<u>Diagram Representation: a comparison of animated and static formats.</u>

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<u>Abstract</u>

Research into diagrams has revealed limited current knowledge of the "cognitive value of *any* graphical representation" (Scaife and Rogers 1996, p.185). This study investigated the effects of different formats of the same graphical representation and of different task presentation on student learning. One hundred and twelve pupils aged thirteen and fourteen used either a static paper or animated computer graphical representation of cardiac circulation. Half of the pupils in each condition used an open task from which to find information, the other half used a structured work sheet. Pupils completed a test diagram to demonstrate their understanding of blood flow through the heart, which was analysed on four different aspects to assess student learning. A two way independent analysis of variance and chi-square analyses were used to determine differences in learning. Although no significant differences in media presentation were found, learning was significantly affected by task presentation. Futhermore, the types of errors made in student learning were found to differ significantly across conditions.

<u>Introduction</u>

Diagrams are graphic forms of conveying information, used extensively in educational contexts across the curriculum. Winn (1987) proposes the function of diagrams to be "to describe whole processes and structures, often at levels of great complexity" (p.153). Larkin and Simon (1987) allege that diagrams offer several pieces of information simultaneously, unlike text which is sequential in processing. This precludes the need to unite separate facts to comprehend a whole concept, as many important aspects for comprehension are perceptually available in the diagram and do not need to be worked out, hence reducing cognitive processing. Diagrams should therefore facilitate understanding, as information should be more explicit and require less inference recognition.

Diagrams are not only available on paper in static format, but also on computer software. An increase in computer technology, and more advanced forms of computer representation, has resulted in a growing collection of educational software. Investigation into literature on diagrams has revealed limited current knowledge of the cognitive value of graphical representation, and many assumptions that multimedia and more advanced technology result in improved learning (Scaife and Rogers 1996). Advances in graphical technology have enabled more varied and dynamic illustration of concepts, for example, using animated videos showing motion more explicitly. This, together with increased computer facilities within schools, highlights the importance of investigating whether educational software, in this form, can be instructionally advantageous, and how diagram design can generate optimum learning.

Previous research suggests that pictures on paper are advantageous over pictures on computer software (Reid and Beveridge 1986). Part of this study, investigating the effect of text and illustration on the learning of a school science topic, focused on the use of paper formats compared with computer formats. The computer condition involved reading text from the screen and pressing a key to display an appropriate picture, which could be recalled as frequently as necessary. Results showed that illustrations did not significantly aid learning in either format, but overall the pupils performed significantly better in the paper format than the computer format.

As well as assessing ‘performance’ it is important to investigate the nature of the underlying cognitive processes leading to conceptual understanding. It has been noted that different representational formats of the same structure “can activate completely different processes” (Zhang and Norman 1994 p.118). Different processes in turn may result in different conceptual understanding. So the representational format may be critical in the way comprehension is actualised.

The Reid and Beveridge (1986) study used static pictures in both formats, so does animation, available on computer presentation, assist learning in diagrammatic form? Assumptions exist that more technologically advanced representations result in more comprehensive and effective learning, for example the more animated or interactive the diagram, the more the learning of an overall concept is facilitated (Scaife and Rogers 1996). However, research investigating both animated and static diagrams, has shown no comprehensive evidence of improved understanding, suggesting that provision of a moving visual image does not necessarily facilitate overall conceptual understanding.

Kaiser, Proffitt, Whelan and Hecht (1992) examined the effect of animation on dynamical judgements, and found that performance on a static task was not enhanced by the use of moving mental images, suggesting that concepts represented through animation are not necessarily generalised to static contexts. They also found that the complexity of a system restricted accurate interpretation of movement, and the errors subjects made occurred on multidimensional problems, or when the "complexity of the motion system was overestimated" (Kaiser et. al. 1992, p.685). This suggests that conceptual understanding of multidimensional or complex structures are not facilitated by animation alone. Where only one dimension of dynamic information was present, then animation facilitated accurate observation. The break down of dynamic occurrences, then, was important in facilitating correct dynamical judgement.

Computer presentation may offer more technologically advanced representation, but not necessarily better learning. Rogers and Scaife (1997) suggest that assimilation of information is more difficult as the learner has to integrate multiple representations, not always simultaneously available on the screen. Written and spoken information relating to a diagrammatic representation may be available in separate parts of the programme, requiring the user to pick out relevant details from separate components and unify them to reach conceptual understanding. Levels of student participation or interactivity are also proposed to affect educational enhancement (Woolf and Hall 1995). A simulation such as The Cardiac Tutor provides facilities for the student to manipulate appropriate responses and actions in a simulated emergency room environment where cardiac resuscitation is required (Woolf and Hall 1995). The programme offers help, feedback and specific instruction when required. This active student participation showed better performance than with classroom instruction. Furthermore, evaluation of educational software cites interactivity as an "important hallmark of quality" (Barker and King 1993, p.312). Thus, those that provide participation by users are rated more highly than those just presenting information. The level of user interaction may influence conceptual learning and understanding.

Diagrams, then, can make important aspects of information salient and facilitate "perceptual parsing and inferencing through directing attention to key components that are essential for different stages of.....learning" (Scaife and Rogers 1996, p. 207). To investigate the cognitive value of graphical representations Scaife and Rogers (1996) propose the following criteria in analysing cognitive processes; *computational offloading* refers to the degree to which diagrams provide cognitive benefit by reducing cognitive processing; *re-representation* encompasses how different representations of the same structure make understanding easier or harder; and *graphical constraints* applies to how graphical elements of the representation constrain inferences that can be made. Thus diagrams need to be investigated to see if they accomplish this by examining particular aspects of learning such as, the kinds of inferences made, what information is lost, misinterpreted or correctly ingested, how understanding is integrated with previous knowledge, and the effect of different representations of the same structure.

This study used a diagrammatic representation of blood flow through the heart, in both CD ROM and paper format, to compare animated with static representation of the concept. As CD ROM presentation invites a more open focus for exploring information, whereas formal teaching situations use specific task orientation, two different forms of task presentation (open and structured) were also used. This study, then, investigated the effect of different formats of the same graphical representation and different task presentations on conceptual understanding of a dynamic process.

Method

a) Subjects

112 year nine pupils aged thirteen and fourteen years, from two Sussex community colleges participated in the study. Fifty three were male (mean age = 13 years 10 months; 166 months sd=3.2), and fifty nine were female (mean age = 13 years 11 months; 167 months sd=3.6). In one college the year was streamed for science with groups graded from one to three, participants being from group two. In the other college pupils were not streamed. 'Blood flow through the heart' had not yet been covered in the curriculum programme. Pupils using the CD ROM all professed to be familiar with CD ROM use, and navigated the programme with little difficulty. Pupils were informed the purpose of the experiment was to investigate learning from different diagram presentations with a view to improving design.

b) Apparatus

Two types of information presentation were used; CD ROM and static paper information. Two types of task were given; either 'open' or 'structured'. The same test was given to all participants. Subjects participated either in a classroom or small laboratory room, according to what was available in the school.

CD ROM condition

The 'heart' section of 'What's the Secret?' CD ROM from 3M Learning Software was used. This was run on a Macintosh Quadra 700 computer and on a Viglen PCI P.560 computer terminal. The programme consists of information covering varying aspects about the heart, including animated video presentation of blood flow through the heart, and accompanying text. Information needed for overall understanding of blood flow was found on separate parts of the programme. Pupils were guided to the relevant areas prior to beginning their own investigations. Pupils interacted with the programme by selecting and clicking on areas of information or animated videos as frequently as desired. Pupils were provided with pens and plain paper to make their own notes while exploring the information if they chose.

Static paper condition

This consisted of colour printed information selected and taken from the heart section of 'What's the Secret' CD ROM (see appendix A). This was designed to ensure coverage of information relating to blood flow through the heart was equivalent to the CD ROM information needed to complete the test. Pupils were provided with pens to make notes on the information if they chose.

Tasks

These were of two types; an open task and a structured worksheet, designed collaboratively with a science teacher (see appendix B). Half the subjects in both the static and CD ROM conditions used the open task and the other half used the worksheet.

Post test

This consisted of a black and white diagram of the heart, which pupils had to complete within five minutes, demonstrating their knowledge of blood flow through the heart (see appendix C). The test was a simplified version of the diagram taken from the CD ROM, as pupils in the pilot study found the original number of blood vessels too confusing. This was not felt to reduce evidence of their knowledge of blood flow through the heart. To complete the test diagram pupils were given blue and red pens and the eight following labels; 'to body', 'from body', 'to lungs', 'from lungs', 'right atrium', 'left atrium', 'right ventricle', 'left ventricle'. They were instructed to use the blue pen for blood 'less in oxygen' (deoxygenated) and the red pen for blood 'rich in oxygen' (oxygenated), and use arrows to show where the blood enters, flows through, and leaves the heart. They were also required to put the eight labels in the appropriate places.

The materials were tested in a small pilot study, using four pairs of pupils in each condition, to ensure that the information, task and test were appropriate. The pilot study was also used to formulate the task instructions. The pilot study enabled the experimenter to assess CD ROM interaction within the restricted time allocation, so that relevant guidance could be given to participants in the CD ROM condition.

c) <u>Design</u>

Subjects participated either in the CD ROM condition or the static condition, and also used either an open or structured task. The experiment was therefore a 2 (CD ROM or static) x 2 (open or structured) design. The two independent variables were type of information presentation, and type of task given. The dependent variable was the test score. Participants were assigned to work with information either in the CD ROM (animated) or the paper (static) format. Half of each of these groups worked from the ‘open’ task, the other half using the structured worksheet. All participants worked in pairs for fifteen minutes on their allocated information, followed immediately by the test, which was undertaken individually. Time allocation was decided as a combination of ensuring adequate time for collecting necessary information and restrictions from school curriculum activities.

d) Procedure

As co-operative working was important the teacher placed pupils in appropriately suited pairs.

CD ROM condition

Participants sat in pairs in front of their allocated computer terminal, with the heart section of ‘What’s the Secret?’ ready loaded. They were informed that they had fifteen minutes to explore the CD ROM to find out the required information. The same instructions were given verbally and in print so that participants could refer back to the task. They were told they could make their own notes if they so desired. Approximately five minutes was initially spent with the experimenter directing them to the most relevant areas of information on the CD ROM, (for example, an animated video of blood flowing in through and out of the heart) as the programme covered several other areas relating to the heart, and time restriction limited the freedom of exploration. Pupils could ask for guidance if they were unable to find the information they needed. After fifteen minutes participants were moved to separate tables to complete the test. Again instructions were given both verbally and in print. Blue and red pens were provided, as were the eight appropriate labels. Use of information and notes was not permitted for the test.

Static condition

Two classes as a whole participated in this condition. One class was given the ‘open’ task, the other used the structured worksheet. Participants were also given the same instructions verbally as in print, except that they were told they could make notes on the paper information if they so desired. Participants again worked with the information in pairs for fifteen minutes. They completed the test individually, also being provided with blue and red pens, eight appropriate labels, and prohibited from using information or notes.

Scoring method.

Four different aspects of the completed test diagram were scored to analyse performance, and to investigate errors in learning. One point was allocated for each of the following; (i) different types of blood (oxygenated and deoxygenated) represented in separate sides of the heart; (ii) depicting different types of blood in the correct sides, oxygenated in the left side and deoxygenated in the right side; (iii) correct labelling using the eight labels, including accurate depiction of right and left sides; (iv) correct depiction of direction of blood flow using arrows, or from labelling if arrows were not used. Subjects could therefore receive a score from 0 to 4. An interobserver reliability score of 95% was achieved.

Results

The data were analysed to determine whether media presentation or type of task affected learning or understanding about blood flow through the heart, and to determine the kinds of inferences made from the diagrams. There were two independent variables (media presentation and task type) with the test score as the dependent variable. The data are presented in three sections. First, analyses of the effects of both variables on the overall test score, second, analyses of the effects of variables on selected areas of the test from which scores were obtained, and third analyses of errors made.

1. Analysis of both variables on the overall test score.

The means and standard deviations of the task scores are given in table 1.

Table 1.

Mean test scores for media presentation and task type.

(sd = standard deviation)

	structured worksheet	open task
CD ROM	**2.29 sd=1.24**	**1.79 sd=.99**
paper static	**2.43 sd=1.43**	**1.86 sd=1.33**

A two way independent analysis of variance (ANOVA) was performed on the test scores (see table 2).

Table 2.

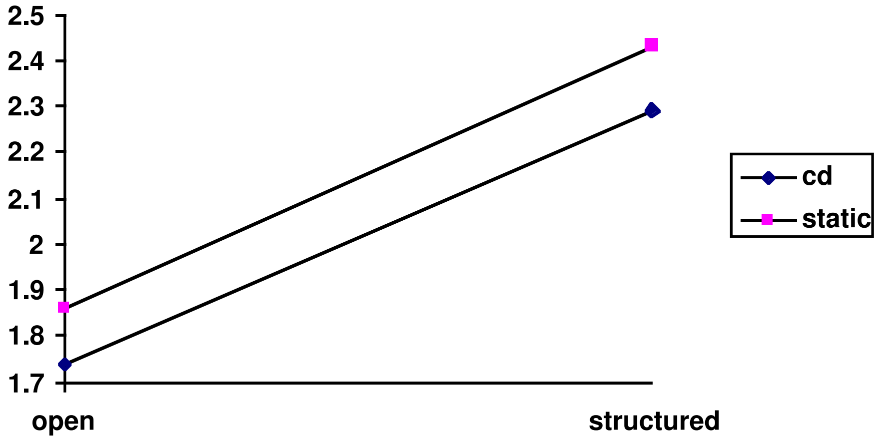
ANOVA table for score.

	DF	sum of squares	mean square	F-value	P-value
media	**1**	**.32**	**.32**	**.20**	**.6529**
task type	**1**	**8.04**	**8.04**	**5.08**	**.0262**
media/task	**1**	**3.57E-2**	**3.57E-2**	**2.26E-2**	**.8808**
residual	**108**	**170.71**	**1.58**		

No significant main effect of media was found, so media presentation did not significantly affect test scores. There was a significant main effect of task type ($F=5.08$; $df = 1,1$; $p<0.02$). A Scheffe test confirmed this effect ($p< 0.0215$); those using a structured worksheet performed significantly better than those using an open task, regardless of media presentation. No interaction was found between the two variables (see graph 1).

Graph 1

Interaction line plot showing effects of media presentation and task types.



2. Analysis of the effects of variables on selected areas of the test

A series of chi-square analyses were performed separately on the four selected parts of the test to determine whether media presentation or task type affected performance in particular areas of the test. No significant differences were shown in any section.

Blood in separate sides	**chi-square = 0.017**, d.f = 1, not significant. Two-tailed test.
Blood in correct sides	**chi-square = 0.013**, d.f = 1, not significant. Two-tailed test.
Labels	**chi-square = 0.505**, d.f = 1, not significant. Two-tailed test.
Directionality	**chi-square = 0.108**, d.f = 1, not significant. Two-tailed test.

As no significant difference was found on the four aspects, figures of overall subject performance on each aspect were examined and found to be as follows;

.84 = correct perception of separate sides.
.69 = oxygenated and deoxygenated blood shown in correct sides.
.21 = correctly labelled.
.34 = correct direction of blood flow.

These figures demonstrate that pupils generally made more errors with labelling and direction of blood flow.

3. Analysis of errors made.

Analysis of labelling and direction of blood flow revealed that differences existed in errors of interpretation of blood flow. The two most noteworthy errors were; showing blood to flow into the heart deoxygenated but to flow out oxygenated or vice versa; and perceiving the blood to enter the heart through the ventricles and leave via the atria. A chi-square was performed to determine whether interpretations were affected by the two variables, and was found to be significant for 'in deoxygenated/out oxygenated' (chi-square = **6.00; d.f = 1;** Fisher exact **p<0.0222)**, and approaching significance for 'blood entry through ventricles' (chi-square = **4.03; d.f = 1;** Fisher exact **p<0.0608**). Some cell counts were less than five, so Fisher exact was used. It should also be noted that one cell count contained a zero (see table 3)

Table 3.

a) Chi-square table for blood flow 'in oxygenated/out deoxygenated'

	structured	open	Total
CD	8	8	16
static	0	8	8
Total	8	16	24

chi-square = 1.333 + 0.667 +
2.667 + 1.333 = 6.000
df = 1
1 cells with expected counts less than 5.0

b) Chi-square table for depiction of blood entering ventricles and leaving via atria.

	structured	open	Total
CD	7	4	11
static	4	12	16
Total	11	16	27

chi-square = 1.415 + 0.973 +
0.973 + 0.669 = 4.030
df = 1
1 cells with expected counts less than 5.0

Discussion

The aim of this study was primarily to investigate pupil learning from diagrams using either a static or an animated format. Although overall understanding was not significantly different according to media presentation, understanding was significantly affected by task presentation. Furthermore, analysis of specific areas of pupil learning showed significant differences in errors made, which may highlight important areas of diagram presentation in producing effective learning.

Four particular aspects of comprehension of cardiac circulation were analysed for the purpose of this study; understanding of oxygenated and deoxygenated blood being confined to separate sides of the heart; depiction of oxygenated blood in the left side and deoxygenated blood in the right side; labelling; and direction of blood flow. The results showed no significant difference in overall test performance between computer and paper diagrams, which does not support the findings of Read and Beveridge (1986). Design of the paper information may have been a contributing factor. For both formats to be informationally equivalent, the paper format consisted of three diagrams of the heart demonstrating the different stages of blood flow. This resulted in multiple representations rather than a single representation to express the information. Consequently, integration of separate pieces of information (to a certain degree) was required in learning from both the static and animated formats. Assimilation of multiple representations and information may not only be more difficult with computer presentation (Rogers and Scaife 1997), but also with paper presentation. One pupil specifically expressed difficulty integrating the information from three diagrams into the one diagram presented in the test. Comparison of diagrams involving one static representation could be beneficial in clarifying this point.

Pupils using a structured worksheet were shown to demonstrate significantly better understanding of blood flow through the heart than those using an open focused task. As diagrams contain large amounts of information in one representation the possibility of a gradual build-up of knowledge is reduced. It is left to the learner to decide which aspects are important and which aspects to focus on first or second. Sequencing particular aspects in separate sections may reduce confusion and result in a more logical and understandable order. However, this is somewhat inconsistent with the proposed difficulty of using the three sequenced static diagrams, which appeared to hinder rather than clarify the concept. The particular type of sequencing, then, may be important in effective learning. Using the worksheet may have provided this by guiding pupils to specifically focus on smaller components of information and to order salient related pieces of information, which were relevant for completing the test diagram, whereas salient information on the sequenced static diagrams may have been less perceptible.

The data was then analysed to assess accurate depiction of each of the four chosen aspects. Although no significant difference was found between variables, overall figures show that pupils in all conditions had more difficulty with blood flow comprehension and labelling than separation of the two blood types (oxygenated and deoxygenated) into correct sides of the heart. This suggests that these concepts were less clear from the diagrams or were more conceptually complex to grasp. These aspects were then analysed in terms of errors made in student learning in order to investigate the type of inferences made from the diagrams. Analysis of depiction of direction of blood flow showed that type of errors made differed significantly across conditions. Although the chi-square does not show where the significant difference lies, representation of blood flowing into the heart oxygenated and out deoxygenated, or vice versa was more prevalent in the animated condition. This seems to attribute to the heart a similar functional role as the lungs. Depiction of blood flowing in via the ventricles and out via the atria was predominant in the static condition.

These findings may be explained by aspects of graphical representation, in particular re-representation and computational offloading, as cited by Scaife and Rogers (1996). *Re-representation;* the results suggest that different representations not only influence whether problem solving is easier or more difficult, but also generate different understanding. This confirms that different representational formats of a common structure "can activate completely different processes" (Zhang and Norman 1994, p.118). In this particular instance the animated version shows simultaneous movement of all aspects of blood flow, which travels to and from different places and in different directions. Multidimensional dynamics are not sequenced into separate dynamical processes (as advocated by Kaiser et. al. 1992), and result in a confused presentation of movement. It seems plausible that 'direction' could easily be misconstrued to show blood flowing in one colour and out the other, thus resulting in the confusion of oxygenated in, deoxygenated out. The static diagram did not explicitly show direction of blood flow, which had to be inferred from labels saying 'to body' 'from body' 'to lungs' 'from lungs'. Without specific attendance to these labels direction could be misconstrued, especially with some blood vessels travelling behind the heart before entering the atria. These may be misperceived as entering the ventricles. Perhaps direction in the static condition may be clarified using more specific annotation of direction, such as arrows. Investigation into this aspect would be beneficial as some confusion of arrow convention was apparent from the data, for example an arrow pointing away from the heart coupled with a label saying 'from body'. This suggests that understanding of the meaning of the arrow (or direction) cannot be assumed.

Computational offloading; Larkin and Simon (1987) propose that diagrams serve to reduce the need for cognitive processing, because all the information is perceptually available and does not need to be worked out. So does the perceptual availability of animation reducing cognitive effort result in effective learning? Overall, improved understanding of the circulation in the heart was not apparent from the use of animation, which supports evidence that multidimensional problems are not aided by animation (Kaiser et. al. 1992). Too much movement of different parts and different types of blood made it difficult to see where each element was going and what each part was doing. Pupils made comments such as 'stop moving' and used the diagram in stationary format to work out the blood flow. Although use of animation may be assumed to provide clarity, animation in this study seemed to increase complexity and add confusion. A breakdown, or parsing, of the motion may add clarity, as proposed by Kaiser et. al. (1992) such as looking at the path of the deoxygenated blood and oxygenated blood separately. Alternatively depicting one particle moving through the entire sequence of blood flow could illustrate the blood path more explicitly. Therefore, perceptual availability in some circumstances may lessen cognitive processing to such a degree that no specific inferences are made and consequently fails to achieve deep comprehension. When completing a test later, all that is available is a perceptual image whose workings are misunderstood. Animation contains more perceptually available information than static by explicitly illustrating blood flow, but may also mean that less 'working out' of dynamics is necessary, perhaps limiting learning as a result of the reduced cognitive processing.

Although animation may be more explicit "our perceptual appreciations do not spontaneously form the basis of our conceptual understanding of dynamics" (Kaiser et. al. 1992, p.686). Overall conceptual understanding may depend on more than animated visual representation. Anderson (1995) proposes that conceptual knowledge is based on the meaning of a representation. Errors in pupil learning suggest that comprehension of the function of the heart or reasoning behind the blood flow was lacking. This information was not explicit in the information in either presentation format, therefore the *meaning* of the representation was not evident. If 'meaning' is important in overall conceptual understanding then awareness of the rationale behind the concept may constrain certain aspects of the process. Knowing the function of the heart, or each part of the heart, would serve to constrain the inferences or information gleaned from the diagram. For example, if the function of the ventricles to 'pump' blood out of the heart is made explicit, then this constrains the way that the blood is likely to flow, consequently affecting diagram interpretation. The context and function of a represented structure may critically influence the effectiveness of a graphical representation. Not only may it be important to investigate the graphical constraints (Scaife and Rogers 1996) of a representation, but also the cognitive constraints.

This study was unable to investigate other pertinent aspects of diagram learning. Firstly, the CD ROM condition offered little in the way of interactivity, or learner involvement or control. The users could choose which areas to click onto, but had no guidance from the programme to other associated pieces of information, nor were users able to manipulate anything that happened on screen, such as putting in valves, altering the blood flow to see what would happen, or building their own circulation system similar to interactivity on the cardiac tutor. Different interactivity levels may have resulted in different understanding. Secondly, restricted time allowance in the CD ROM condition prevented possibilities of pupils engaging in more extensive exploration of available information, and prevented assessment of which parts were most interesting or boring possibly resulting in distraction from significant information. Thirdly, investigation of pupils' previous knowledge was lacking. A more thorough investigation into previous knowledge and experience with this type of diagram may have enabled a clearer understanding of how pupil inferences were achieved. Fourthly, time restrictions also meant that pupils were unable to participate in other kinds of assessment such as recognising the correct diagram from a choice of several, or talking through the process showing more explicitly where the difficulties in comprehension lay.

Although this study did not to demonstrate improved learning from a particular diagram format, it has demonstrated that different representational formats of the same process result in different inferences made. It has also suggested that learning a dynamical concept is not necessarily facilitated by animation alone, and that comprehension may be dependent on other factors. To enable optimum design of diagrams to maximise learning, further research needs to look more closely at several aspects. First, the degree to which 'computational offloading' offered by diagram representation can be beneficial in learning, and whether different annotations such as use of arrows would clarify or confuse direction of flow, including the validity of assuming understanding of arrow convention. Second, the effect of cognitive constraints on learning, for example, the role of 'function' in guiding inferences and comprehension, and more research into the effects of previous knowledge on the types of inferences made. Third, investigation into the role of sequential salience of appropriate aspects, especially the effect of different ways of sequencing information, for example, highlighting in a logical order on one representation using computer presentation. These aspects would help clarify cognitive understanding from diagrams and be informative to diagram design.

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Appendix A;

Shows example of information and diagrams in static format. This information is not available on-line.

APPENDIX B
Tasks and Worksheet given to participants.

1. Open task for static paper condition.

Blood flow through the heart
You have a friend Iona Heart, who is taking a first aid exam. Iona needs to know how the blood flows through her heart. In fifteen minutes use the diagram and information provided so that you can explain to Iona;

〈 how the blood flows in through and out of the heart.

〈 about blood that is rich in oxygen, and blood that has less oxygen.

〈 about the different chambers of the heart.

2. Open task for animated CD ROM condition

Blood flow through the heart
You have a friend Iona Heart, who is taking a first aid exam. Iona needs to know how the blood flows through her heart. In fifteen minutes use the CD ROM provided so that you can explain to Iona;

〈 how the blood flows in through and out of the heart.

〈 about blood that is rich in oxygen, and blood that has less oxygen.

〈 about the different chambers of the heart.

3. Structured worksheet for static and animated conditions.

Heart Worksheet
Using the information provided, find out about the following, and complete all sections.

1. Your heart is divided into left and right sides.
a) Which side has blood that is less in oxygen?...
b) Which side has blood that is rich in oxygen?..

2. Answer the following about the heart's chambers.

a) How many chambers are there in the heart?...
b) Which chambers receive blood?...
c) Which chambers pump blood?..

3. Your heart receives and pumps out both blood that is rich in oxygen and blood that has less oxygen.
Answer the following about blood that has less oxygen.
a) Where does blood that is less in oxygen come from?.................................
b) Which chamber of the heart does this blood enter?.....................................
c) Which chamber does it flow to next?..
d) Where is blood that has less oxygen pumped to?..................................

Answer the following about blood that is rich in oxygen.
a) Where does blood that is rich in oxygen come from?..................................
b) Which chamber of the heart does it enter?...
c) Which chamber does it flow to next?...
d) Where is blood that is rich in oxygen pumped to?.....................................
4. The blood flows around your body, heart and lungs in a continuous circular pattern. Show that you understand the order of blood flow by filling in the empty brackets using numbers 1 to 8, starting with ....(*1*) *from body*;

( ) to body	( ) to right ventricle
(*1*) *from body*	( ) to left ventricle
( ) to lungs	( ) to right atrium
( ) from lungs	( ) to left atrium

5. Draw your own simplified diagram of how the blood flows through your heart, a diagram that would help you to remember the sequence and direction of flow.