# ADVANTAGE FOR VISUAL MOMENTUM NOT BASED ON PREVIEW

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Previous research has indicated that smooth rotation of geographic terrain between two- and three-dimensional (2D and 3D) views aids task switching. However, the time taken to show the smooth rotation may also provide a terrain preview for a post-rotation judgment. To test this possibility, we examined a situation where preview was provided but smooth transition violated. Twenty-four participants made judgments about the properties of two points placed on 2D or 3D displays of terrain. Participants performed the tasks in pairs of trials, switching tasks and displays between trials. In the continuous transition condition, the display rotated in depth and in azimuth from one display format to the other. In the discrete transition condition, the azimuth rotation was in the opposite direction, and then the terrain "snapped" to the final orientation. The results showed that response time after transition was less for the continuous condition. We argue that smooth transition to the correct position provided improved visual momentum between displays.

## INTRODUCTION

One method for providing *visual momentum* (Woods, 1984) involves gradually transforming one display into another using a set of smooth rotations (geometric rotations and translations). In a series of studies (Hollands & Ivanovic, 2002, Hollands, Ivanovic, & Enomoto, 2003), we have been investigating if the visual momentum provided by such rotation helped people when they switched tasks.

The effectiveness of two-dimensional (2D) and three-dimensional (3D) displays of geographic terrain depends on the judgment task (St. John, Cowen, Smallman, & Oonk, 2001; Wickens & Hollands, 2000). For example St. John et al. had participants perform two tasks. In the *A-Hi-B* task, participants indicated whether point A was higher than B. In the *A-See-B* task, participants indicated whether they could see point B if they were standing at A. They found that the 2D display was better for the A-Hi-B task, whereas the 3D display was better for the A-See-B task.

In many contexts (e.g., military mission planning, geological exploration), the observer needs to switch tasks frequently. While the display can be changed to match the task at hand, abruptly changing frames of reference can cause disorientation. A continuous transition between 2D and 3D perspectives incorporating animation of viewpoint during task switching may alleviate the problem.

In our recent experiments (Hollands & Ivanovic, 2002; Hollands et al., 2003), participants performed the A-Hi-B and A-See-B tasks, but switched tasks across a pair of trials. In the continuous transition condition, the terrain was rotated in depth from a 2D to a 3D view (or vice versa). The two studies differed in the design of a discrete control condition. In the Hollands and Ivanovic (2002) study, participants were shown a blank screen instead of the rotation. In the Hollands et al. (2003) study the second display was shown immediately after the first. Both studies showed reduced time to make the judgment in the continuous case in the second trial of the pair (after transition).

However, because the terrain was shown during the smooth transition, participants may have used this preview to anticipate the second trial of the pair. Was the source of the obtained advantage for visual momentum due to preview or improved momentum? In an experiment, we tested this question by showing the rotating terrain in the control condition for as long as in the continuous transition condition. If the advantage for continuous rotation does not occur, it would suggest that the preview time was the source of the advantage in earlier studies. In contrast, if the advantage is obtained, it would suggest that the source is the continuous, uninterrupted flow of terrain views, providing improved visual momentum.

In the earlier experiments (Hollands & Ivanovic, 2002; Hollands et al., 2003), the rotation from 2D to 3D (and vice versa) only occurred in depth. In this experiment, we also rotated the terrain in the azimuth so that the viewpoint for the 3D display was aligned with an imaginary line connecting points A and B. This was done to make the 3D display more immersive or *egocentric* (Wickens & Hollands, 2000), and to provide a method for equalizing the rotation time in continuous and discrete conditions. This should serve to improve performance with the 3D display, especially in the A-See-B task. Our previous studies did not show a consistent 3D performance advantage for this task: the A-See-B task was performed more quickly but less accurately with 3D than 2D.

## METHOD

### Participants

We ran 24 participants with normal or corrected-to-normal vision, recruited from DRDC Toronto and the nearby community. Participants were financially compensated for their participation.

### Stimuli and Apparatus

Ten terrain models were created from Digital Terrain Elevation Data (DTED) of 13351 x 11288 m areas of Wyoming using Creator/TerrainPro (Multigen-Paradigm, 2001a) modelling tools. 2D and 3D displays were constructed to resemble those used by St. John et al. (2001). The Vega visual simulation system (MultiGen-Paradigm, 2001b) was used to render each terrain model as a 3D display, and an example is shown in Figure 1. The 3D display depicted the terrain model at a viewing angle of 45 degrees with respect to the ground plane. Azimuth position was defined by the vector connecting two points on the terrain (see below). The 3D display was centered with respect to this vector. MICRODEM (Guth, 2001) was used to create a 2D display with colored contour lines (see Figure 1 for an example).

Four pairs of A and B points were randomly selected for each terrain model with the following constraints. The distance between points in a pair was at least 2000 m, and points were separated in altitude by at least 500 m. Points were selected from a central 11600 m x 10600 m area. Each pair of points satisfied a specific task condition. For half the A-B pairs, point B could be seen from A (See-Yes pairs). For the other half (See-No pairs), point B could not be seen from A. For half the See-Yes pairs, point A was higher than B, and for the other half, B was higher. The same was true for See-No pairs. Terrain models and pair locations were the same for both transition conditions.

Stimuli were presented on a 21” (53 cm) Sony GDMF520 Multiscan Trinitron CRT monitor at 1280 x 1024 resolution, and keystrokes and response times were collected by an IBM IntelliStation graphics workstation.

### Design and Procedure

The experiment had a 2 x 2 x 2 x 2 within-subjects design with display (2D vs. 3D), task (A-See-B vs. A-Hi-B), transition (continuous vs. discrete), and trial ($1^{st}$ vs. $2^{nd}$ trial in the pair) as independent variables. Dependent measures were response time and accuracy (proportion correct).

Each participant read a brief experimental description and signed an informed consent form. General questions about the experimental design were answered. Participants performed two tasks. In the *A-Hi-B* task, participants indicated whether point A was higher than B. In the *A-See-B* task, participants indicated whether they could see point B if they were standing at A. There was one block of practice trials prior to each transition condition.

Participants performed the tasks in trial pairs. The terrain model and A-B points were the same within each trial pair. For each pair, there was a switch in the display type across trials from 2D to 3D (or vice-versa), and a simultaneous task switch, leading to 4 task-display sequences. Four sequences times four pairs of A-B points resulted in 16 combinations of trial pairs for each of the 10 terrain models, or 160 trials pairs in total. These 160 trial pairs were arranged in 4 blocks (40 trials per block).

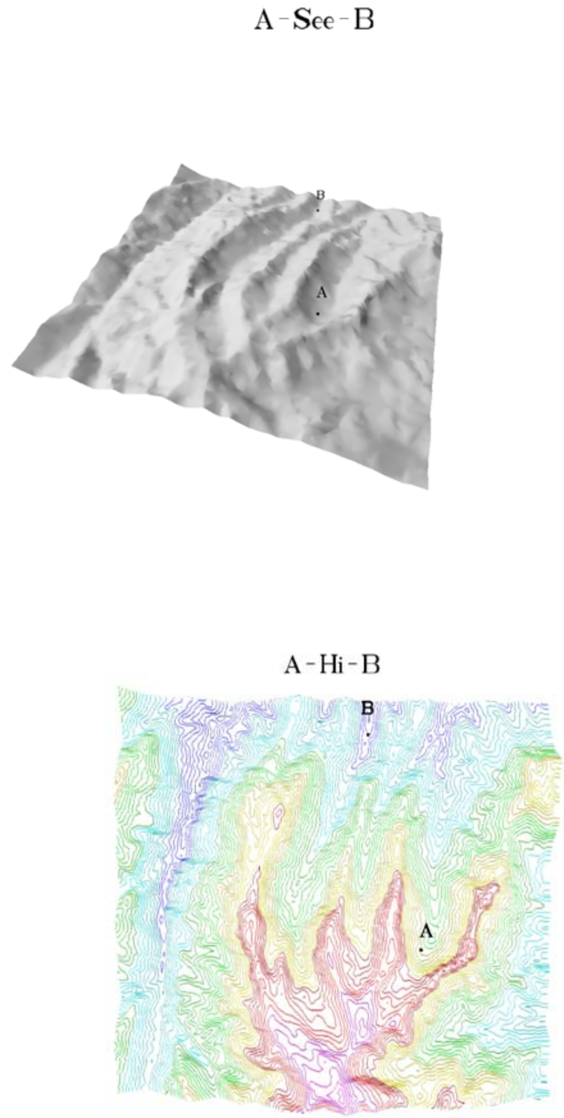


*Figure 1.* Example of 2D and 3D displays used in experiment. Example task prompts are also shown.

To create each block, a set of 4 trial pairs was chosen randomly without replacement for each of the 10 terrain models, with the constraint that only one combination of four A-B pairs was included (to avoid repetition of the same A-B pairs within a block). The order of the terrain models was randomized within blocks. Ordering of terrain models and trial pairs across blocks was unique for every participant.

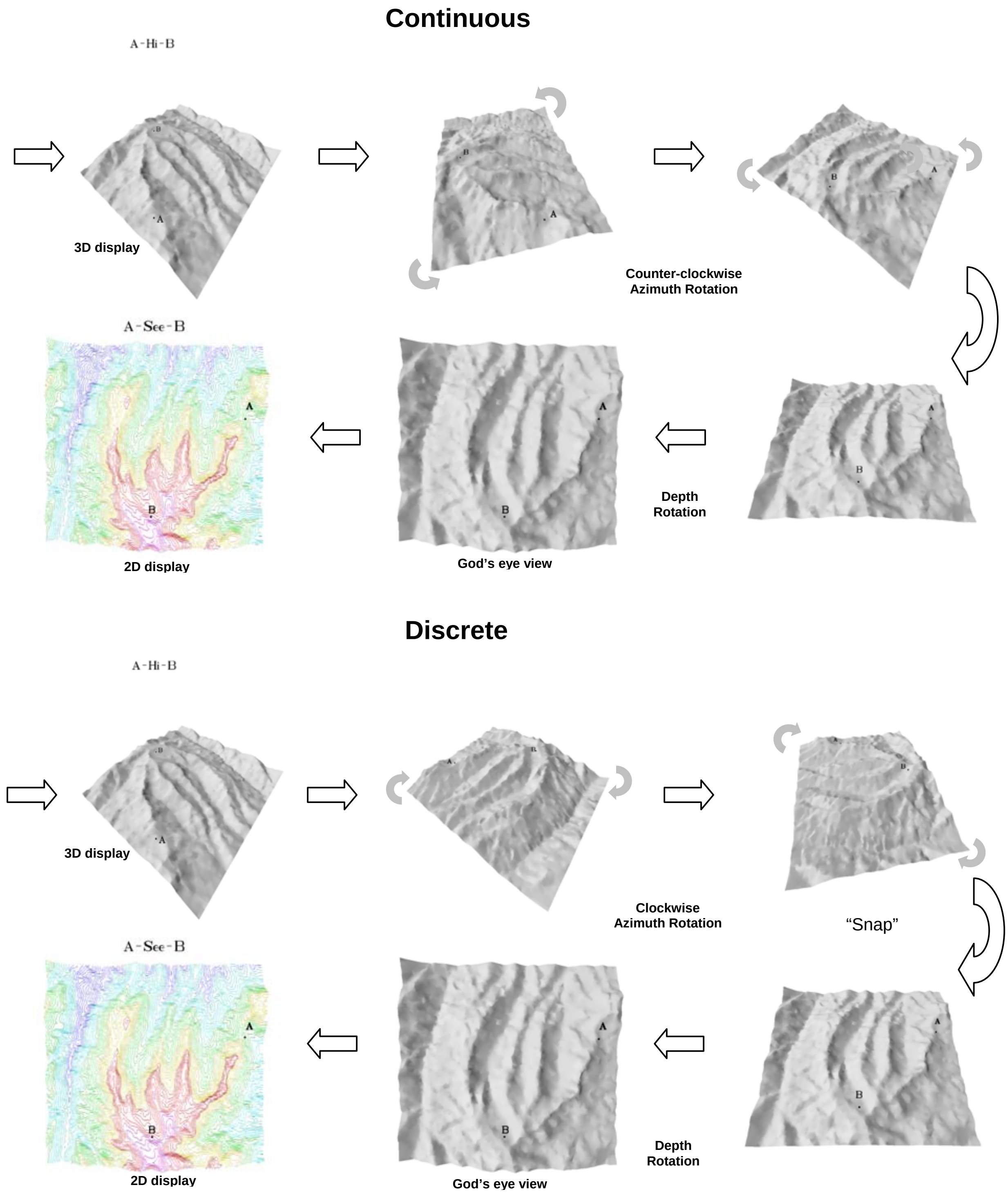


*Figure 2.* Depiction of smooth transitions between the 2D and 3D displays as used in continuous and discrete experimental conditions. Horizontal translations are not depicted.

The same 160 trial pairs (identical with respect to order of terrain model and trial pairs) were used for each transition condition. In the *continuous transition* condition, the following transformation sequence was used in transitioning from 3D to 2D (see Figure 2). First, the 3D terrain was depicted so that: 1) the line of sight was defined as an imaginary vector connecting the points A and B and 2) the viewpoint angle between ground level and the line of sight was 45 degrees with apex at the terrain center with respect to the y-dimension (depth). Then the terrain was shifted left or right (horizontal translation) so that the apex of the viewpoint angle was the geographic center of the terrain. (The line of sight was still parallel to the A-B vector after the translation.) Then the terrain was rotated in the azimuth around this center point until the side of the terrain nearest the observer corresponded to the bottom of the 2D map (azimuth rotation). The terrain was rotated in the direction having the smallest angular deviation. The terrain was then rotated upwards until the viewpoint was centered directly above the terrain, producing a "God's eye view" (depth rotation). The height of the viewpoint above the terrain center was constant. The opposite transformation ordering was used to transition from 2D to 3D. A-B points were visible during the transition.

In the *discrete transition* condition, the same sequence of transformations was used with one exception: azimuth rotation was in the direction opposite to that which occurred in the continuous case. For example, if the azimuth rotation to the A-B vector was 120 degrees counter-clockwise in the continuous condition, then it was 120 degrees clockwise in the discrete condition. This sequence is depicted in Figure 2. Upon reaching this position, the display orientation would immediately switch to the azimuth position aligned with the bottom of the 2D map. Then the horizontal translation occurred.

A fade-in/fade-out process occurred after the depth rotation when transitioning from the "God's eye view" to the 2D display (before the rotation when transitioning from 2D to 3D). Shading was removed when fading out the 3D display (and added when fading in the 3D display). The transition took approximately 3.2 seconds in both continuous and discrete conditions. The order of transition conditions was counterbalanced across participants.

At the start of each trial, a task prompt ("A-See-B" or "A-Hi-B") was shown (see Figure 1). Response time (RT) was measured from display onset until the participant responded. Each pair of trials was initiated by pressing the space bar. The participant's response on the first trial initiated the transition. For each trial in the pair, the participant responded by pressing a key marked "Y" or "N" (the "1" or "2" key on the numeric keypad), and the participant was asked to respond as quickly and accurately as possible. The experiment took about 90 minutes to complete.

## RESULTS

### Response Time

A mean RT for accurate trials was computed for each participant in each condition. These data were submitted to a 2 x 2 x 2 x 2 within-subjects analysis of variance (ANOVA) with transition, task, display, and trial serving as independent variables. As shown in Figure 3, continuous transition produced shorter RTs than discrete transition for the second trial in a pair (but not the first), $F(1,23) = 9.11$, $MSE = 0.23$, $p < .01$. RTs were shorter for the 3D displays in the A-See-B task, and in the 2nd trial with the A-Hi-B task, $F(1,23) = 6.68$, $MSE = 1.81$, $p < .05$ (see Figure 4).

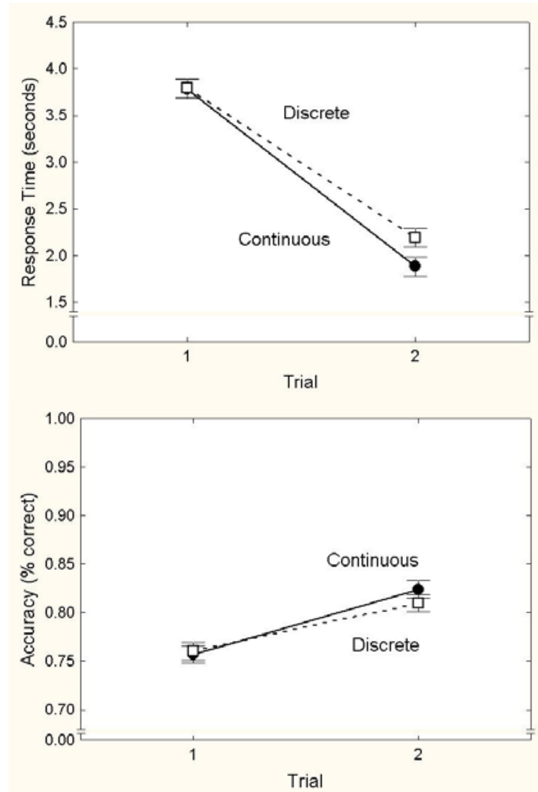


*Figure 3.* Response time and accuracy as a function of transition and trial in pair. Error bars indicate the within-subjects standard error of the mean (Loftus & Masson, 1994) in all graphs.

### Accuracy

The proportion of correct trials was computed for each participant in each condition. These data were submitted to a 2 x 2 x 2 x 2 within-subjects ANOVA. Continuous transition produced higher accuracy than discrete transition for the second trial in a pair, although the difference failed to reach conventional significance levels, $F(1,23) = 3.92$, $MSE = 0.0019$, $p < .06$ (see Figure 3). For the A-Hi-B task, there was an advantage for the 2D display for the first trial only, and display type had no effect for the A-See-B task, $F(1,23) = 60.94$, $MSE = 0.0037$, $p < .0001$ (see Figure 5).

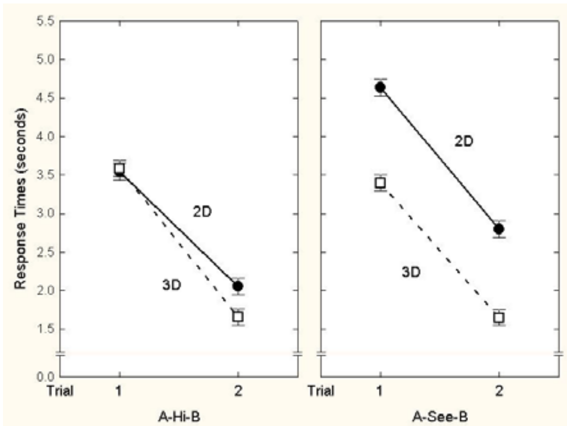


*Figure 4.* RT as a function of task, display, and trial.

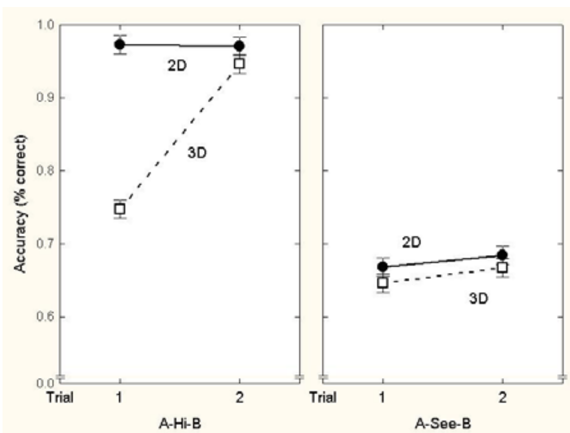


*Figure 5.* Accuracy (proportion correct) as a function of task, display, and trial.

## DISCUSSION

An advantage for smooth rotation was obtained. The terrain was shown for the same amount of time in both continuous and discrete conditions, so a preview explanation cannot account for the current result. There was no evidence for a speed-accuracy trade off—accuracy was not reduced after continuous transition.

The accuracy results showed a 3D advantage for the A-Hi-B task. This was greater on the first trial, which is not surprising given that one would expect to see the greatest effect of display type when observers have not yet seen the same terrain in the other display format. RT results showed a 3D advantage for A-See-B, and there was no tradeoff in accuracy. The 3D advantage for A-See-B is consistent with results obtained by St. John et al. (2001). Alignment of the viewpoint with the A-B vector may have provided a useful feature for the 3D display for A-See-B, in contrast to earlier experiments (Hollands & Ivanovic, 2001; Hollands et al., 2002) which showed a tradeoff. The RT advantage for 3D in A-Hi-B occurred only on the 2nd trial of a pair, suggesting that the 2D-3D sequence aided performance more than the reverse with this task.

Thus, it would appear that smooth transition assists the observer in a multi-task environment, presumably because it provides good visual momentum. This may be useful in the design of future command and control systems, and other domains, such as geographic information systems and virtual environments. The use of dynamic transition is therefore recommended when observers view multiple display windows over time.

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