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Cognitive demands of face monitoring: Evidence for visuospatial overload

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Young children perform difficult communication tasks better face to face than when they cannot see one another (e.g., Doherty-Sneddon & Kent, 1996). However, in recent studies, it was found that children aged 6 and 10 years, describing abstract shapes, showed evidence of face-to-face *interference* rather than facilitation. For *some* communication tasks, access to visual signals (such as facial expression and eye gaze) may hinder rather than help children's communication. In new research we have pursued this interference effect. Five studies are described with adults and 10- and 6-year-old participants. It was found that looking at a face interfered with children's abilities to listen to descriptions of abstract shapes. Children also performed visuospatial memory tasks worse when they looked at someone's face prior to responding than when they looked at a visuospatial pattern or at the floor. It was concluded that performance on certain tasks was hindered by monitoring another person's face. It is suggested that processing of visual communication signals shares certain processing resources with the processing of other visuospatial information.

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 (like eye gaze, gesture, and facial expression) are often important sources of information. Indeed, many researchers have proposed that such signals play a facilitatory role in human communication (e.g., 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. For example, 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 (Glenberg, Schroeder, & Robertson, 1998). This paper addresses the impact of processing facial information on the accomplishment of referential communication and on visuospatial working memory.

A number of studies have shown that children may be particularly dependent upon nonverbal signals in their communication attempts. Church and Goldin-Meadow (1986) found that when explaining their reasoning on conservation tasks, children transmit information via hand gestures that they do not verbalize. The authors suggested that gesture–speech mismatches reflect transient knowledge states. Doherty-Sneddon and Kent (1996) reported that young children relied on visual communication to support their relatively poor language. They found a face-to-face performance benefit over unseen interactions for 4- and 6-year-olds completing problem-solving communication tasks of the kind used in Boyle, Anderson, and Newlands (1994) with adults. They concluded that when the information to be transmitted is demanding, visual signals, such as gesture are central to a child's abilities. This makes sense if one accepts that gestures and speech have different complexities and that young children process the less demanding information more readily (Church & Goldin-Meadow, 1986; Feyereisen & de Lannoy, 1991).

In contrast to this, in certain tasks visual signals may interfere with performance. For example, Glenberg et al. (1998) reported that when adults are asked moderately difficult questions, they often avert their gaze. They demonstrated that the frequency of gaze aversion is related to the difficulty of cognitive processing and that averting the gaze improves performance. They suggested that averting gaze helps people to disengage from environmental stimulation and thereby enhances the efficiency of cognitive processing directed by non-environmental stimulation. Glenberg et al. proposed that whereas some tasks (e.g., naming or object recognition tasks) may be facilitated by environmental cues, conceptually driven tasks will be hindered. This is similar to conclusions from earlier work linking gazing and cognitive load (Beattie, 1981; Ellyson et al., 1981).

There is some evidence that face-to-face processing may be linked to the processing of other types of visuospatial information. In this vein, Ozols and Rourke (1985) have proposed a link between visuospatial processing problems and problems of processing visual–perceptual communicative information such as facial expressions and

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gestures, and so on, 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 E.L.D. From her pattern of deficits and abilities on visuospatial and verbal tasks, Patient E.L.D. illustrated the distinction between the visuospatial sketchpad (VSSP) and the phonological loop in working memory (Baddeley, 1986): E.L.D. had deficits in VSSP while retaining an intact phonological loop. In addition to her impairment in VSSP, E.L.D. was impaired on some tasks of face processing, suggesting a common substrate for social and nonsocial visuospatial processing. However, her impairment appeared to be in learning faces, rather than perceiving them (Hanley, Pearson, & Young, 1990), and expression recognition remained intact. Demands of *dynamic* face processing, however, may be greater than those for static face processing. The on-line processing of dynamic facial expressions, eye gaze, gesture, and so on, may involve VSSP to a far greater extent than do tests using static images. Further evidence for the link between right-hemisphere, visual IQ and the processing of visual communication signals comes from Ellis, Ellis, Fraser, and Deb (1994). They found that children with Asperger syndrome had relatively low visual IQs relative to their verbal IQs and that their right-hemisphere functioning was impaired. In addition, the same individuals were poor at discriminating eye gaze.

Similarly, Goldin-Meadow (2000) has proposed a link between the processing of hand gestures and the visuospatial sketchpad. In addition, she has proposed that although 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 suggesting that the processing of visual communication signals may be related to other types of visuospatial processing.

As mentioned, face-to-face *benefits* for communicative problem-solving tasks with adults and children are well documented (Boyle et al., 1994; Doherty-Sneddon et al., 1997; Doherty-Sneddon & Kent, 1996; McEwan, 1997). However, in some of our recent work, we have found that face-to-face access can actually hinder performance. Doherty-Sneddon et al. (2000) asked children to describe and perform a referential communication task involving the description of complex abstract shapes. Such a task requires the information sender to scrutinize the shapes for distinctive visual properties, and the information receiver must build a visual representation of the described shape over time, sufficient to select the correct target shape from among distractors. These materials differed from those with which we have previously found face-to-face benefits with young children (Doherty-Sneddon & Kent, 1996; McEwan, 1997). The earlier tasks, investigating the impact of different levels of visibility on children's communication, involved communication about pictures of real objects that were nameable to the children. For example, Doherty-Sneddon and Kent used a map task (Boyle et al., 1994) with 6- and 10-year-old children. This task involved communication about a path around a schematic map containing features such as cows, houses, and trees. When describing the abstract stimuli, both groups of children showed evidence of face-to-face *interference* rather than facilitation. It was concluded that, contrary to previous research, for *some* communication tasks, access to visual signals (such as facial expression and eye gaze) may hinder rather than help children's communication. If visuospatial processing and the perception of visual communicative signals share common processing resources, then it follows that the presence of facial expressions and gestures may in some circumstances *interfere* with the processing of other kinds of visuospatial information.

Related to this is research with adult participants showing that certain task-irrelevant social signals produce Stroop-like interference effects when participants are asked to make speeded keypress responses to spoken words (Langton, 2000; Langton & Bruce, 2000; Langton, O'Malley, & Bruce, 1996). In one experiment, for instance, participants were significantly slower to respond to the word *up* when presented with a picture of someone pointing downward compared with conditions where the to-be-ignored pointing gesture was directed upward. In other studies, eye-gaze direction, pointing gestures, and head orientation were found to exert similar interference effects on participants' responses to spoken directional words, despite instructions to ignore these visual cues. Together, studies such as these suggest that adult participants are simply *unable to ignore* irrelevant directional signals from the head, hand, and eye when processing the spoken words. Langton and Bruce have speculated that participants find these gaze, head, and pointing gestures difficult to ignore because they form cues as to the direction of another's social attention, which may be analyzed and combined by a specialized processing mechanism, the direction of attention detector (Perrett, Hietanen, Oram, & Benson, 1992). It appears that visual communication cues may facilitate communication when they provide task-relevant information. However, if they do not, then the cognitive cost associated with processing them may outweigh the benefits normally associated with them.

The theoretical basis of the studies carried out here is that processing of environmental visual information and internally driven visualization (such as mental imaging) involve VSSP. This includes tasks involving retention of visual information in a visual code or translation of verbal information to a visual code. It is therefore predicted that performance of tasks involving the encoding and decoding of visuospatial information will be worse when a secondary task also involving VSSP is carried out simultaneously. Furthermore, visual communication signals such as facial expression, facial gestures, and hand gestures are types of visual environmental information the processing of which involves loading VSSP. Attending to any of these signals while doing another visuospatial task will therefore act like a secondary task. In contrast, when the secondary task involves the articulatory loop, no such interference should occur. The exception to this would be if performance of the primary task was accomplished by spreading processing demands across verbal and visuospatial resources. We therefore predict that attending to visual communication signals will interfere with other types of visuospatial tasks.

In this paper we describe five new studies that provide further evidence of interference produced by access to another person's face. The first experiment tested both adults and children. Study 1 investigated whether there were interference effects when a listener monitored a face while listening to descriptions of abstract shapes. Studies 2A and 2B investigated the impact of facial signals on children's visuospatial memory using two different tests of visuospatial working memory. Studies 3A and 3B looked at the relative impact of face-to-face interference *and* articulatory suppression on visuospatial memory. In these studies we have taken Baddeley's (1986) distinction between VSSP and the articulatory loop of working memory as a model. Articulatory suppression, involving the repetition of verbal material, has been shown to prevent verbal recoding of visual information (Baddelely, 1986). Suppression should therefore not interfere with tasks loading on VSSP processing per se; however, it does prevent participants from using a verbal strategy to recall visual information, implying that all recall has to be based on visual coding.

The hypotheses are as follows:

1. The processing of faces and of descriptions of abstract shapes requires visuospatial working memory resources. It is predicted that in Study 1 monitoring a face will interfere with children's abilities to decode descriptions of abstract shapes.

2. Processing faces and decoding descriptions of abstract shapes will carry visuospatial working memory loads for both adults and children. It is, however, predicted that the relative processing load of the task in Study 1 will be smaller for adults than for children. Interference with performance on the task is therefore not expected for adults.

3. In Studies 2A and 2B it is predicted that monitoring a visuospatial pattern *or* a face will produce interference effects for children's visuospatial memory.

4. In Studies 3A and 3B it is predicted that monitoring a face will interfere with visuospatial memory but that articulatory suppression will have no impact on visuospatial performance. Articulatory suppression should therefore provide a nonrelevant secondary task.

Six- and 10-year-olds were chosen as age groups in the current set of studies since these are groups of children that we have found to differ in important ways in terms of their communicative adaptability. For example, earlier work showed that 6-year-olds often failed to adapt their communication strategies when they could not see one another compared with when they could, resulting in communicative performance deficits. In contrast, 10-year-olds did not show performance deficits when they could not see one another while communicating (Doherty-Sneddon & Kent, 1996). For these reasons, these age groups were also investigated in the study that first showed that when describing *abstract* stimuli, both groups of children showed evidence of face-to-face *interference* rather than facilitation (Doherty-Sneddon et al., 2000). The present studies extend this work and investigate in more depth the cause of this face-to-face interference in the same age groups of children.

Ten-year-olds were chosen in Study 1 so that a direct comparison with adults could be made, using the same abstract shapes and similar descriptions. Materials would have been simplified had 6-year-olds taken part, making such comparisons harder. We expected that adults would, like the children, experience an increase in VSSP load when monitoring faces. However, we predicted that adults would be better able to deal with this because of their greater ability to cope with dual tasks (Beattie, 1981). In Study 2A 10-year-olds completed a visuospatial memory task (called the "Mr. Peanut" task) in order to investigate whether face-to-face interference would also be evident in visuospatial memory in this age group. Study 2B extended this to a second visuospatial memory task (Corsi block), this time with 6-year-olds. Having established similar interference effects in both age groups, the final studies on the additive effects of articulatory suppression were also carried out with 6-year-old participants.

STUDY 1
Children and Adults as Listeners

Study 1 investigated the source of interference previously found with a referential communication task involving the description of abstract shapes (Doherty-Sneddon et al., 2000). The aim of the study was to see whether the face-to-face interference found was due to monitoring the interlocutor's face and could therefore be eliminated by looking away. Three conditions were included in the design to investigate this. Participants listened to referential descriptions either while looking at the speaker's face, looking at the floor, or closing their eyes. If it is face monitoring that interferes with the processing of descriptions of abstract shapes, performance while looking at the face should be worse than in the other two conditions.

In the earlier study this task was done with an interactive dyad of participants. Here we controlled the information that was sent: an experimenter gave preset descriptions to participants who were acting as information receivers (listeners). This allowed us to examine whether access to faces interfered with the processing of the required information without confounding this with the quality of the information delivered. Effects are investigated in samples of adults and 10-year-old children.

Method

Participants. The child participants were 28 10-year-olds (19 males and 9 females), mean age 10 years 11 months, age range 9 years 3 months to 11 years 2 months. Twenty-one adult participants also took part. They were students at Stirling University (6 females and 15 males), all between 18 and 25 years of age. The adults were paid £5/hour for their participation in the experiments. The children were each given book tokens valued at £5.

Design. This was a within-subjects design with all participants being tested in each of the three conditions. The order of conditions was counterbalanced across participants, as was the order of presentation of the blocks. The dependent measures were number of correct choices, confidence level, and "time to choice" (the time taken to identify the target shape from when the description ended to when the selection was made).

Stimuli. Stimuli consisted of 48 abstract shapes that were pasted onto three-dimensional cubes (see Figure 1 for an example of a set). All the shapes were black. A different set of shapes was used in the three different experimental conditions. For each condition, the experimenter had four target shapes that were described individually to the participant, who had a choice of 12 shapes from which to select the shape he/she thought had been described. These included the four target shapes and two distractor shapes for each target shape—that is, two shapes that were visually similar to the target one but that were different from each other.

Piloting the task with children showed that it was necessary to make the descriptions in the children's task more concise and slightly easier than those used with the adult participants. Apart from this, the procedure involved for the adults and children was the same. Descriptions were entirely verbal and included no hand gestures. The following examples illustrate how descriptions differed for the adults versus the children:

Example 1: Description in adult study:
"The longest side of this shape is the left one which is also a straight line. A large triangle has been cut out of the right-hand side."
Example 2: Description in child study:
"It's a large rectangle and a large triangle has been cut out of the right-hand side."

Procedure. Participants were tested individually in a quiet room within their school or the university. The procedure lasted about 20 min. The experimenter described the shapes in turn. During the descriptions the shapes were hidden from view. Participants were asked to try to picture the shapes in their mind's eye as they were described. While listening to the descriptions, participants had to look at the experimenter continuously, look at a designated spot on the floor, or close their eyes. Each participant completed four trials in each of these conditions—a total of 12 trials per person.

Participants were told that they could ask for further information or ask for a description to be repeated if they wished, but that such feedback was permitted only while they were still looking at the experimenter, looking at the floor, or had their eyes closed. They were not allowed to ask for further information once they had uncovered and looked at the blocks.

After each trial, participants were asked to write down their answer (each block had a different code on the base) and also to rate the confidence they had in their answer on a 5-point scale. A rating of 1 indicated that they were very sure they had selected the correct block, and a rating of 5 indicated that they were guessing. Partici-

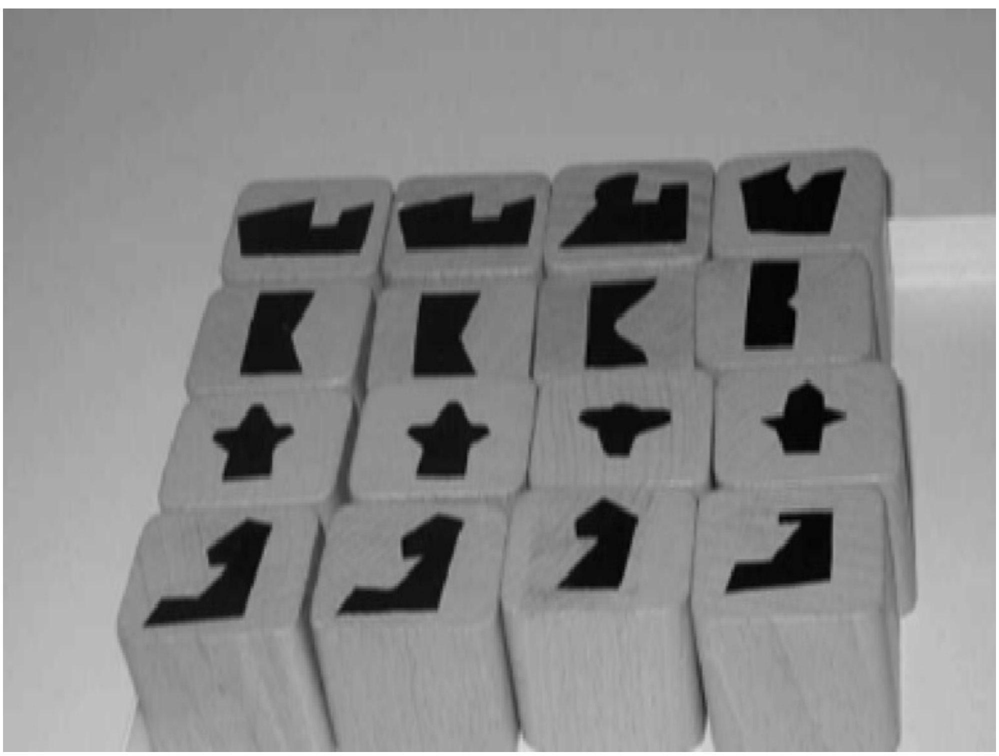

Figure 1. A set of blocks used in Study 1. The left-hand column shows the blocks that the experimenter described. The others show the array from which the instruction follower had to choose.

pants were given practice in each of the three conditions and with the response procedure.

After testing was complete, participants were questioned to see which condition they had found easiest to concentrate in and which they had found difficult to concentrate in. They were also asked about strategies they had used to remember the shapes—whether they used verbal rehearsal, mental imaging, or something else.

Results

Task scores (child). Mean task scores are given in Table 1. Children made more correct responses when they had been looking at the floor than when they had been looking at the experimenter's face during the description. A one-way analysis of variance (ANOVA) was performed. Interference condition (three levels: looking at experimenter's face, looking at floor, eyes closed) was a within-subjects variable. The dependent variable was the total correct target blocks chosen in each condition. This revealed that performance was better when participants looked at the floor than it was when they looked at the experimenter. The effect of interference condition approached significance [$F(2,54) = 2.97, p = .06$]. Post hoc t tests were used to investigate the comparisons between the three levels. The difference between looking at the face and looking at the floor was significant [$t(27) = 2.3$, $p < .05$]. Performance in the eyes-closed condition was between the other two and was not significantly different from either of them.

Time to choice (child). Means for time to choice are given in Table 1. Data from 4 children were excluded from this analysis due to loss of recordings. Children were faster in making their choices when they had looked at the floor while listening to the descriptions than when they had looked at the experimenter's face. A one-way ANOVA showed that the effect of condition approached significance [$F(2,46) = 2.67, p = .08$]. Post hoc t tests revealed that participants were quicker in making their choices when looking at the floor than when looking at the experimenter [$t(23) = 2.3, p < .05$]. Time to choice in the eyes-closed condition was in between that in the face and floor conditions, and not significantly different from either of them.

Confidence (child). Children were equally confident that they had chosen the correct target regardless of condition. See Table 1 for means.

Adult data. Adults performed the task equally well regardless of condition. Means are shown in Table 1. Similarly, there was no difference in the length of time they took to choose or their confidence in their choice across condition.

Postexperiment questionnaire. Participants were asked, "In which condition did you find it easiest/most difficult to concentrate?" Out of those who chose a "most easy" condition, most of the children and adults (20/24 and 19/21, respectively) found the eyes-closed and looking-at-the-floor conditions to be easier than the looking-at-the-face condition. In addition, most of the adults (14/18) found looking at the face the most difficult condition. The majority of children (74%) used mental imagery as a strategy (although 57% combined this with verbal rehearsal) when trying to understand the descriptions of the shapes. Similarly, 95% of adults reported using mental imaging (80% also used verbal rehearsal).

Children were therefore faster and more accurate in decoding the descriptions when they looked at the floor than when they looked at the experimenter's face. This supports our first hypothesis that face-to-face access would interfere with children's abilities to do the task. It is not clear why closing the eyes did not differ from the other two conditions. A number of adult and child participants reported feeling uncomfortable closing their eyes in front of the experimenter. It could be that this social discomfort was distracting in itself and counteracted the benefits of cutting out visual information.

No face interference was found in terms of task performance for the adults. Their scores were generally better than those of the children, suggesting that the task was easier for them. Any interference from monitoring the face may therefore have been negligible for this task. Furthermore, it is well known that adults are good at adapting to different communicative scenarios and often maintain task performance regardless of, for example, whether they can see their interlocutor or not (Boyle et al., 1994). The crucial finding for the adults related to their experience of the different conditions. The adults reported that the face monitoring condition was the most *difficult.* This suggests that adults experienced face-to-face interference but were better able to manage it. This is not surprising since adults are very experienced communicators, used to dealing with all sorts of information in face-to-face conversations. Furthermore, we know that adults have ways of "switching off" environmental stimulation when cognitive demands are high. For example, adults will increase the amount that they avert their gaze from a questioner as questions get more difficult (Glenberg et al., 1998).

There is thus evidence that looking at faces can interfere with decoding descriptions of abstract shapes. We interpret this via the assumption that decoding abstract shapes

Table 1
Child and Adult Task Scores, Reaction Times (in Seconds), and Confidence Scores

	Looking at Face		Eyes Closed		Looking at Floor	
	Child	Adult	Child	Adult	Child	Adult
Task score	1.96	2.86	2.32	2.86	2.57	2.71
Time to choice (seconds)	16.63	21.0	15.48	19.17	14.21	19.46
Confidence rating	2.66	2.44	2.61	2.28	2.48	2.27

involves mental imaging—in other words, translating the verbal description into a visual code. This assumption is supported by the subjective reports of using mental imaging while doing the task (74% of children and 95% of adults). The aims of Studies 2A and 2B were twofold. First, to replicate the face interference effect with different tasks that also involve VSSP. Second, to compare the interference produced by monitoring a face with that produced by monitoring another secondary source of visuospatial information. The tasks used are visuospatial memory tasks known to tap VSSP: the Mr. Peanut task (De Ribaupierre & Bailleux, 1994) and the Corsi Block task (Corsi, 1972). These two different tasks tap different components of VSSP: Mr. Peanut, the visual component; Corsi block, the dynamic component (Pickering, Gathercole, Hall, & Lloyd, 2001).

STUDY 2A
Face-to-Face Interference With Visuospatial Memory—Mr. Peanut Task

Method

Participants. Thirty children took part, 18 females and 12 males, mean age 10 years 2 months (range 9 years 2 months to 10 years 10 months). Children were recruited from local primary schools in Stirlingshire.

Task. A short-term memory task was adapted from De Ribaupierre and Bailleux (1994). Children were presented with a clown figure with a varying number of dots stuck onto different locations. They were permitted 2 sec of viewing time per dot and then the figure was removed. Children had to try to remember the locations of the dots over a 10 sec retention interval while looking at the experimenter's face, while looking at a visuospatial pattern, or while looking at the floor. During these 10 sec, children had to monitor the face or the pattern and tap their pen on the desk when the experimenter smiled or when they noticed a change in the pattern, such as a shape moving (or look at the floor and make no response). After the 10 sec had elapsed, they were presented with a blank clown figure on which they had to place blue stickers to indicate where they believed the dots were in the original picture.

All dots were the same color, blue, so that the children would focus on visuospatial information only. There were three levels of task complexity: the easy condition contained two dots, the middle condition contained four dots, and the hard condition contained six dots. There were 12 different configurations of dots for each level of difficulty. These configurations were generated at random, but ensured that no figure contained two dots in symmetrical locations, that no obvious patterns were used, and that identical positions were not used on consecutive trials.

Procedure. Children were tested individually and were given six practice trials with figures that contained two dots. This included two trials looking at the experimenter's face, two looking at the pattern, and two looking at the floor. Children then began the test proper, subject to passing all the practice trials. Each child completed 36 trials in total. These consisted of four trials per level of difficulty in each of the three types of interference; thus level of difficulty and type of interference were within subjects. Level of difficulty, type of interference, and the order of stimuli were counterbalanced across participants.

The sessions were audio-recorded so that the time taken to complete the tasks could be obtained after testing. Response time was not restricted and children could think about their answers for as long as they wanted. The number of correctly recalled dots per trial was recorded and an overall score were computed for each condition. The overall scores were computed as the percentage of dots correctly recalled in each condition.

Results

Task Scores. Table 2 shows the mean percentage of dots correctly recalled in each condition over the four trials. Children performed the visuospatial memory task best when they had monitored the pattern and worst when they had attended to the experimenter's face. A two-way ANOVA was carried out on the accuracy scores, with interference type (three levels: looking at the face, pattern, or floor) and task difficulty (three levels) as within-subjects factors. There was a main effect of interference, [$F(2,58) = 4.46, p < .025$], where the greatest percentage of correctly recalled dots occurred when children looked at the pattern (68.1%), then when they looked at the floor (67.7%), and the lowest when they looked at the experimenter's face (62.9%). Post hoc t tests revealed that the differences between the face condition and the floor condition and the face condition and the pattern condition were significant [$t(29) = 2.63, p < .05$ and $t(29) = 2.76, p < .01$, respectively]. Performance in the pattern and floor conditions did not differ. There was also an effect of task difficulty [$F(2,58) = 123.15, p < .001$], where the percentage of dots that were correctly recalled decreased as task difficulty increased. Planned comparisons t tests revealed that each level of difficulty was significantly different from the others. Easy–middle, easy–hard, and middle–hard contrasts were $t(30) = 10.55, p < .001$; $t(30) = 14.72, p < .01$; and $t(30) = 5.25, p < .01$, respectively. There was no interaction between variables.

The results supported our prediction that attending to faces would interfere with children's visuospatial memory. This increased support for the idea that faces share a common processing substrate with other types of visuospatial information. The face-to-face interference found in our earlier work (Doherty-Sneddon et al., 2000) and in Study 1 of the present paper may therefore, at least in part, be due to competition for visuospatial processing resources. The third hypothesis, that monitoring a face during retention would interfere with visuospatial memory, was therefore supported. However, no interference occurred when children monitored the pattern. This might suggest that faces are particularly salient sources of visual stimulation that are harder to ignore than other visuospatial patterns. Alternatively, the face interference found with the Mr. Peanut task might in part be due to the fact that the stimuli the children were trying to recall were face-like. Study 2B addressed this possibility by investi-

Table 2
Mean Percentage of Dots Correctly Recalled Per Condition Over Four Trials

Condition	Looking at Face	Looking at Floor	Looking at Pattern
Easy	78.3%	85.4%	86.3%
Middle	58.8%	64.8%	64.8%
Hard	51.5%	52.8%	53.3%

gating the interference effect with a different visuospatial memory task.

STUDY 2B
Face-to-Face Interference With Visuospatial Memory—Corsi Block Task

The aim of Study 2B was to investigate whether the same face-to-face interference effect would be found with a different visuospatial memory task that did not involve a face-like stimulus. The task chosen was the Corsi block. This task was originally developed for use as a nonverbal version of a digit span task (Corsi, 1972). However, Corsi found various dissociations between performance on digit span tasks and that on the block tapping task for groups of participants with different loci of brain lesions. From this neuropsychological research, it emerged that whereas digit span tasks measure verbal working memory, the Corsi block task actually assesses visuospatial working memory (Berch, Krikorian, & Huha, 1998). Over the past 25 years, the task has been widely employed by neuropsychologists, cognitive psychologists, and developmental psychologists and has been used alongside the Brooks spatial matrix task in studies assessing visuospatial working memory in adults (e.g., Hanley et al., 1991; Morton & Morris, 1995).

Method

Participants. Twenty-five 6-year-olds (13 girls and 12 boys) took part in the study. The mean age was around 6 years 5 months, the range 5 years 11 months to 6 years 9 months. They were recruited from local schools. These children had not taken part in any of the other studies.

Procedure. The children were tested individually in a quiet room in school. In the Corsi block task, the experimenter taps out a sequence on an array of blocks placed between him/her and the child. There were nine identical wooden blocks set out in rows of three. The experimenter tapped the blocks in a particular order, and the participant was then required to retain (for 10 sec) the information about which blocks had been tapped in which order and to reproduce the sequence at test. Each child completed four trials in each condition.

The first 15 children were tested in three interference conditions (face, floor, and pattern) and at two levels of task difficulty (easy and hard). The easy level involved the children recalling two block sequences. The difficult level involved the recall of three block sequences. However, it was apparent that the three-block sequences were too difficult for this age range, since the children were performing very poorly on them. This was demoralizing for the children, and so it was decided to continue the study with the two-block sequences only. Context of the two-block sequence performance (either along with three-block sequences or not) was included as a between-subjects factor.

Results

Task scores. Children recalled significantly more sequences correctly when they looked at the floor during the retention interval than when they looked at the experimenter's face or at the pattern. A two-way ANOVA was carried out on the children's mean number of correctly recalled sequences (across four trials) on the *two-block* sequences only. Interference was a within-subjects variable (three levels: face, floor, and pattern), and testing context was a between-subjects variable (two levels: with three-block trials, without three-block trials). Interference had a significant effect on the recall scores [$F(2,46) = 3.90$, $p < .05$ (mean face = 1.64, floor = 2.30, pattern = 1.60)]. Post hoc t tests revealed that performance in the floor condition was better than in either the face [$t(24) = 2.32$, $p < .05$] or the pattern conditions [$t(24) = 3.0$, $p < .01$]. Performance in the face and pattern conditions did not differ. Testing context had no effect on performance.

The results support our prediction that looking at a face during the retention interval interferes with visuospatial working memory. Similarly, monitoring a moving visuospatial pattern also interfered with recall. This suggests that other visuospatial environmental information can also be distracting. The particular impact that the face had over the pattern in Study 2A may have been partly due to the face-like stimuli used in the Mr. Peanut task. The more similar the VSSP demands, the more interference.

STUDY 3A
Articulatory Suppression in the Mr. Peanut Task: 6-Year-Olds

Studies 3A and 3B of the present paper investigated face-to-face interference in the Mr. Peanut task with 6-year-olds. In addition, an extra condition was added—articulatory suppression. In this condition children were asked to repeat the word *the* during the retention interval. This requires some attentional resources, but these should not be relevant to the task at hand. Furthermore, articulatory suppression takes up articulatory loop processing capacity and will make verbal encoding of the visuospatial information less likely, thereby forcing all of the visuospatial information to be processed in the visuospatial sketchpad. The predictions therefore were that monitoring the face during retention would interfere with performance on the memory task (as it had with the older children) and that articulatory suppression would mean that children could retain the task information only in a visual code, but that the extra effort caused by this should not influence task performance.

Method

Participants. Participants were 26 6-year-olds, 17 boys and 9 girls, mean age 6 years 7 months (range 6 years 2 months to 7 years 3 months).

Task. The task and procedure were identical to those in Study 2A except that in the articulatory suppression condition children had to look at the designated spot on the floor and repeat the word *the* over and over for the duration of the 10 sec of the retention interval. The face and the floor conditions were the same as in the previous study. Only two levels of difficulty were used (easy and middle) since pilot work had shown that the hardest version of the task was too difficult for children of this age.

Procedure. Children were tested individually and were given six practice trials with figures that contained one dot. This included two trials looking at the experimenter's face, two looking at the floor with articulatory suppression, and two looking at the floor without suppression. Children then began the test proper, subject to passing all the practice trials. Children completed 24 trials, 4 trials per level of interference in both the easy and middle conditions. The number of correctly recalled dots per trial was recorded and an overall score was computed for each condition. The overall scores were then computed as the percentage of dots correctly recalled in each condition.

Results

Task scores. Children recalled fewer correct dot locations when they monitored the experimenter's face during retention than they did when they looked at the floor either with or without articulatory suppression (mean face = 55.2%; mean suppression = 60.5%; mean no suppression = 62.8%). A repeated measures ANOVA was carried out with two within-subjects factors: interference (face, articulatory suppression, and no suppression) and task difficulty (easy and middle). Task difficulty had a main effect [$F(1,25) = 48.23, p < .01$], with performance decreasing as task difficulty increased (mean easy = 67.6; mean middle = 51.3). There was a trend toward an effect of interference [$F(2,50) = 2.91, p = .06$]. Planned comparisons *t* tests were carried out on this effect relating to the prediction that performance in the face condition would be worse than that in either of the floor conditions. The *t* tests confirmed this, with performance in the face condition worse than the articulatory suppression condition and worse than the floor with no suppression condition [$t(51) = 1.82, p < .05$; $t(51) = 2.49, p < .01$, respectively]. No interaction was found.

The children generally performed better when they looked at the floor than when they looked at the experimenter's face. This supports the prediction that monitoring the face can interfere with visuospatial memory. Articulatory suppression did not produce any additional interference.

STUDY 3B
Articulatory Suppression in Face and Floor Conditions of the Mr. Peanut Task: 6-Year-Olds

The aim of Study 3B was to replicate the findings of Study 3A. Furthermore, the manipulation of articulatory suppression was factorially crossed with whether the children looked at the face or the floor.

Method

Participants. Participants were 31 6-year-olds, 11 boys and 20 girls, mean age 6 years 3 months (range 5 years 9 months to 7 years 9 months). Three of the boys were removed from the sample because of a lack of concentration during the testing procedure.

Task. The task and procedure were identical to those in Study 3A. This time a face plus articulatory suppression condition was included, giving four conditions: face without articulatory suppression, face with suppression, floor without suppression, and floor with suppression.

Procedure. Children were tested individually and were given four practice trials with figures that contained one dot. This included a trial looking at the experimenter's face, looking at the experimenter's face with articulatory suppression, looking at the floor, and looking at the floor with articulatory suppression. The criterion for passing the practice trials was that the child correctly recall the location of the dot in each trial, and that he/she adequately carry out the instructions regarding the secondary task. Three children required an extra couple of trials before continuing with the experiment proper because of uncertainty about the secondary task. Children completed 24 trials, 3 trials per level of interference in both the easy and middle conditions. The number of correctly recall dots per trial was recorded and an overall score was computed for each condition. The overall scores were then computed as the percentage of dots correctly recalled in each condition.

Results

Task scores. As in Study 3A, when children attended to the face they remembered fewer dot locations correctly (mean face = 62.6%; mean floor = 67.9%). A three-way ANOVA was carried out on the percentage of correct dots in each condition. There were three within-subjects variables: interference (two levels: looking at face or floor), difficulty (two levels: easy or middle difficulty), and suppression (two levels: with or without). The effect of interference approached significance [$F(1,27) = 3.75, p = .06$]. Difficulty also had a significant effect on task scores, with poorer performance on the more difficult trials [$F(1,27) = 5.28, p < .05$ (mean easy = 67.7%; mean middle = 62.7%)]. No other effects or interactions were found.

The children seemed adept at changing strategy for recall and alternated between a verbal and mental imagery strategy. Eight reported using a verbal strategy only (one child commented that he tried using a "picture in his head" during articulatory suppression trials but couldn't manage it—he did not differentiate between face plus suppression and floor plus suppression). Ten children said they used imagery only. Nine reported using both. Indeed, 4 particularly precocious children said that they definitely used a "picture in their head" during suppression and a verbal strategy in no suppression. One child explicitly said that she used a verbal strategy when the task was harder and imaging in the easy trials. It was not possible to pinpoint exactly what strategy children used in which trials. What was clear from the children's reports was that they could change strategy in response to condition.

Discussion

In Study 1, 10-year-old children found greatest difficulty in decoding descriptions of abstract shapes while looking continuously at the experimenter's face. Their task performance decreased in this condition and they took longer to respond. In contrast, their performance was best and their response time fastest when they looked at the floor while listening to the description. Eyes closed seems to lie somewhere in between these two. It is unclear why this should be the case. It appears that participants found closing their eyes in front of another person a strange thing to do. A number of participants reported that they felt uncomfortable doing this. Adults maintained their performance and did not vary their response times (although they did take longer overall to respond than the children). This could mean that maintaining gaze with the experimenter had no effect upon the adults. However, the subjective reports in the postexperiment questionnaire suggested otherwise. Most of the adults (67%) found looking at the experimenter's face the most difficult condition. Therefore, although adults adapted well to this condition, they experienced it as difficult.

In Study 2A, 10-year olds' performance on a visuospatial memory task was worse when the children had to attend to a face during a retention interval than when they were looking at the floor or at a moving visuospatial pattern. It is interesting that the visuospatial pattern did not interfere with retention of the information. This suggests that faces have a particularly strong effect on processing capacities—either because they are rich sources of visual information (e.g., Ekman, 1980) and/or because they are difficult to ignore (see Langton & Bruce, 2000). Alternatively, since Mr. Peanut is face-like, perhaps attending to another face produced a task-specific source of interference. This is unlikely to explain the effects found given some of the recent work showing interference across different visuospatial tasks. For example, Recarte and Nunes (2000) reported that performing mental visuospatial tasks interferes with drivers' patterns of visual fixations performance while driving. In addition, the results of Study 2B showed that attending to a face *or* a visuospatial pattern interfered with recall in a different VSSP memory task where stimuli were sequences of blocks rather than face-like.

The results of Study 3A showed a similar face-to-face deficit with 6-year-old children performing the Mr. Peanut task. Furthermore, articulatory suppression did not interfere with performance of the task. Study 3B replicated this effect, again showing face interference for the task and no additional load caused by articulatory suppression. Both of these findings suggest that the children use a visuospatial representation of the information to be recalled and that monitoring a face interferes with the processing of this information.

The cognitive interference hypothesis was therefore supported. Looking at an interlocutor's face during interaction involves cognitive load that can interfere with task demands (e.g., Beattie, 1981; Glenberg et al., 1998). This supports the proposal by Ozols and Rourke (1985) that the processing of visuospatial information and the processing of nonverbal communicative signals are related. In addition, Study 1 showed this effect when participants were listeners. The cognitive interference hypothesis is normally associated with visual access interfering with cognitive process involved in speaking (e.g., speech planning and verbal encoding). We showed that children's abilities to effectively decode verbal information (at least relating to the description of abstract shapes) was negatively affected when they had to look at the speaker. It is suggested that decoding the descriptions of abstract shapes may involve visuospatial processing and that this, and the perception of visual communicative signals, share common processing resources. It then follows that the presence of facial expressions and gestures may in some circumstances *interfere* with the processing of other kinds of visuospatial information. Studies 2A/B and 3A/B provide additional support for this and suggest that the source of interference is a competition for specific visuospatial processing resources. Face-to-face interference was found in two different visuospatial memory tasks with both 6- and 10-year-old children. It is suggested that the results of all the different studies relate to similar processes in all the age groups studied.

Goldin-Meadow (2000) has proposed that the processing of hand gestures is linked with the processing of other visuospatial information since the encoding and decoding of gestures may be processed in visuospatial working memory. The present results support this by showing that facial cues (another type of visual communication signal) are also linked to other visuospatial processing. In addition, she has proposed that although 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. We have shown that facial information can interfere with the accomplishment of other visuospatial tasks.

An alternative explanation is that the face-to-face interference found is mediated by social embarrassment rather than a competition for visuospatial resources. There are rules about how much and for how long it is acceptable to look at other people (Kleinke, 1986). Furthermore, there is evidence that inappropriate amounts of mutual eye contact can interfere with cognitive processing (Beattie, 1981). It is likely that the 6-year-olds are still acquiring rules of gazing behavior (Abramovitch & Daly, 1978), and it would therefore be expected that they would be less affected by the constant gazing from an adult female (Ashear & Snortum, 1971). Nonetheless, we found face-to-face interference with this age group. Older children are more aware and may be more self-conscious when talking to adults (Ashear & Snortum, 1971). However, all of the children who took part appeared to enjoy the procedures and none showed signs of embarrassment in the face condition. In fact, the only condition across the studies that participants reported feeling uneasy in was the eyes-closed condition in Study 1. We therefore conclude that it is the informational load of faces rather than social embarrassment that interferes with performance on the tasks.

These findings make an important contribution to what we know about the role of visual communication signals in children's communication. When children are doing certain tasks—for example, those involving mental imaging —information from faces hinders their performance. This contrasts with other work, including our own, showing that these signals often benefit children's communication and performance of tasks. However, the present and earlier work are not anomalous. Visual signals are likely to benefit communication if looking at the other person adds information that facilitates the task (e.g., a gesture used to describe the shape of an object). In contrast, if the visual signals do not have an "added value" for the task at hand, the cognitive resources required to process them may detract from processing of task-relevant information. Problems of processing task-irrelevant visual communication cues are compounded by the fact that such cues are very difficult to ignore even for adults (Langton & Bruce, 2000). Furthermore, for children of this age, attention-shifting skills are still developing (e.g., Pearson & Lane, 1991). Ignoring irrelevant visual signals may therefore be doubly difficult for children.

Glenberg et al. (1998) reported that when adults are asked moderately difficult questions, they often avert their gaze. They demonstrated that the frequency of gaze aversion is related to the difficulty of cognitive processing, and that averting the gaze improves performance. The present work has investigated whether children attempt to ignore irrelevant environmental information by averting their gaze in the way that adults do. Preliminary results suggest that 8- and 9-year-olds also increase their gaze aversion when they are asked difficult questions. The present studies suggest that this gaze aversion (if timed appropriately) is likely to have a functional effect on performance.

This work has potential implications for teaching. When do we want children to look at us, and when is it of most benefit to encourage them to look away? Visual cues like eye gaze, gesture, and facial expression are often extremely important in facilitating children's understanding of what is explained to them. For example, Otteson and Otteson (1980) found that eye gaze from a teacher during story telling increased recall of information, perhaps due to gaze functioning to provide emphasis to the speech. Similarly, Goldin-Meadow, Kim, and Singer (1999) found that gestures that teachers used while explaining arithmetic problems influenced and facilitated children's comprehension. What we have shown here is that, there may be critical points within interactions where it is necessary to switch off from the visual information given by an interlocutor. The critical points are likely to be when a child is thinking of a response, particularly if the information is cognitively demanding and/or involves mental imaging.

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