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Explaining Spatial Problem Solving in terms of Cognitive Load or Responsiveness and Selective Attention

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Earlier studies (e.g. Owens, 1994) had suggested that attention and responsiveness were key aspects of spatial learning. An experimental study considered the effect of different responding modalities (looking only, listening, doing, and speaking) on students' performance in a spatial task (equal-angle selection) presented on computer screens. Tasks varied in difficulty. A training phase was followed by a testing phase and a sample of the 60 participants were interviewed. Different responding modalities did not significantly affect the students' performance on the harder items contrary to capacity-constrained theories. The variance between students together with the interview data suggested that attention, especially resulting from expectation, intention, and existing schema, were important in student learning. Interestingly the group that looked and decided performed better, but not significantly, than the other groups who listened, used materials, or spoke. The speaking group improved their performance in the testing phase.

(Note. The paper distributed at the conference was a draft version of this fuller paper.)

Introduction

With the current interest in innovative ways to deliver educational material including CD-ROM and web-based approaches, it is relevant to consider their potential effectiveness in light of theories of attention and information processing. The present study examines this broad issue in the context of spatial problem solving with adult participants performing an equal-angle selection task. Motivated by contemporary theories of cognitive load and attention the experiment examines the effect of response modality (e.g. visual, auditory, interactive) and task difficulty on the accuracy of selecting an equal angle.

Many mathematics educators emphasise that concepts are not passively received but are actively constructed as the learner uses existing schema to interpret information and draw inferences from this information (see, for example, Skemp, 1989; Steffe, 1991). "The stored memories and information processing strategies of the brain interact with the sensory information received from the environment *to actively select and attend to* the information and to actively construct meaning" (Osborne & Wittrock, 1983, p. 4; my emphasis).

Flavell (1977) commented that attentional processes become increasingly interwoven with other cognitive processes such as memory, learning, and intelligence. Attention is attracted by perceptually outstanding features such as nearness, isolation, size, special form, colour (Flavell, 1977), number of items, and the inherent interest of the items (Vurpillot, 1976). As a result, people attend to certain features of a visual stimulus.

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Selective attention is the result of focusing on both external and internal stimuli (Flavell, 1977). Selective attention can be affected by the visual ability of making ground-figure changes. For example, a student can change focus from a part of a shape to the whole shape. Less experienced students may focus on partial features to decide equivalence and may not be logical or recognise relevant orders such as size (Vurpillot, 1976). Selective attention can be improved by repetition and the recognition of a relationship which can be employed to solve a problem (Vurpillot, 1976). If students consciously or unconsciously assess information as incoherent, then they do not attend to the input (Neumann, 1987; van der Heijden, 1992). Such restrictions may reduce the effectiveness of selective attention in developing conceptual links but students' attention can be influenced by others through looking and listening to others.

There can be an interference effect when students respond to problem-solving tasks with manipulatives or computer assistance. Some researchers have contributed the difficulties to cognitive overload (e.g., English, 1994). English argues that the equipment can make excessive demands on the individuals' working memory and this cognitive overload interferes with the learning of desired concepts. Attending to redundant materials or splitting attention in the same perceptual mode can reduce learning (Sweller & Chandler, 1991).

Disputes about selective attention have been about early and late selection and about limited and unlimited capacity. For example, Johnston and Heinz (1978) demonstrated that selection can be either early (based on physical characteristics) or late (based on semantic analysis) depending on the nature of the task, the instructions, and so on. More recently a flexible view of attention has been considered. Rather than identifying rigid upper limits, studies have demonstrated that our capacity to attend and use information is influenced by the nature of the material and its familiarity, difficulty, uncertainty, and modality of presentation (Baddeley, 1992; Kahneman, 1973; Liu & Wickens, 1992). Stimuli to the same set of sense organs cause greater overload than to different sense sources, presumably because more capacity was available with dual modalities. For example, two auditory stimuli (one to each ear) increased response times compared to the effects of an auditory and a visual stimulus together (Sweller & Chandler, 1991). We know that material can be chunked, tasks can be practiced to the point where performance becomes automatic, and redundant or irrelevant information can be ignored (Halford, 1993; Schneider & Shiffrin, 1977; Sweller, Chandler, Tierney, & Cooper, 1990). These abilities appear to have the effect of utilising cognitive resources, and performance of the task becomes efficient and, under some circumstances, other tasks can then be undertaken simultaneously. Nevertheless, individual differences can still be large (large variance) as Bobis found in the times taken by Year 4 students to complete a task on paper-folding when instructions contained redundant material presented separately from the main diagrams (Bobis, Sweller, & Cooper, 1992).

Allport (1987) extends the argument further. He argues that early selection is really about "the relative efficiency of*selective cueing* (which) is simply irrelevant to questions about the level of processing accorded to the 'unselected information'" (p. 409). Processing of both cued and noncued information proceeds at least to categorical levels of analysis. Allport argues that an unlimited capacity for perceptual attention for action explains results of experiments. He refers to "crosstalk interference between parallel processes. ... Whenever the task-specified inputs are not the single most compatible among concurrently available inputs for the task-specified actions, (inputs need to) be actively decoupled from the control of particular actions. ... It is a radically different conception, however, from the earlier notion of a central, limited capacity, or even from that of multiple limited 'resources'" (Allport, 1987, p. 411).

Allport (1987) gave support to the theoretical interpretations of van der Heijden on selective attention (1987, 1992). Van der Heijden (1992), based on his experimental findings with short exposures, disagreed with both the spotlight and filtering metaphor for selective attention. Both metaphors imply limitation and loss of sensory information. Van der Heijden (1992) provided a model involving the separation of location and identity for stimulus inputs and the importance of a feedback loop during processing from the location to the inputs.

Unlimited Capacity Model of Attention for Action

Different sensory features of objects are coded automatically and spatially in parallel and are located in appropriate maps (Treisman, 1988; van der Heijden, 1992). Combinations of features specify objects through a master map of where features are located by neuronal activity selectively enhancing (not inhibiting or attenuating) processing (van der Heijden, 1992). The end result, though, is action (Allport, 1987).

Van der Heijden (1992) explained that a mental input, such as the perception of an object, can be thought of as having both an *identity* and a *location* within an individual's schema. There is a feedback from the mental location to the input that may change both the identity and the location of images; for example, schema and relationships of concepts about angles and shapes are modified. For a correct identification response, identity information has to be addressed by location information. A feedback loop explains why it takes longer to attend to an uncued item. "The operation of the feedback loop can be regarded as a visual-perception internal kind of selective attention triggered by position information or the onset of position information. So, in this view, it is not attention, coming from nowhere, that is directed at a position in a map of locations. The map of locations is the *source* of the attention. ... The operation of the feedback loop has no function in the identification of the information but only in the selection of identified information" (van der Heijden, 1992, p. 254). Using bar-probe tasks, van der Heijden has shown that for a correct identification response, identity information is addressed by location information.

Thus, even a relatively low-level perceptual task can be influenced by higher-centres or top-down knowledge or information. The stimulus inputs are located in possible different mental locations. These also provide feedback inputs. One is selected and this location provides the identity for the stimulus. Higher centres can influence the locations. These centres involve expectations and intentions which influence selective attention. For example, if a person expects only to see an angle without a line dissecting it, they will not attend to angles that are dissected. Van der Heijden (1992) suggests that higher-order cognitive information assists expectation and attention. Van der Heijden discussed numerous experiments that gave cues or instructions other than location cues. *Expectation* was precipitated by cueing. Position cueing improved accuracy of recognition in experiments. Direct verbal cues, indirect attributional cues (e.g., colour-coding), or symbolic cues (e.g., an arrow pointing to the place of the object) were used. Expectation influences the location (a) directly with verbal cueing, (b) via another module with attribute cueing, and (c) with a link from identity to the higher centre and then to location if symbolic cues are used. This theoretical position suggests a dependence on prior experience.

It seems that the above summary provides a way of understanding selective attention in classroom settings as well as perception experiments. Various aspects of the classroom environment¾ words from the teacher or fellow students, the position of concrete materials, the expectation associated with a routine of classroom activities, and the task description¾may influence selective attention. The student identifies, processes through higher centre schema, to give a location that leads to attending selectively to the inputs, with further loops as needed. Selective attention is influenced by expectation and intention as well as perceptual inputs and internal feedback through the higher centres. Expectations and intention are part of the inner visual system and alter internal and external feedback. Classroom and other social interactions form part of past experiences, and they frequently

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influence expectations and intentions. For example, the prior knowledge and feelings associated with equal-angle selection tasks will influence students undertaking such tasks in the computer environment.

Attention and Responsiveness

Attention for action (Allport, 1987) is an apt concept that links well with the model of problem solving that developed from an earlier study by Owens (1993, 1994). This is illustrated in Figure 1 which suggests that responsiveness or action results from the complex interaction of cognitive processing. The term *responsiveness* implies a degree of understanding of the situation, involvement, and interest in the activity. The analysis of data indicated that cognitive processing embraced selectively attending, perceiving (e.g. listening, looking), visual imagining, conceptualising, intuitive thinking and heuristic processing (such as establishing the meaning of the problem, developing tactics, self-monitoring and checking). Responsiveness involves affective processes, and indicates changes in imagery, selective attention, and understanding. Responsiveness provides progress in problem solving.

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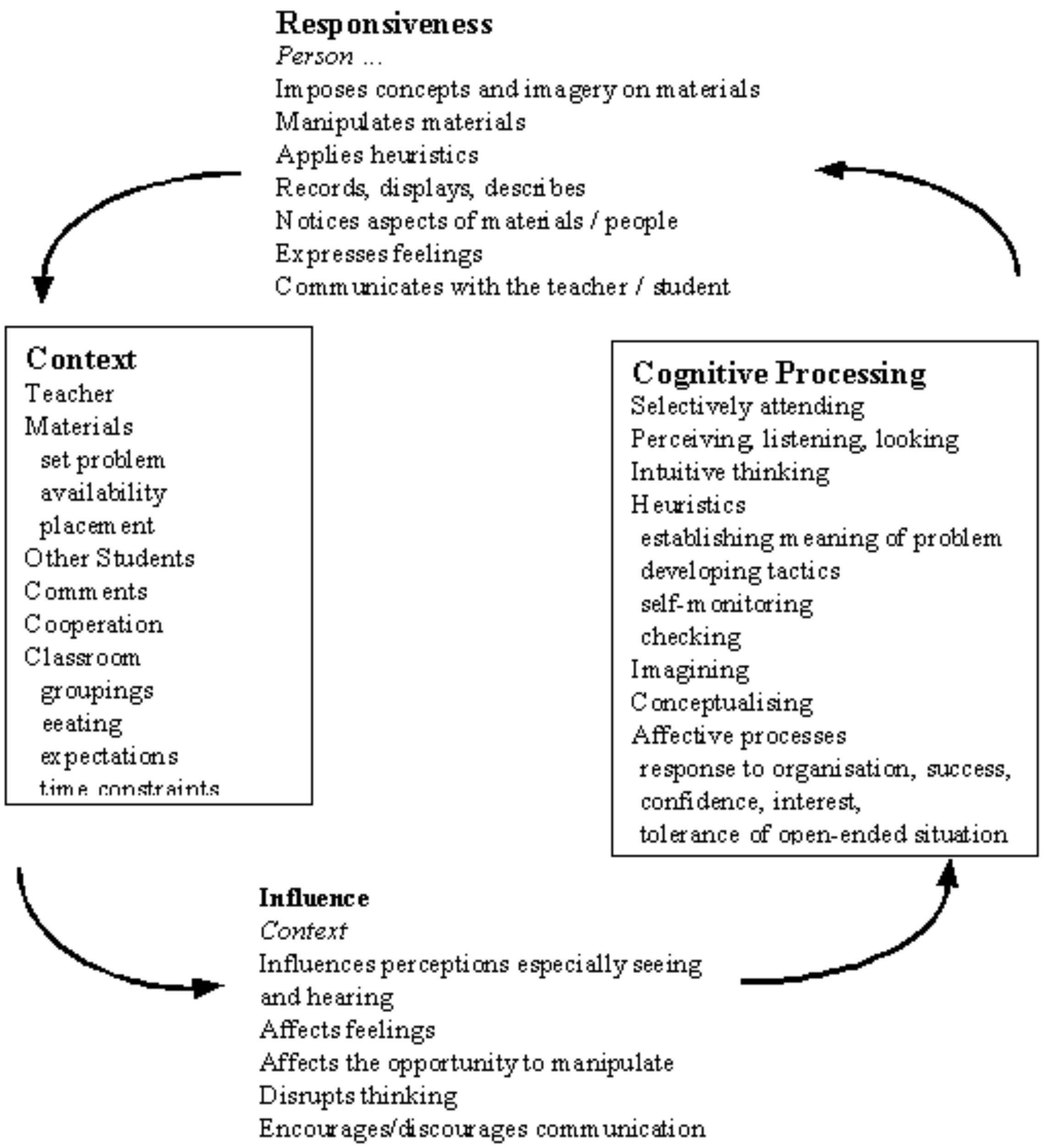

Figure 1. Aspects of problem solving

Materials or words spoken by others are important in students selectively attending and hence using concepts and images actively to solve problems (Owens, 1994). While imagery has a role in generating intuitive responses, in inducing selection of and reflection on concepts, and in precipitating the direction of actions, the verbalisation of concepts often assists in interpreting perceptions and actions. In this way, conceptualising and verbalising are important in assisting meaning and late attention where analysis of the imagery is possible.

An example might clarify the role of expectation and intention in selective attention. (See Owens & Clements, in press, for other examples.) Students joined five squares to form different (pentomino) shapes. At first, some students made only symmetrical shapes or shapes with names. When they realised they were required to make more shapes, they realised that symmetry and a common name were not essential for defining *a shape*. Their prior expectation influenced selective attention and initial schema location. Intentional and conceptual changes also occurred when they considered shapes in different orientations and the students developed their understanding of what constituted sameness and difference in that context.

A subsequent study corroborated the theoretical explanation on responsiveness within the context of adult students learning mathematics through interactive construction of concepts. An analysis of critical incidents revealed that interactions, affect, responsiveness and attention were important features of learning in a problem-solving classroom setting (Owens, Perry, Conroy, Geogeghan, & Howe, 1998).

Attention and Visualisation

Tasks themselves, especially the directions given to students may encourage use of different kinds of reasoning; for example, novel tasks and tasks which relate to physical objects may encourage imagery (Paivio, 1971). Krutetskii (1976) pointed out that some students preferred visual methods, others analytical or verbal methods while other students preferred to use both methods. Lowrie (1994) found that students chose visual or verbal methods depending on the nature of the problem and how difficult they found it. Many studies (see, for example, Burden & Coulson, 1981; Guay, McDaniel, & Angelo, 1978; Lohman, 1979; McGee, 1979; Poltrock & Agnoli, 1986) make it clear that often different subjects use different strategies for doing the same spatial tasks. For example, on tasks in which the subject has to decide if the object has been rotated, some subjects have rotated the visual image to the new orientation, others have considered the object from a different perspective, and others recognised features and used more *analytic* strategies. Studies by Egan (1979) and by Carpenter and Just (1986) have made it clear that part-whole analysis can be used in both "orientation" (other perspective) and "visualisation" (transformation) tasks. If this is indeed the case, then visualisation (used in the broad sense of all visual imagery) is a skill which can involve analysis and checking and hence concepts (Clements, 1983; Krutetskii, 1976). Categories and concepts are maintained and linked through visual imagery (Lakoff, 1987; Johnson, 1987). For example, in classifying vertically opposite angles, an image as well as meaning for the words is established and a full appreciation of the meaning is only available when the equality of the angles is actually perceived (Van Hiele, 1986).

"Spatial ability may not consist so much in the ability to transform an image as in the ability to create the type of abstract, relation-preserving structure on which these sorts of transformations may be most easily and successfully performed" (Lohman, Pellegrino, Alderton, & Regian, 1987, p. 274). Some spatial abilities as well as visual memory appear to assist visual imagery; for example, in Poltrock and Agnoli's (1986) study, efficient image rotation, image integration, adding detail, and image scanning contributed to performance on spatial tests but image generation time did not. Tartre (1990b) found that, in finding an irregular area, picture-completion scores were related to the quality of the estimate, changing an unproductive mind set, adding marks to show relationships, mentally moving or assessing size and shape of part of a figure, getting the correct answer without hints, and relating to previous knowledge structures. The influence of visual skills, and diversity of means by which students can answer a simple equal-angle selection task should not be underestimated. Spatial skills such as disembedding or re-seeing are helpful in using imagery and in solving spatial problems. The skill of being able to disembed shapes and parts of shapes, seems to be a different skill from those requiring mental manipulation of images (Eliot, 1987; Tartre, 1990a) but the tasks which seem to require this skill may still be completed by analytic procedures. It is, therefore, expected that a broad range of methods will be used in equal-angle selection tasks and this is expected to influence performance scores on these tasks.

Van Hiele (1986) suggested that concepts in geometry such as equality of angles develop through the following stages:

1. The student reasons about basic geometric concepts ... primarily by means of visual considerations of the concept as a whole without explicit regard to properties of its components. ...

2. The student reasons about geometric concepts by means of an informal analysis of component parts and attributes. Necessary properties of the concept are established. ...
3. The student logically orders the properties of concepts, forms abstract definitions, and can distinguish between the necessity and sufficiency of a set of properties in determining a concept. (Burger and Shaughnessy, 1986, p.31)

Students with less developed approaches to equal-angle selection may be operating in the earlier two levels.

Classroom Learning

Mental representation of equal angles may be verbal and imagistic (Del Campo & Clements, 1990; Goldin, 1987). Verbal representations are encouraged by interactions between people even if mediated by a computer. Communication encourages identification and representation of the angle-problem situations, and development of cognitive processes for solving angle problems. Interactions with others and internal representations assist analysis which is an important aspect of concept development and problem solving (Krutetskii, 1976; Lean & Clements, 1981). If this is the case, both visual and auditory presentations of the analysis of equal-angle selection tasks may assist later performance.

Classroom learning environments should not only provide receptive-language opportunities when students process another person's communication by listening, reading, interpreting diagrams, pictures, and actions but also expressive-language opportunities for speaking, writing, drawing, performing, and imagining (Del Campo & Clements, 1990). Battista and Clements (1991) encouraged teachers to allow students to use visual reasoning and to foster discussion in which students explain their reasoning and relate their concepts and visualisations. If expressive-language is important in learning, then students who manipulate and speak about their equal-angle selection tasks are more likely to perform better on this kind of task in future.

Sometimes, though, visual diagrams seem to mislead students and this is likely when concepts are not well established (Kouba, Brown, Carpenter, Lindquist, Silver, and Swafford, 1988). In equal-angle selection tasks, students are more likely to perform better if they know analytical principles such as vertically opposite angles are equal and can decide quickly when an analytical principle is relevant and when visual rotation and decision-making is needed. Equal-angle selection tasks are more difficult if the diagrams are more complex, angles are dissected by lines, angle distractors are visually close in size, or angles are rotated, more distant, or external (when only internal angles of a polygon are anticipated).

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Experimental Design and Hypotheses

The previous discussion has indicated that there is some conflict in understanding why students find some tasks more difficult than others. Poor performance can be attributed, on the one hand, to cognitive load or it may be attributed to attending to irrelevant aspects. If students expect to use certain actions because of instructional procedures, it is possible that their attention may assist or detract from their performance on the problem. There could be variance from one instructional mode to another.

The present experiment is a preliminary examination of the effect of responding modality (looking, listening, speaking, doing) and task difficulty (low, high) on the accuracy of performance by adult participants on an equal-angle selection task. The responding modality variable was between-subjects whereas task difficulty was a repeated measures within-subjects variable; the two-way 4 x 2 factorial design is shown in Figure 2.

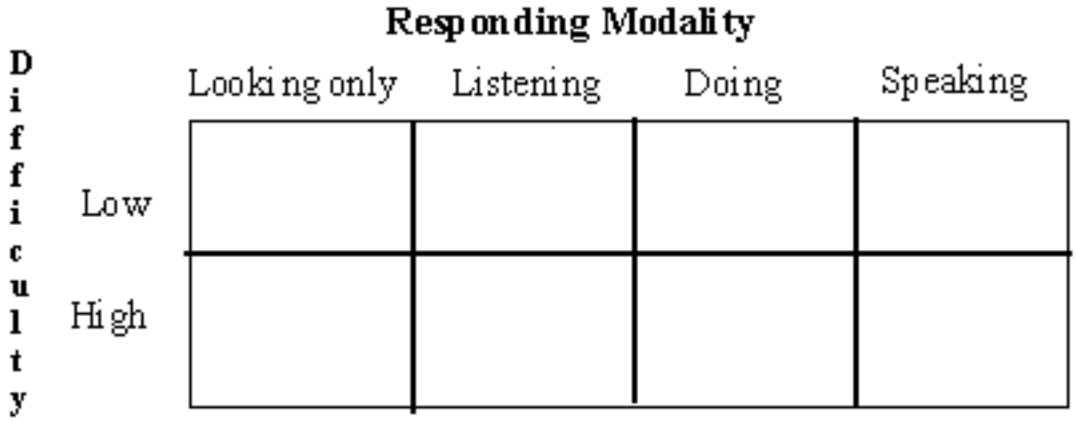

Figure 2. Representation of the study variables.

The mode of responding was encouraged by the instructions given to the participants. Task difficulty (internal load) may become significant under certain responding modes (external load) in accord with cognitive load theory. In this case, the looking-only group are expected to perform better than those required to use a second response modality so long as they reached capacity due to task difficulty. It was anticipated that there would be an interaction effect between task difficulty and responding type. This should be apparent if the looking-only group performs better on hard items than the groups who are encouraged to respond in another way (listening, doing, speaking). This would be consistent with a capacity-constrained approach (Just & Carpenter, 1992) which suggests that individual differences will emerge only when sufficient working-memory capacity has been exhausted for some subjects.

If it is the case that proximal multi-mode instruction facilitates learning and task performance then accuracy of the listening group during the test phase should exceed that of the looking-only group.

On the other hand, since speaking and doing are expressive learning modes involving interaction and external actions, it is expected that these responding modalities, especially speaking, will encourage learning and the use of concepts in analysis. If this is the case, the accuracy of these groups should exceed that of the looking-only and listening groups. That is, an internal attentional input is expected in terms of van der Heijden's theory.

It is thought that listening may focus attention more than the other modes of responding. If small variance in accuracy is a measure of a limited range of attentional foci, then this group is expected to have a smaller variance than other groups.Variance was expected to increase with diversity of attention and responsiveness, especially on harder tasks.

Retrospective recall of participants should indicate diversity of attention. Matters of effort, stress, fatigue, selective attention, expectations, intentions, perceptions, feelings, knowledge, and responsiveness should be indicated in line with the model presented by Owens (1994).

Participants

The participants were 60 female and male volunteer Education and Arts students (mainly from Introduction to Psychology). Participants were allocated to one of the four responding conditions, depending on the condition running on the day they came. Four of the 15 participants from each of the conditions were randomly selected for interview.

Method

Equipment. Instructions, training and test phases were presented to participants using Macintosh G3 or 7600 computers. Geometric figures were created in MacDraw and imported into SuperLab. The SuperLab program presented all trials and key-presses and responses times were recorded with accuracy to one milliseconds. Auditory instructions for the listening condition were digitized using SoundEdit and also imported and presented in SuperLab. Students in the doing group had acetate transparency sheets and marker pens which could be placed over the computer screen for copying angles.

Stimuli. The experimental tasks consisted of a series of equal-angle selection problems presented on computer. There were six different figures involving straight line intervals forming polygons. The vertices (points) were labelled with letters. The equal-angle selection tasks referred to one of the angles of the figure and the question was asked, for example, "What angle is equal to angle EFG?" The participants were asked to type in the letters of an angle equal to it. There was at least one other angle of the same size in the figure. Sample tasks are shown in Figure 3.

The difficulty of the tasks varied. For example, vertically opposite angles were easy. Some angles were judged on purely perceptual grounds (they looked equal) while others could be gauged as equal because of geometric properties such as the equality of alternate angles with parallel lines.

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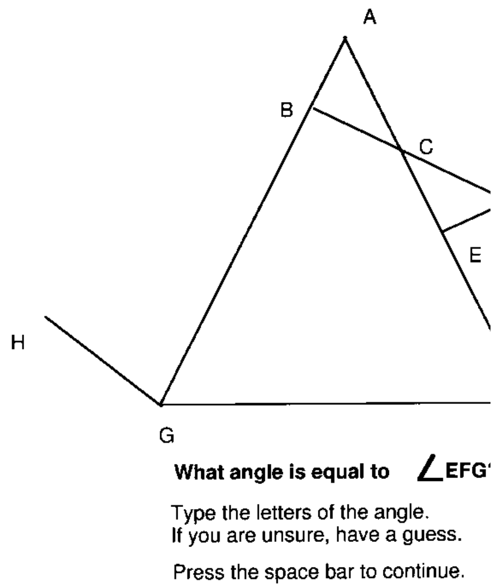

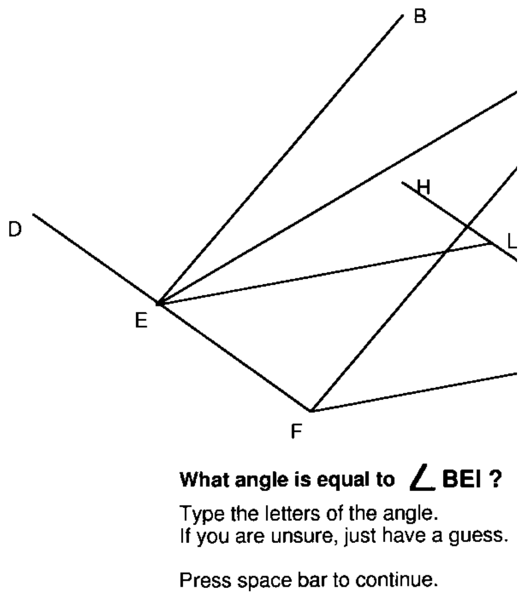

3a. Screen used during training and testing 3b. Screen used during testing only.*Figure 3.* Two of the six diagrams used in the study.

Procedure. A series of geometric equal-angle selection problems were presented to participants individually on computer.

Participants were first told how to name an angle using letters, and to type X if they made a mistake before typing their answer. They were given a simple practice task.

The *training phase* consisted of nine equal-angle selection tasks. The first four tasks used one figure and the remaining five tasks used a second figure.

In the learning (training) phase, the question was posed, participants typed their answer, and then the correct solution was presented. The rays of the angle were darkened, the angle then moved to the matching angle which was darkened too. If a geometric explanation could be used it was written on the screen. The participants were able to move onto the next question by pressing the space bar.

The computer program's visual stimuli were the same for each of the four responding-modality conditions. The only difference between conditions in the training phase was the nature of the interaction and response required of participants. Specifically:

1. In the looking-only group, the participants watched the screen and responded.

2. In the listening group, participants were presented with the same screens, attempted the questions and then watched and listened to the same explanations.

3. In the doing group, participants were encouraged to use materials to help them perform the task. They were provided with clear acetate sheets and pens which they could place over the screen and move around.

4. In the speaking group, participants were asked by the presenter to tell her how they decided which angles were equal, i.e., to think aloud. Participants were provided with the same explanations as the looking-only group.

A baseline score for the learning (training) phase was calculated on the first eight tasks.

To minimise direct memorisation from training to test there was a ten-minute delay and filler between phases. Participants were asked to talk about their course and the lectures they had recently attended. Some demographic information was also collected.

The *test phase* consisted of 18 equal-angle selection tasks presented randomly. Six different figures were used including the two used in training. Four tasks were tasks used in training. Seven were near transfer tasks from the initial figures but asking about different angles or an angle that was previously an answer (a reversal). Seven were far transfer tasks on new figures. The test phase was exactly the same for all participants, starting and ending with an easy task, with familiarity and difficulty levels presented randomly. An overall test score was the number correct from all 18 items.

Immediately after the testing phase, the interviewed participant was asked a set of questions about how they were thinking and feeling during the training and test phases. The responses were audiotaped. Copies of an easy and a hard computer screen were shown to the participant to encourage stimulated recall of thinking during the task and to ask about their effort. The qualitative data were coded using the descriptors for the cognitive load and responsiveness/attention models. A story line was developed to illustrate how students were processing information.

Results

Accuracy during Training Phase

It was expected that the groups would be similar initially but the training may have quickly affected their attempts on the items. There was a significant difference as measured by an analysis of variance ($F = 3.52$, $p = 0.02$). The means and standard deviations are given in Table 1 with the confidence intervals for the means presented in Figure 4. The doing group could use the acetate sheets to check and some did well, but the speaking group performed significantly below the listening group. This was contrary to what was expected since it was thought that the use of concepts and analysis would focus attention on equal angles.

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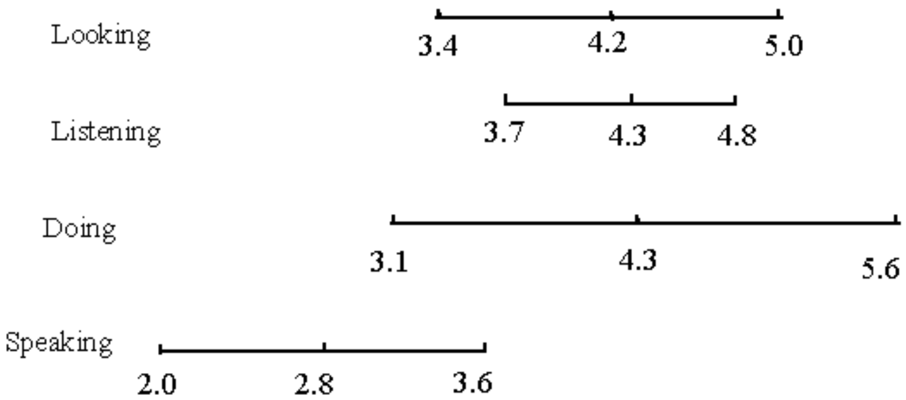
Table 1

Means and Standard Deviations for Training and the Test, and Adjusted Means for the Test by Group

Group	Training Scores		Test Scores		Adjusted Means	
	Mean (% of total)	SD	Mean (% of total)	SD	(% of total)	
Looking	4.20 (53)	1.42	10.5 (58)	2.56	10.22 (57)	
+ Listening	4.27 (53)	0.96	9.0 (50)	2.39	8.62 (48)	
+ Doing	4.38 (55)	2.17	7.7 (43)	3.13	7.26 (40)	
+ Speaking	2.80 (35)	1.37	8.2 (46)	3.12	9.36 (52)	

Note. The maximum score was 8 for the training and 18 for the test.



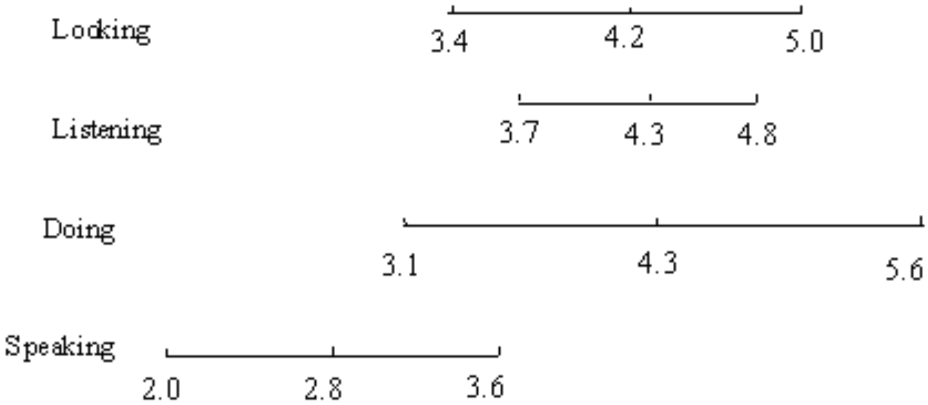


Figure 4. Confidence intervals of means of training groups.

Effect of Training on Test Scores

When all test items are considered there is a significant difference between the groups when training totals are taken as covariates (F = 4.14, p = 0× 01). The means adjusted for group and covariate are presented in Table 1. If the training totals are not taken as covariate, there is a significant difference in total scores (F=2.85, p=0.046) but no particular groups are significantly different (post hoc Scheffe test) from the others (Figure 5). The means and standard deviations for each group on the test are given in Table 1. It is only when the training scores (pretest scores) are taken into consideration that the speaking group as well as looking-only group showed improvements (see adjusted means column).

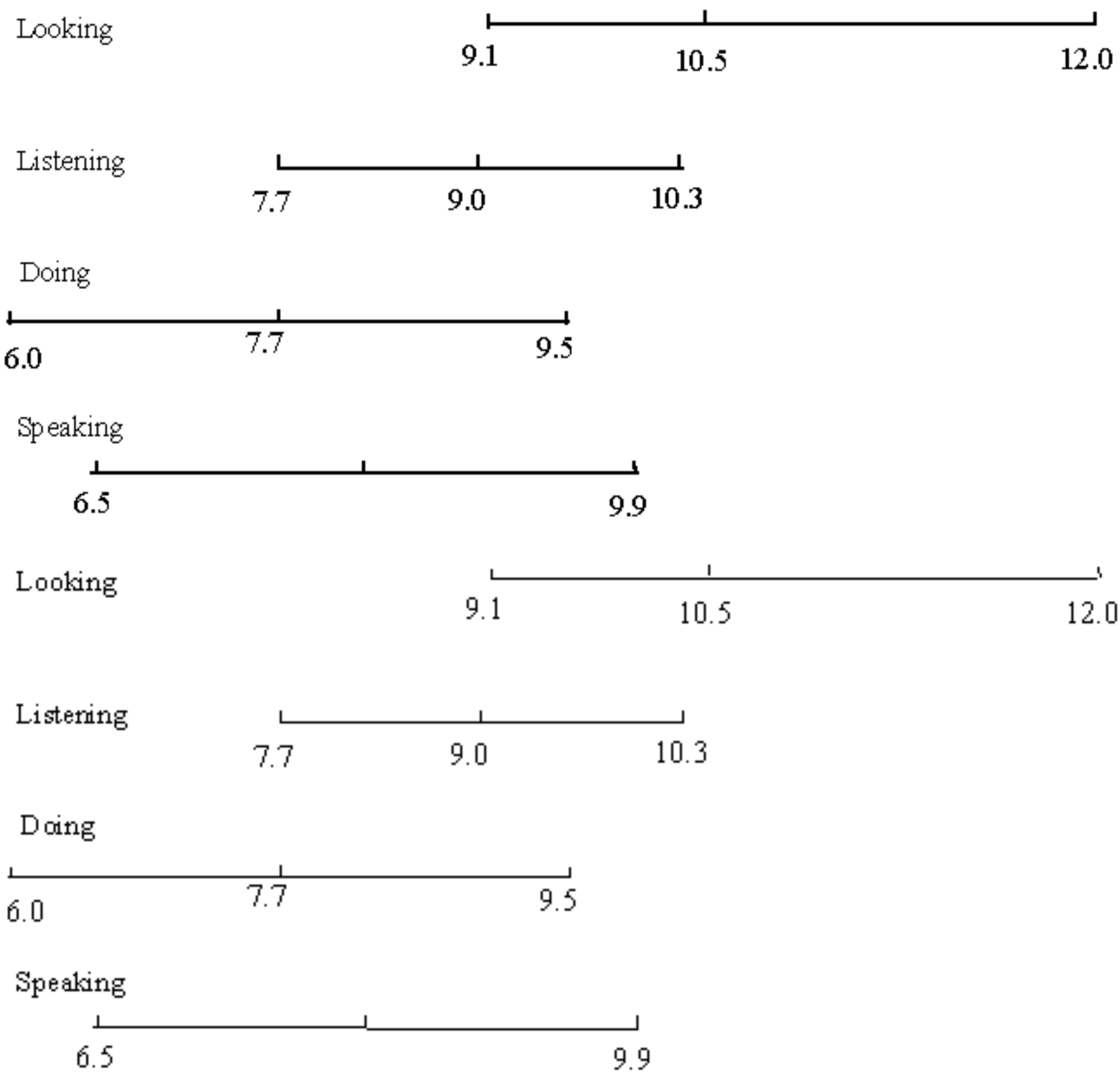


Figure 5. Confidence intervals of means for testing phase.

Although some of the doing group did well during the training phase, it can be seen from Table 1 and Figure 5 that the doing group generally were poorer, but not significantly, than the other groups in the test phase.

There was no significant difference between the groups on a score based on the four tasks in the test phase which were also given in the training phase (F=1.65, p=0.18). There was a significant difference between the groups on tasks involving new angles on the two figures used in training (F= 3.28, p=0.03). Mean performances on these near transfer tasks indicate that doing had not assisted students to analyse these two figures as much as the looking-only group but no two groups were significantly different. Part of the reason for lack of significance is the large variances within the scores. In checking far transfer in the sense of scores on tasks which are on new figures (not used in training), there was no significant difference between the groups (F=1.13, p=0.35). There were insufficient items to check for task difficulty and transfer.

Effect of Task Difficulty

Scores were analysed using two-way (group responding modality x difficulty) analyses of variance. Table 2 shows that while difficulty had an effect, the interaction of responding modality and difficulty did not have an effect. Using a cognitive load explanation, the type of responding modality did not add external load to the internal load of task difficulty.

Table 2

Effect of Task Difficulty and Responding Modality on Test Accuracy

Source of Variation	DF	MS	F	Sig of F
Group	3	3.91	2.22	0.096
Difficulty	1	165.75	115.45	0.000
Group by difficulty	3	0.98	0.68	0.567

The scores on the training and test easy tasks were very significantly correlated (r = 0.43, p=0.001), and similarly scores for the training and test hard items were nearly significantly correlated (r = 0.25, p=0.054). The selection of items seems to be validated by these correlations. The lower correlation for hard items might suggest an effect of variance between groups or individuals due to training.

There was a significant difference between the groups on the training scores for the four easiest questions (F = 3.94, 0.01) and a Scheffe test indicated that the listening and speaking groups were significantly different to each other. Table 3 gives the means for the groups. However, there was no significant difference between the groups on the training scores for the four hardest questions (F=2.64, p=0.06) but the speaking group tended to be poorer while the doing group tended to perform better. However, this group had a large standard deviation.

Table 3

Mean and Standard Deviations for Easier and Harder Items during Training by Group

Group	Easier Items		Harder Items	
	Means (% of total	SD	Mean (% of total)	SD
Looking	3.20 (80%)	0.94	1.00 (25%)	0.76
+ Listening	3.27 (82%)	0.80	1.00 (25%)	0.93
+ Doing	2.71 (68%)	0.73	1.64 (41%)	1.74
+ Speaking	2.27 (57%)	1.16	0.53 (13%)	0.83

Note. There were 4 items of the 8 in both the easier and harder groups.

There was no significant difference between groups on the six easier items of the test (F = 2.32, p = 0.09). The means and standard deviations are presented in Table 4.

There was no significant difference between the groups on the six hardest items of the test even when training total scores were taken as covariate (F = 0× 62, p = 0× 60). The means and standard deviations are presented in Table 4.

Table 4

Means and Standard Deviations for the Easiest and Hardest Items on the Test by Group

Group	Easiest Items		Hardest Items	
	Mean (% of total)	SD	Mean (% of total)	SD
Looking	5.20 (87%)	0.86	2.33 (39%)	1.54
+ Listening	4.67 (78%)	1.35	2.33 (39%)	0.98
+ Doing	4.21 (70%)	1.58	1.93 (32%)	1.21
+ Speaking	4.00 (67%)	1.51	2.00 (33%)	0.85

Note. There were 6 out of 18 items in each of the easiest and hardest groups.

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Variances in Scores

Table 1 shows that there was less variation (standard deviation squared) for the listening group during training as predicted in that the voice encourages focusing of attention. Table 3 gives the standard deviations in scores of easier and harder items for the training. Only the variance for harder items for the doing group is significantly different (using an F test) than the other variances.

Table 4 gives the standard deviations for the hardest and easiest tasks in the test. The looking-only group interestingly had a lower variance for the easiest tasks (significantly lower than the other groups) and a larger variance for the hardest tasks (significantly different from all but the doing group). Listening and speaking may have focused attention more.

Discussion

The opportunity to speak, followed by the written correct answers seems to have assisted students to do well in the test although not as well as the looking-only group (see adjusted means in Table 1). In particular, speaking seems to have assisted with the hard tasks (Table 4). Despite this result, overall the expressive modes of learning (doing and speaking) did not seem to assist more than receptive modes (listening and looking) (Tables 1, 3 and 4, Figures 4 and 5, F tests). Interestingly, the looking-only group performed better, if not significantly. It could be speculated that the looking-only group needed to really concentrate and problem solve without assistance. They needed to take in the visual cues which they could do without distraction. This might be in line with cognitive load theory but the dual-modality listening group should have increased capacity to perform well. Again there is no conclusive support for the previously described cognitive-load interpretation. The looking-only group might have performed better due to entry differences. However, there were no differences in the range of mathematics or visual design experience in this group compared to the speaking and listening groups although the doing group did have fewer participants with visual-design experiences. The top scoring student in the test was in the looking-only group. This person also did well in the training and although she had not done mathematics or visual design at school or university she had completed a related TAFE course. There were other high scores in the looking-only group but they had a variety of backgrounds.

However, the low variance for the test for the looking-only group on the easiest tasks and high variance on the hardest tasks suggests that some students did not learn to attend to important aspects for difficult tasks. The doing group generally showed large variance, suggesting that the use of acetate to check results was used to varying degrees. While one participant in the speaking group would have liked to use the acetate sheets, two-thirds of the group who had this opportunity (doing group) chose not to use it, possibly because they were able to use analysis or they were happy with visualising. The lack of use of the acetate sheets may have been affected by expectation¾ it is not an adult thing to use materials. Of those who used the acetate sheets, two performed well, one average and two very poorly in the test as well as in training (they, by chance, also had poorer visual-design or mathematics backgrounds.) One participant in the doing group scored full marks in training but without using the acetate sheets. There was no difference between the scores of the participants who chose to use acetate sheets and those who did not as there was significant variation between the students in each group. The acetate sheets may have been an ideal way to focus attention during training but it was unavailable during the test phase. It could also be argued that they were affected by being tested in a mode different from training.

In general, there is some support from the tests of variance for the effects of attention afforded by the different response modalities. However, this is not conclusive, and the qualitative analysis assists our understanding. Oral reporting by subjects on levels of stress in cognitive load studies was espoused by Paas and van Merrienboer (1994), and oral reports were used in the current study to provide further insight into how students were responding to the tasks. The interviews of the four participants of the listening group will be used in this paper

Attention and Expectation

Previous studies have suggested that dual-modality perception may provide more resources and so improve performance (Sweller & Chandler, 1991). This was not substantiated by the quantitative analyses, and all four interviewed participants said that they did not think that the listening condition affected them carrying out the task for various reasons. Nevertheless, one respondent said she began to listen to what was said when she thought it might help her in the second phase of the experiment. One participant said that he did not think the listening condition helped or hindered "because I was concentrating on the visual 'cause that was the task that I was doing really." Another student commented "at the beginning it did tell you the different types of angles and everything which would have made it easier but I didn't pay that much attention to that, to carry that on. Which is pretty silly really, I shoulda (sic)." Another student commented she did not think the listening condition had much of an effect as she had learnt so much about angles before whereas another said "So I'd listen to it and read as well but I couldn't remember what they were so it didn't make sense anyway." It seems that some were already focused by existing knowledge, one was focused by the comments while others felt they could not link it to existing schema easily. In other words, a lack of expectation or prior knowledge was affecting attention.

Listening to another speak cannot be self-paced like reading or speaking to oneself so it is possible that the members of the listening group were not advantaged by listening. However, the expectations affected the responsiveness of those who thought listening would help in the test while another did not appreciate the value of the comments at the time. The results support the theory that expectation and prior knowledge can influence attention and hence responsiveness and learning.

Differing Backgrounds, Feelings, and Approaches

Students were able to say which tasks they found easier (e.g., right angles) and harder (e.g., diagrams that had lines crossing through the angles or angles that were further apart).

A female participant said that initially she "just did it visually, ... remembered about what the angle looked like, like made a visual picture of it (and) sort of rotated around the other angles, to find one that matched, basically." She thought we were interested in the accuracy of the brain in estimating angle size. Later she changed her approach; "(I'd) see if there was a geometrical law that would tell if it was the same. If not, then I just sort of looked at what looked like it was the same." She used the parallelogram, and right angles. "The ones where I had to guess were slightly more difficult because there was no way of knowing if I was right or not ... (but I) eliminated as many as possible; ... separate triangles were more difficult. I wouldn't say emotion came into it ... The beginning was helpful because it told me what to expect of the actual demonstration ... hopefully (I learnt) about visual sort of processing." Interestingly, this student shows how higher order schema assisted in location and identity and how expectations influenced attention. She also gives a range of tactics that she used to solve the tasks. Her feelings seem to have little influence expect that she liked to be sure she was correct.

Another students used similar approaches but with less effort He said that he had done this sort of question at school and he was analysing using the geometric facts but on a few it was concentration that was needed to match them. He also tried to remember from the training, and to just look quickly and select. Howeverthe other two students did not verbailse their attempts well. They were more influenced by feelings.

One commented that she had not liked mathematics at school or put an effort into it, and she was pretty shocked about what she had to do in the experiment. However, she put an effort into it to assist the researcher and to do her best. She just looked for similar triangles and "I'd attend to (the letters of the angle), try and locate it first, ... try and visualise it to the other one to see if it's okay, ...look overall ... then one by one ... and wondering whether I'm getting it right or wrong. I started listening, and trying to figure out and then I thought maybe this is going to be the same question in the second one so I'll try and remember it but it didn't work so... when the diagrams were more complicated, I thought oh no, I thought how am I going to get through this one."

The other participant did not like maths at school but she said she was not too stressed by the experiment. She "just matched it up." However, it is clear from her comments and body reactions that the experiment brought back negative feeling from school. She questioned what she was learning but thought it was visual recognition. She would compare visually, quickly, and then when the correct answer is given "I find that it's wrong. Can you imagine? ... I didn't look at all the mathematical phrases and see which one's the opposite one's to that." She just wanted to get it over, she was embarrassed that she was doing poorly. She thought we might have been seeing how people think under pressure in the two phases.

These retrospective comments have shown that emotions can play a role and that expectations (e.g., thinking that the training would help with the second part) or intentions (e.g., get this finished quickly or e.g., "do well so I am not embarrassed") will influence selective attention and responsiveness. There were also differences in approaches between those who expected to do it by visually matching and those who expected to be able to analyse. The focus was further narrowed when specific geometric ideas (e.g., angles in a parallelogram) were considered. The expectations assisted in locating visual perceptions in existing schema. Having established the location, the identity of the inputs could be established. One explanation is that schema (e.g., using a number fact rather than counting to solve a problem) can reduce load English (1994). An alternative explanation is that using geometric ideas may have reduced the number of searches and matches by focusing attention.

Conclusion

This study was an initial experiment using spatial tasks with different types of responding in order to evaluate the effects of attention and responsiveness on learning. The type of responding affected the cognitive processing and expectations of the students to some extent. The different inputs, visual and auditory, also seem to have affected attention. The looking-only participants were reliant on their own mental processing and the visual inputs. Participants who could use acetate sheets or who spoke were more involved in outwardly responding. Interestingly, the looking-only group generally performed better although not significantly and the reason for this is not clear. The looking-only group's performance does not seem to be due to less cognitive load as they were not significantly better on the harder items as was predicted by cognitive load theory. It may have been due to an increased reliance on themselves in decision-making as there was less interaction with materials or other people. With such an expectation, they may have concentrated and focused on ways to analyse and ways of making visual judgments. In addition, the use of dual modalities with the listening group was not more effective.

Cognitive load was not an issue for participants using materials in training as they did not do significantly more poorly. However, the use of a physical representation seems to have reduced the need to internalise and visualise so they may not have improved in recognising angles for the test phase.

It is often said that active involvement is better than passive listening or looking. There seems to be some evidence here that listening was not so useful but that looking could be more self-paced. The auditory explanations could not be played back and listened to again but participants could choose when to finish reading a comment or working on a task. This is often the case in a lecture or linear computer program that is not interactive. Speaking, however, was a way of self-paced hearing.

The study has emphasised that expectations and intentions along within the control of the responding modality focused attention. Attention and responsiveness did influence the results to some extent and this is seen mostly in the variance within the groups, and the verbal reports of students even within one group. These reports, however, emphasised the strength of affective aspects on attending and responsiveness.

The findings of this study can be understood in terms of the problem solving model of Owens (1994) with its emphasis on responsiveness as influenced by affect and cognitive processes such as visualising, conceptual analysis, and selective attention. The study illustrates how concepts or higher centres can influence the locating and identifying of inputs as an aspect of attention.

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