity shots for an exhibition about the research. The first author explained to him that often people look away when asked difficult questions and we wanted a photograph of him doing just this. He adamantly claimed that he never looked away under these circumstances, and was surprised with himself when the questioning session began and he engaged automatically in classic gaze aversion.

[2.] Some preliminary work we have done supports this idea. In a study of scaffolding 6-year olds through understanding arithmetical concepts, we found that gaze aversion was lowest when they consistently gave incorrect responses (i.e., they did not understand enough to begin to work out the problem correctly). The amount of gaze aversion increased dramatically (from 20% to 47%) when the children began giving partially correct responses. Once they fully understood and were able to give consistently correct responses their gaze aversion reduced (to 32%) but was still significantly higher than the level found during incorrect responding. We interpret this to mean that gaze aversion reflects cognitive effort and engagement on task (Longbotham, 2001).

[3.] In support of this, other related work carried out by the authors showed that when questions are very difficult for preschool children, they typically look at the questioner rather than away, perhaps as a way of eliciting further help and support, as they would normally expect from an adult.