Studying Problem Solving Using Eye-Tracking

Theoretical Framework:

- The split-attention principle in multimedia learning states that people learn more deeply when words (written or narrated) and pictures are spatially and temporally integrated in a presentation.
  - That is, students learn better when words are near the pictures they describe (spatial contiguity), or when the words and pictures appear at the same time (temporal contiguity).
  - The spatial and temporal components of the split-attention principle can be tested independently.
  - Thus, four conditions may be studied (see Figure 1): when words and pictures are spatially and temporally contiguous (S1); when words and pictures are spatially but not temporally contiguous (S2); when words and pictures are temporally but not spatially contiguous (S3); and when words and pictures are spatially and temporally not contiguous (S4).
  - Based on the split-attention principle, we expect that condition S1 will result in the best learning outcomes, while condition S4 will give the worst learning outcomes.

- The modality principle in multimedia learning states that people learn better when pictures are accompanied by narration than when they are accompanied by written text.
  - This comes from research that different channels process visual and auditory information.
  - Therefore, cognitive load is reduced when information is presented in both visual and auditory modes compared to a visual-only mode of presentation.
  - Thus, if we consider conditions 1 and 4 above, and we want to test the modality effect we would again have four conditions (Figure 2): conditions A1 and A4; and the same conditions, but without narration (M1, M4).
  - Based on the modality principle, we expect that condition A1 will result in better learning outcomes than M1, and condition A4 will outperform M4.

- Signaling principle in multimedia learning states that people learn better when cues are added that highlight the important material in the presentation.
  - Studies show that highlighting relevant areas of a diagram reduces the cognitive load in the working memory allocated to search task.
  - Four conditions may also be considered (Figure 3): conditions A1 and M4 from Figure 2; and the same conditions, but with the addition of visual cues (S1, S4).
  - Based on the signaling principle, we expect that condition S1 will produce the best learning outcomes out of the four conditions, while condition M4 will produce the worst learning outcomes.

- The worked-out examples principle in multimedia learning states that people learn more deeply when worked-out examples are provided during initial skills learning.
    - It has been shown that the learning outcomes when using worked-out examples are better than problem solving after a single example.
    - This can be attributed to cognitive load theory.
        - In traditional problem solving, beginning learners of a process are still not able to chunk information effectively, so they usually use means-end-analysis to solve problems, thus increasing cognitive load in their working memory.
        - In learning from worked-out examples, learners are not constrained by the problem solving process, and hence can concentrate more on gaining understanding of the principles behind the solution.
    - Based on this principle, we expect that problems presented after a worked-out example will produce better solution rates than problems presented before a worked-out example.

Research Design

- In this research, we will study the integrated split-attention, modality and signaling effects on multimedia presentation of worked-out examples.
    - Instead of studying the individual effect of the split-attention, modality and signaling principles, we will combine all three in a multimedia condition, and compare to a static condition (Figure 4).
        - In the static condition, the problem solution will be presented below the graphs without visual cues, animation or narration.
        - In the multimedia condition, each step of the problem solution will be presented in proximity to the graph it is describing, and the narration and visual cues will be presented in temporal correspondence with the solution step.
    - Each participant will be presented with two sets of problems.
        - Each problem contains a position-time graph and a velocity time graph.
        - To solve each problem correctly, the students should realize that the area under the curve in the v-t graph and the change in position in the x-t graph both give the displacement.
    - For each set, an initial problem will be given, followed by two training problems and two transfer problems (Figure 5).
        - For the initial problem, the students will be asked to explain how they would solve the problem.
        - The worked-out examples will be presented in the training problems.
            - The static condition will be applied to the first set of training problems while the multimedia condition will be applied to the second set of training problems (Figure 6).

        - Two types of transfer problems will be given: a near transfer problem, where the participants will be asked to solve the same unknown variable as the initial and training problems; and a far transfer problem, in which a different quantity will be solved.
            - For the transfer problems, the students will be asked to explain the solution, and then solve the problem on a sheet of paper.
    - We expect that:
        - In line with the worked-out examples principle, the percentage of participants correctly solving the transfer problems will be larger than the percentage of participants correctly solving the initial problem (for each set).
        - In line with the split-attention, modality, and signaling principles, the performance of each participant in the second set of problems (multimedia condition) will be better than their performance in the first set (static condition).

- Eye movements will also be recorded during the study.
    - Areas of interest (AOIs) will be established, and the allocation of visual attention in the AOIs will be investigated.
        - The area under the curve in the v-t graph, as well as the vertical axis in the x-t graph between the initial and final positions, are AOIs.
        - The entire x-t graph and the entire v-t graph are also considered AOIs.
    - We expect that:
        - There will be more saccades between the x-t graph and v-t graph in the multimedia condition than in the static condition.
        - Specifically, we expect the saccades to be between the vertical axis in the x-t graph and the area under the curve in the v-t graph.

- Limitations of the study:
    - The split-attention effect, the modality effect, and the signaling effect are not individually studied.

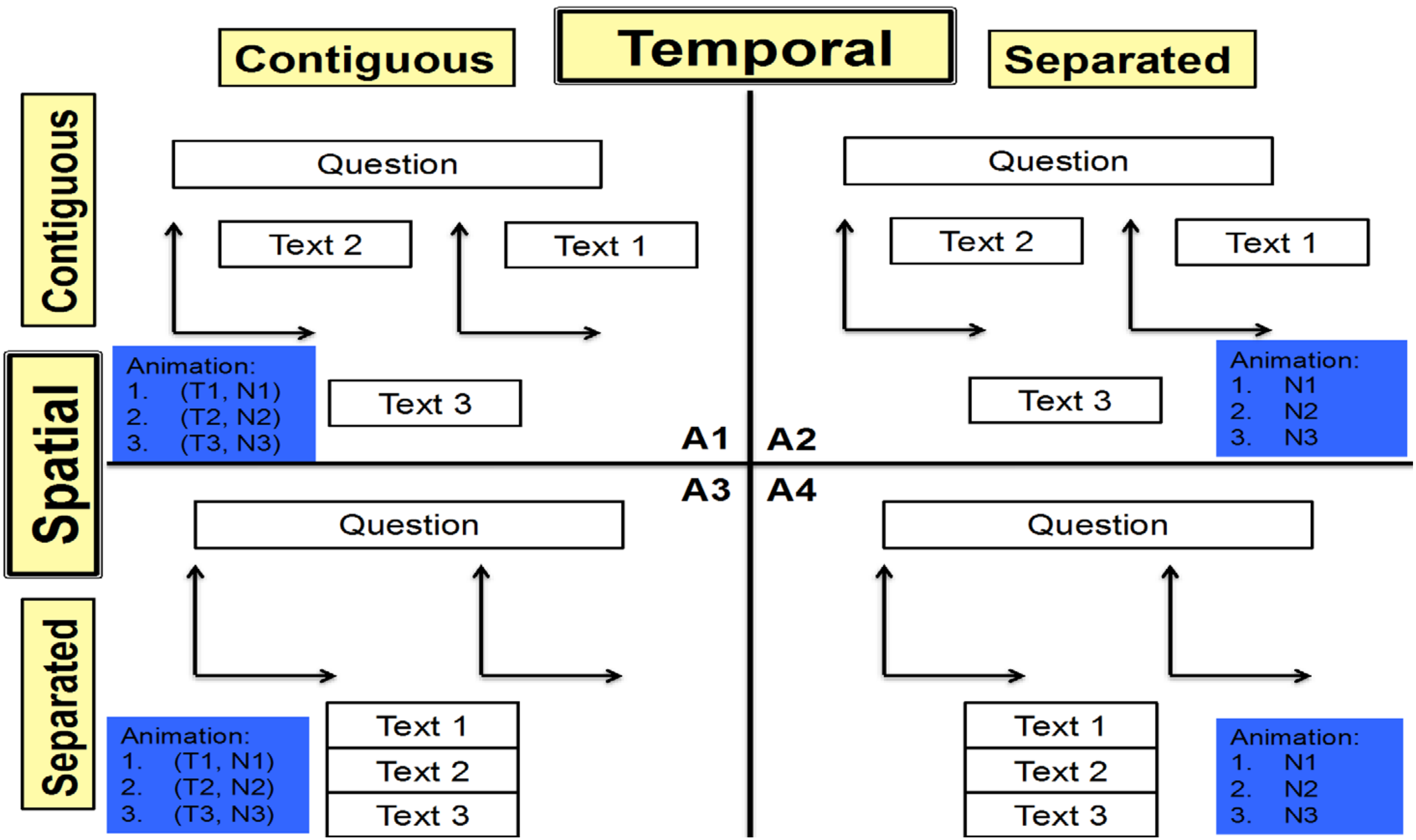

Figure 1. Conditions to test the split-attention effect. To investigate the spatial split-attention effect, the problem solution may be presented either below the graphs (A3, A4) or within the graphs (A1, A2). To investigate the temporal split-attention effect, the problem solution may be animated such that the narration is presented as the solution appears (A1, A3), or narration occurs after the written solution (A2, A4).

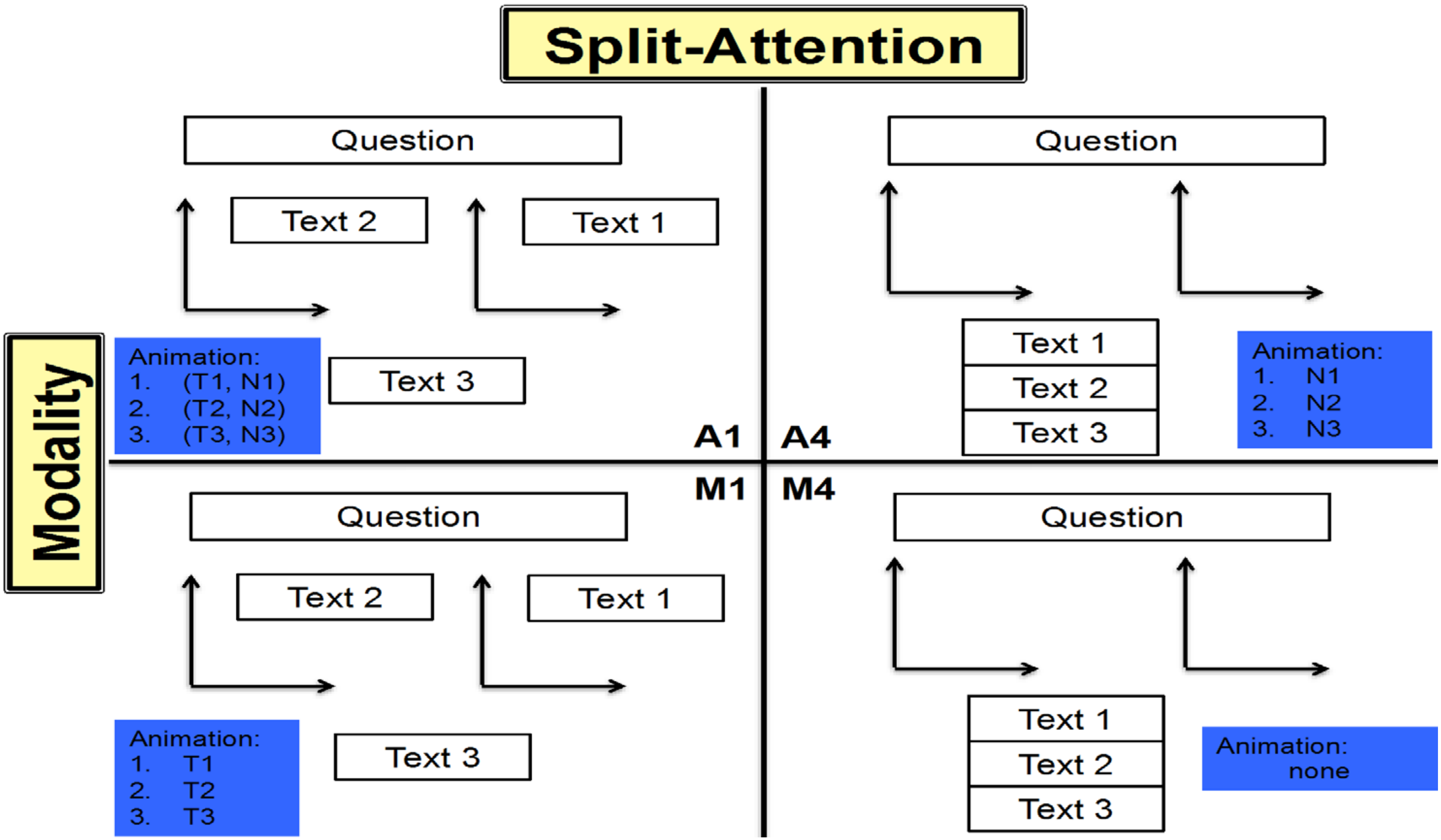

Figure 2. Conditions to test the modality effect. To investigate the modality effect, the worked-out examples are presented either with narration (A1, A4) or without narration (M1, M4).

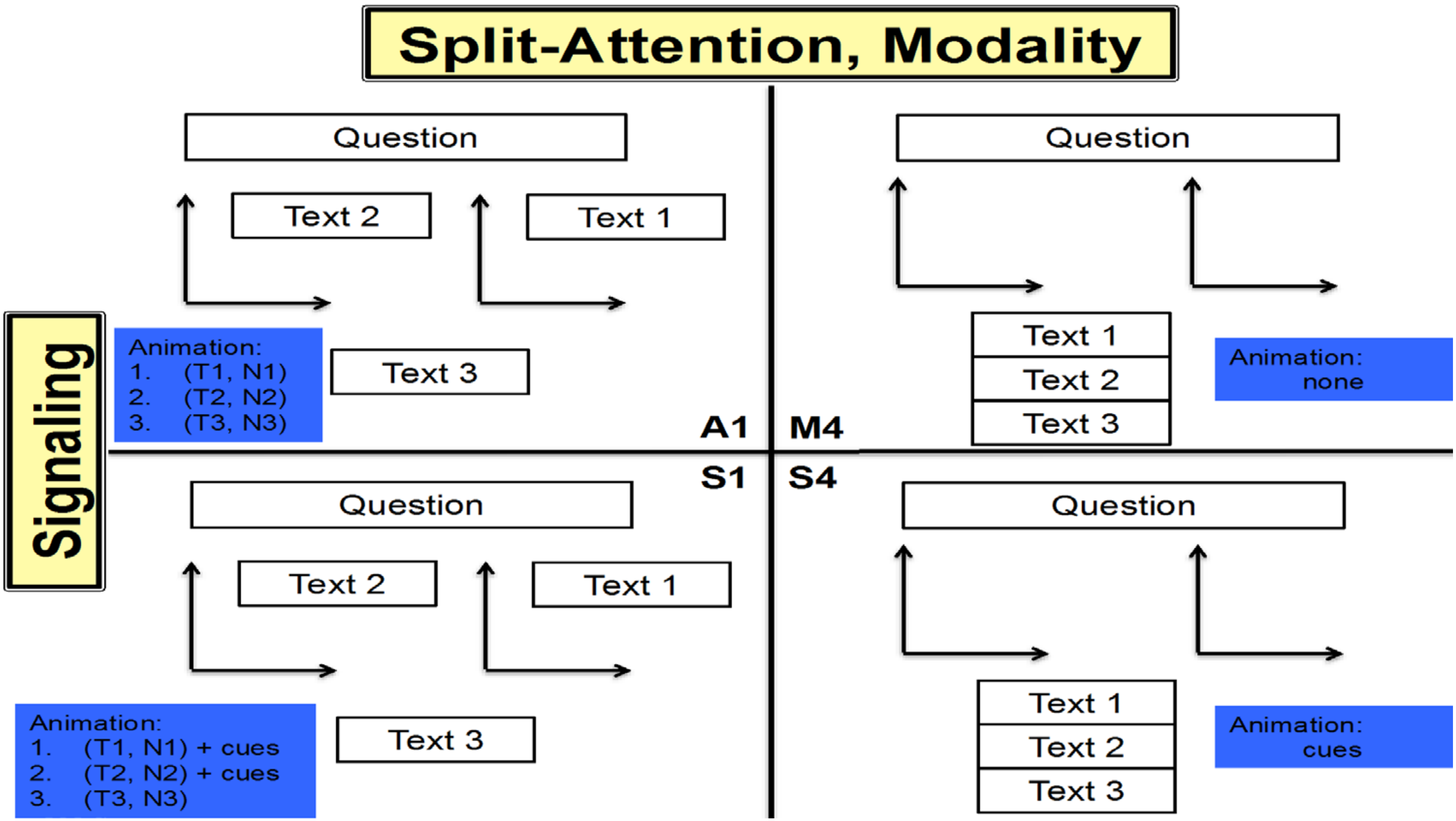

Figure 3. Conditions to test the signaling effect. To investigate the signaling effect, visual cues may be added to the worked-out examples (S1, S4).

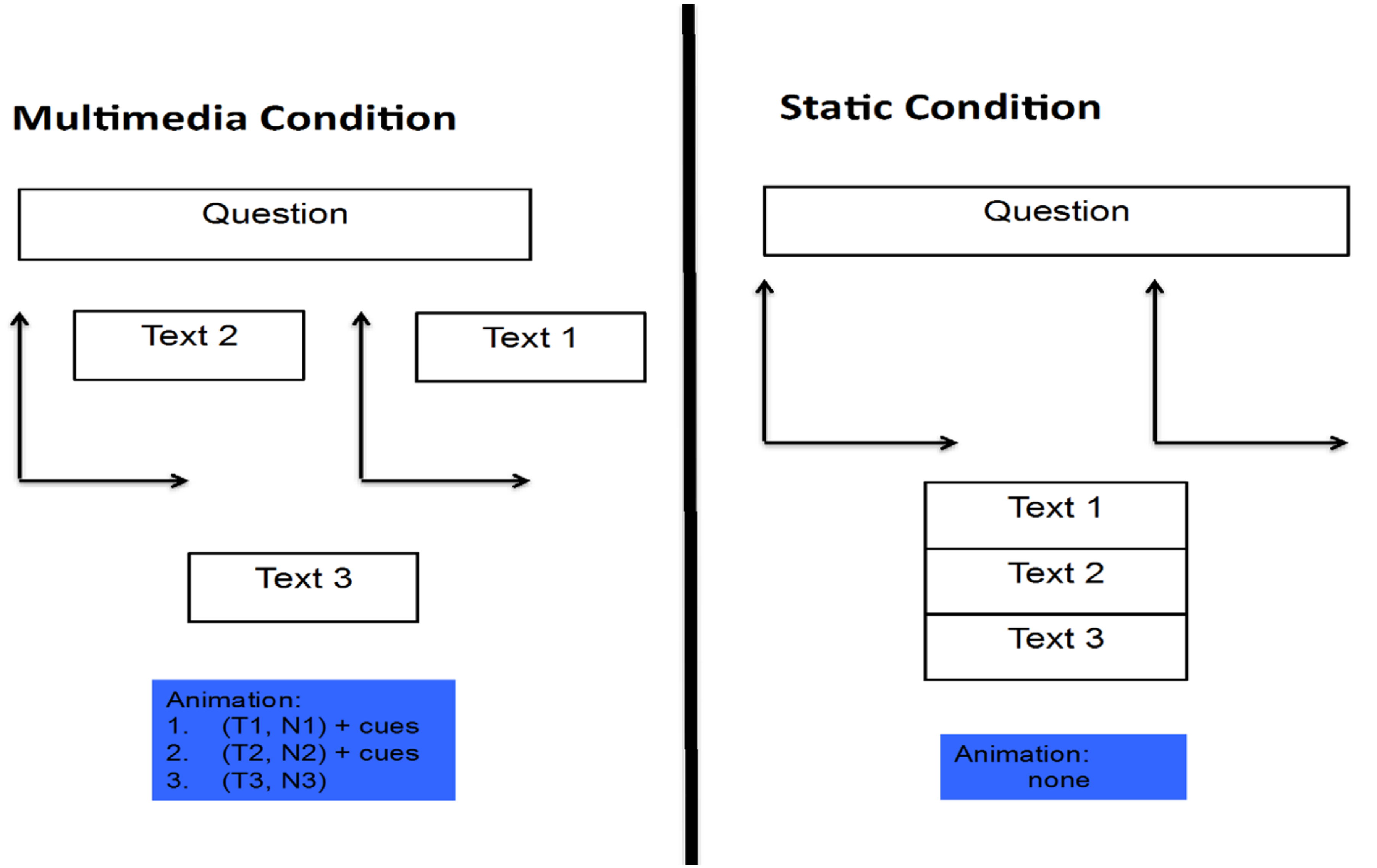

Figure 4. Conditions for the study. In the multimedia condition, the solution to the problem is presented such that each step of the solution appears at the same time as the narration, and visual cues would highlight the areas in the graphs that are relevant to the solution. In the static condition, the entire solution to the problem is presented below the graphs without animation or narration.

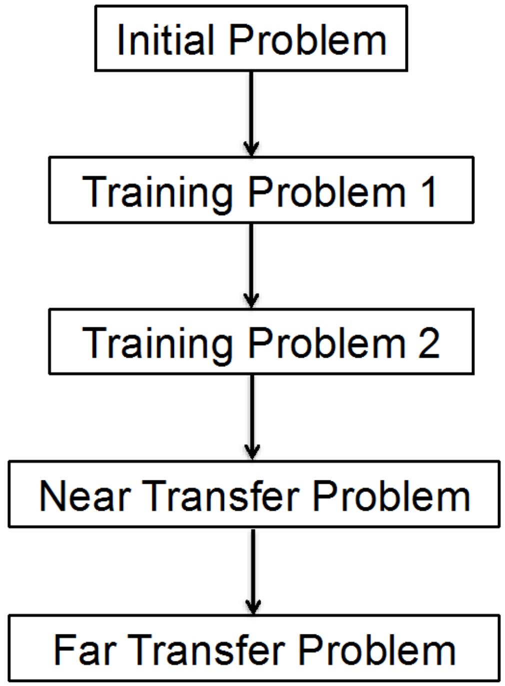

Figure 5. Flowchart of problems given. Each set will start with an initial problem in which students will be asked to explain the solution. Then, two worked-out examples will be given as training problems. Finally, near and far transfer problems will be given, in which the students will be asked to outline the solution to the problem, and then actually solve the problem.

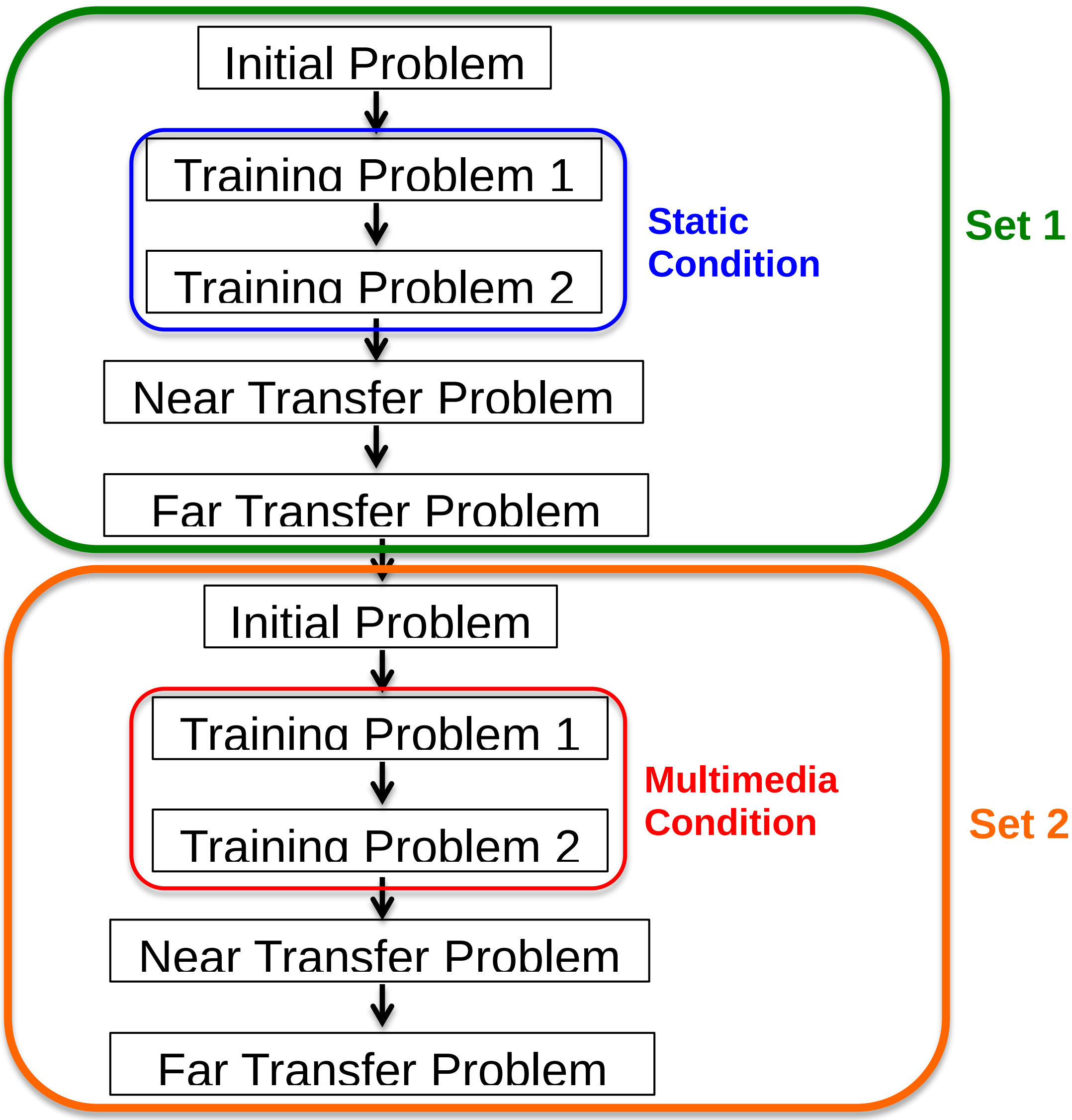

Figure 6. Experiment set-up. Two sets of problems will be provided, with the training problems in the first set presented in the static condition and the training problems in the second set presented in the multimedia condition.