Perceptual Switch for Gaze Interaction

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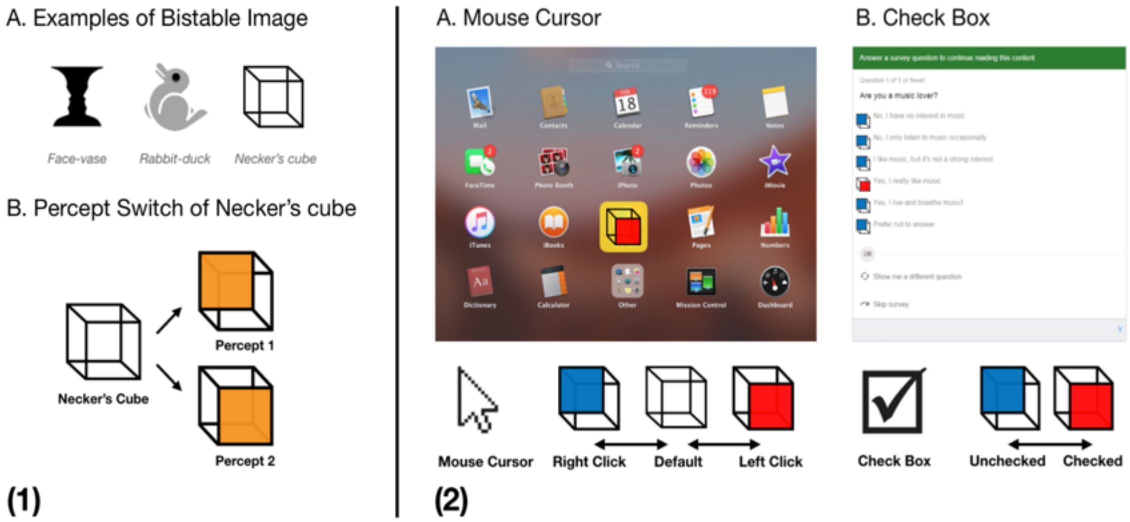

Figure 1. (1) A. Each of the bistable images have two rivaling percepts. The face-vase figure can be seen as a dark vase or two white faces facing each other, and the rabbit-duck figure can be seen as either a rabbit facing right or a duck facing left. The Necker's cube can be seen as a cube with the upper left plane on top (Percept 1) or a cube with the lower right plane on top (Percept 2). B. The detailed Illustration on the two rivaling percepts of the Necker's cube. (2) Examples of the Necker's cube user interface as replacements of a mouse cursor and a check box in the online survey.

ABSTRACT

One of the main drawbacks of the fixation-based gaze interfaces is that they are unable to distinguish top-down attention (or selection, a gaze with a purpose) from stimulus driven bottom-up attention (or navigation, a stare without any intentions) without time durations or unnatural eye movements. We found that using the bistable image called the Necker's cube as a button user interface (UI) helps to remedy the limitation. When users switch two rivaling percepts of the Necker's cube at will, unique eye movements are triggered and these characteristics can be used to indicate a button press or a selecting action. In this paper, we introduce (1) the cognitive phenomenon called "percept switch" for gaze interaction, and (2) propose "perceptual switch" or the Necker's cube user interface (UI) which uses "percept switch" as the indication of a selection. Our preliminary experiment confirms that perceptual switch can be used to distinguish voluntary gaze selection from random navigation, and discusses that the visual elements of the Necker's cube such as size and biased visual cues could be adjusted for the optimal use of individual users.

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Author Keywords

Gaze Interaction; Selection User Interface; Necker's Cube; Ambiguous Illusion; Bistable Image; Percept Switch.

INTRODUCTION

Most of the current gaze-mediated interfaces such as OptiKey [2] and Quikwriting [4] use the duration of fixations or artificial gaze patterns as an indicator of selection. However, too often they prone to make wrong selections, and they are unable to distinguish between the deliberate fixations for selection and the random fixations for navigation. If the users mistakenly fixate at some salient points or buttons, or examine eye-catching features for new information, the area under the fixations will be automatically selected. To overcome this limitation, we propose "perceptual switch," a new approach for the gaze-selecting action that reflects binary decisions of a user without explicit actions taken.

THE NECKER'S CUBE AND PERCEPT SWITCH

Bi-stable figure is an ambiguous image which has two mutually exclusive percepts in a single constant image as shown in Figure 1-(1)-A. One of the most well-known examples of the bistable image is called the Necker's cube. Looking at the Necker's cube image, people can interpret two different orientations of the cube interchangeably: one percept with nearer upper left face (percept 1) and another percept with nearer lower right face (percept 2) as in Figure 1-(1)-B. Even if the eyes perceive the same visual stimulus, brain interprets the image differently depending on the context of the image and attentional focus [5]. This cognitive phenomenon is called "percept switch," and it reveals distinctive eye-movements.

There are several notable works on how eye movements such as gaze pattern, peak velocity, and pupil dilation, are related to percept switch and percept hold of the Necker's cube. Einhauser et al. [6] found a close connection between the percept of the Necker's cube and eye position and observed that the average eye position during percept switch is at an extreme value. In other studies, it was found that saccadic velocity (or peak velocity) can reflect percept switch [3] and it was observed that people can apply specific strategies to voluntarily change the duration of percept stability of the Necker's cube [1].

Moreover, the Necker's cube has two interesting properties qualified to be a button user interface for gaze selection: (1) the reversal effects should be learned to perceive the dual percepts of the figure and (2) the rivaling percepts cannot be simultaneously recognized. We found the Necker's cube a good candidate for gaze selection button user interface, because a button should reflect one of two discrete states exclusively to reflect a binary decision, and once users learn how to use the user interface, the effects of learning should not be undone.

PROPOSED USER INTERFACE FOR GAZE SELECTION

The Necker's Cube can be designed as either a push button or toggle switch. For a push button as shown in Figure 1-(2), the Necker's Cube can be designed to change from percept 1 to percept 2 to trigger selection action. For a toggle switch, one percept can be held against another percept. As illustrated in Figure 1-(2)-A, the two discrete percepts of the Necker's cube can be designated to right and left buttons on the mouse, so that users can manipulate the mouse cursor only with eye gazes, assisting confirmation on selecting a menu option by hovering over the fixated icons. The Necker's cube icon can also replace the radio buttons or check boxes on online surveys as in Figure 1-(2)-B. As users voluntarily change the dominant percept, the eye-tracking system will detect users' percept switch or percept hold with their special characteristics such as saccadic velocities and location of fixation, and the user interface will display the related visual feedback reflecting his or her implicit binary decision on selection.

USER STUDY

We conducted the eye-tracking experiment with eight subjects using three IR cameras to distinguish the "percept switch" as an indication of selection, and interviewed the subjects afterwards to discuss whether our proposed interface would be useful to discern a user's selecting action from random navigation only with eye movements.

In the experiment, we found that the location of fixation, gaze path and pupil velocity are important features to distinguish the percept switch from random navigation. Overall, we could observe two different gaze clusters for each percept; people tended to look at the area around the innermost protruded points or the center of the protruded plane when switching percepts regardless of sizes and visual cues. The two clusters became more discrete when people looked at the larger Necker's cubes. In addition, when percept switches occurred, saccades with peak velocities were observed in the fixation-saccade analysis. The differences on the visual elements such as size, salient visual feature, and volitional control also influenced where people fixated for each percept.

Although the subjects could not keep holding on a percept of bi-stable figures for a longer period time, they were able to voluntarily switch or hold a percept for an adequately short period of time for gaze selection. If a percept of a bi-stable figure is visually biased by some stronger visual cues with higher contrast, brighter stimulus patches, or densely contoured features, people seemed to hold predominance over the biased percept at ease. With these visual characteristics, called “the biased visual cues” over a percept, the perceptual switch would be a useful visual trigger that bolster gaze selection with percept switch at ease. We found that the biased visual cues actually helped to prevent unwanted percept switch, stabilizing on a dominant percept. When people freely viewed the Necker's cubes for prolonged time, the visual cues had strong effects on holding a percept, and the frequencies of unwanted percept switch with biased visual cues were low for all subjects. With the result from the experiment, we believe that the perceptual switch could help to enhance the previous selecting action methods for eye-tracking UI. By using the perceptual switch, people will be able to freely navigate the eye-tracked digital environment undistracted with the sense of control over selecting action.

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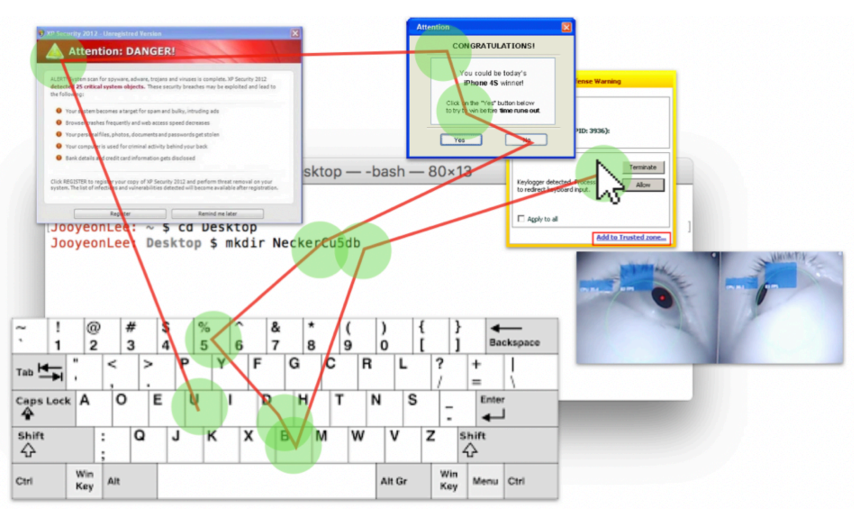
Another Way to Select a Button with Gaze?

One of the main drawbacks of fixation-based gaze interaction interfaces is that they are unable to distinguish top-down attention (or selection, a gaze with a purpose) from stimulus driven bottom-up attention (or navigation, a stare without any intentions) without time durations or unnatural eye movements.

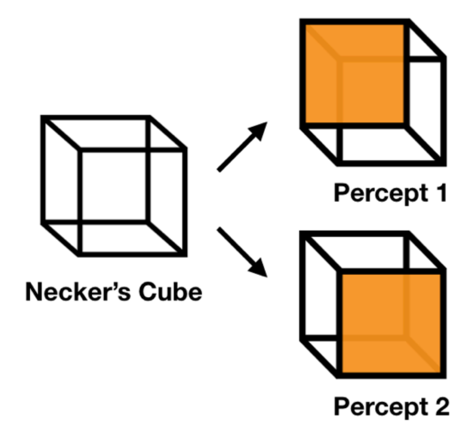


An example of error-prone gaze selection interface. If eye-catching visual stimuli disturb user's attention, they often cause unwanted selections.

Bistable Images & Percept Switch

The Necker's cube, one of the bistable images, displays two rivaling percepts one at a time exclusively from the same visual stimulus, and it has become a good visual tool to explore the relationship between visual perception (bottom-up process) and cognition (top-down process), because it triggers distinctive eye-movements when the cognitive phenomenon called "percept switch" flips one perceived image to another rivaling image from the same visual stimulus.

Examples of Bistable Image



Percept Switch of Necker's cube

Proposed UI System Using "Perceptual Switch"

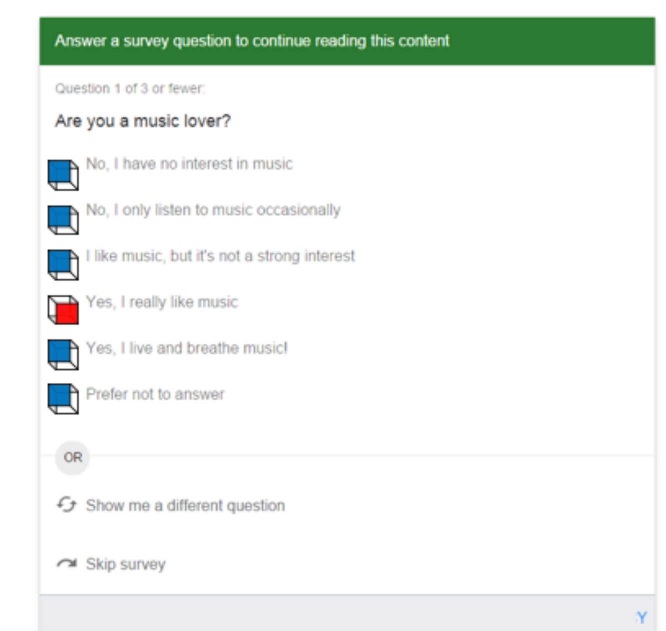
By using the cognitive phenomenon called "percept switch" of the Necker's cube, gaze selection can be detected with distinctive eye-movements, and users will be able to freely look at digital environments uninterrupted, selecting any bi-stable buttons at will without explicit actions taken. We will call the Necker's cube button the "Perceptual Switch."

The Necker's cube has two interesting properties qualified to be a button user interface for gaze selection: (1) the reversal effects should be learned to perceive the dual percepts of the figure and (2) the rivaling percepts cannot be simultaneously recognized.

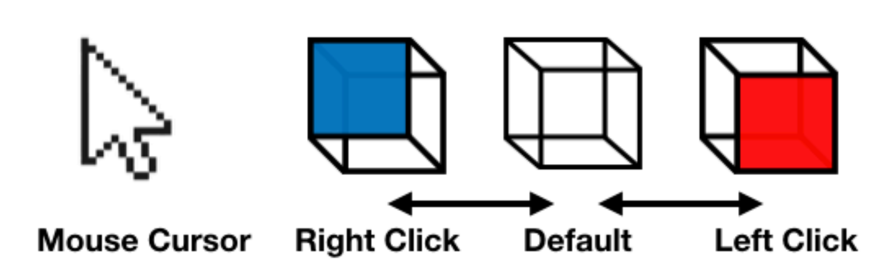
For these reasons, we found the Necker's cube a good candidate for gaze selection button user interface, because a button should reflect one of two discrete states exclusively to reflect a binary decision, and once users learn how to use the user interface, the effects of learning should not be undone.

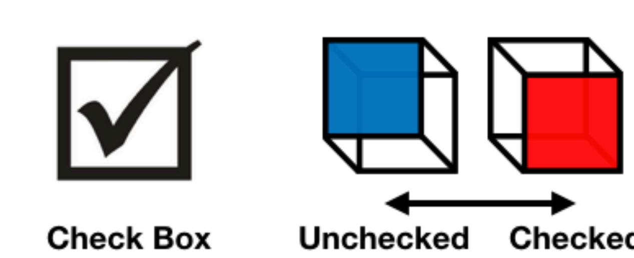
A. Mouse Cursor

B. Check Box



(← Left Figure) Examples of The Necker's cube user interface as replacements of a mouse cursor and a check box in the online survey.



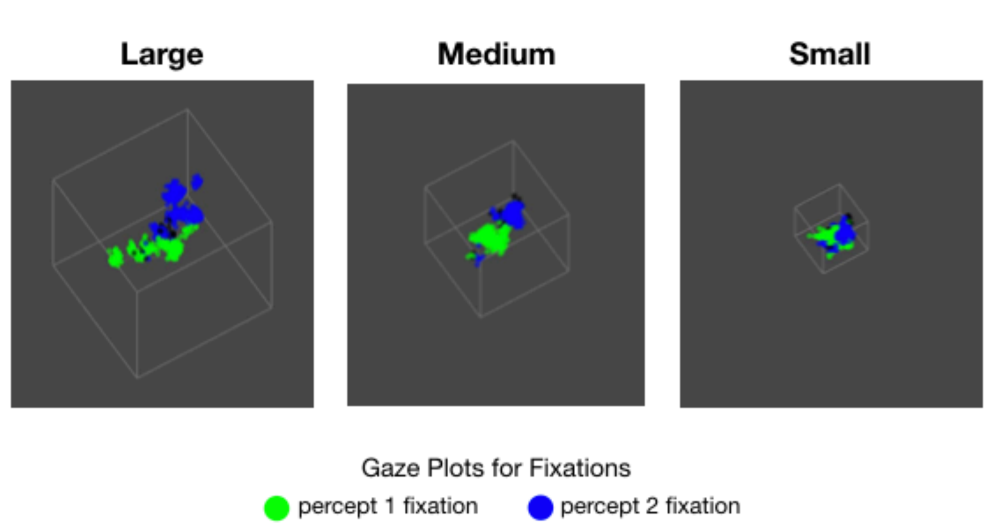


(↓ Down Figure) Two different usages of the Necker's cube. It can be used as either a toggle switch (A) or a push button (B) for the gaze selection user interface.

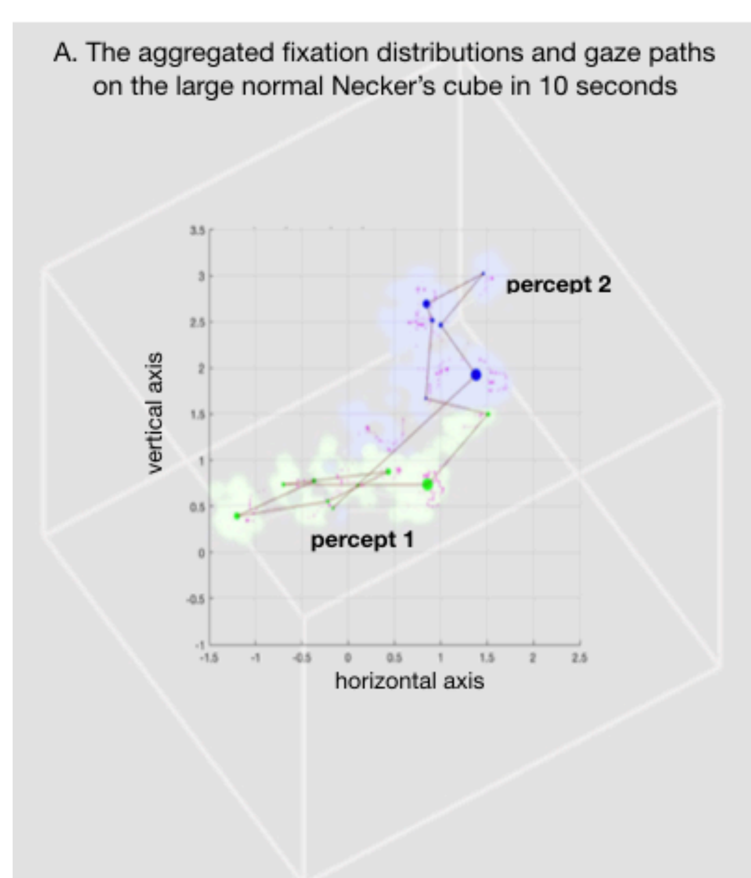
User Study

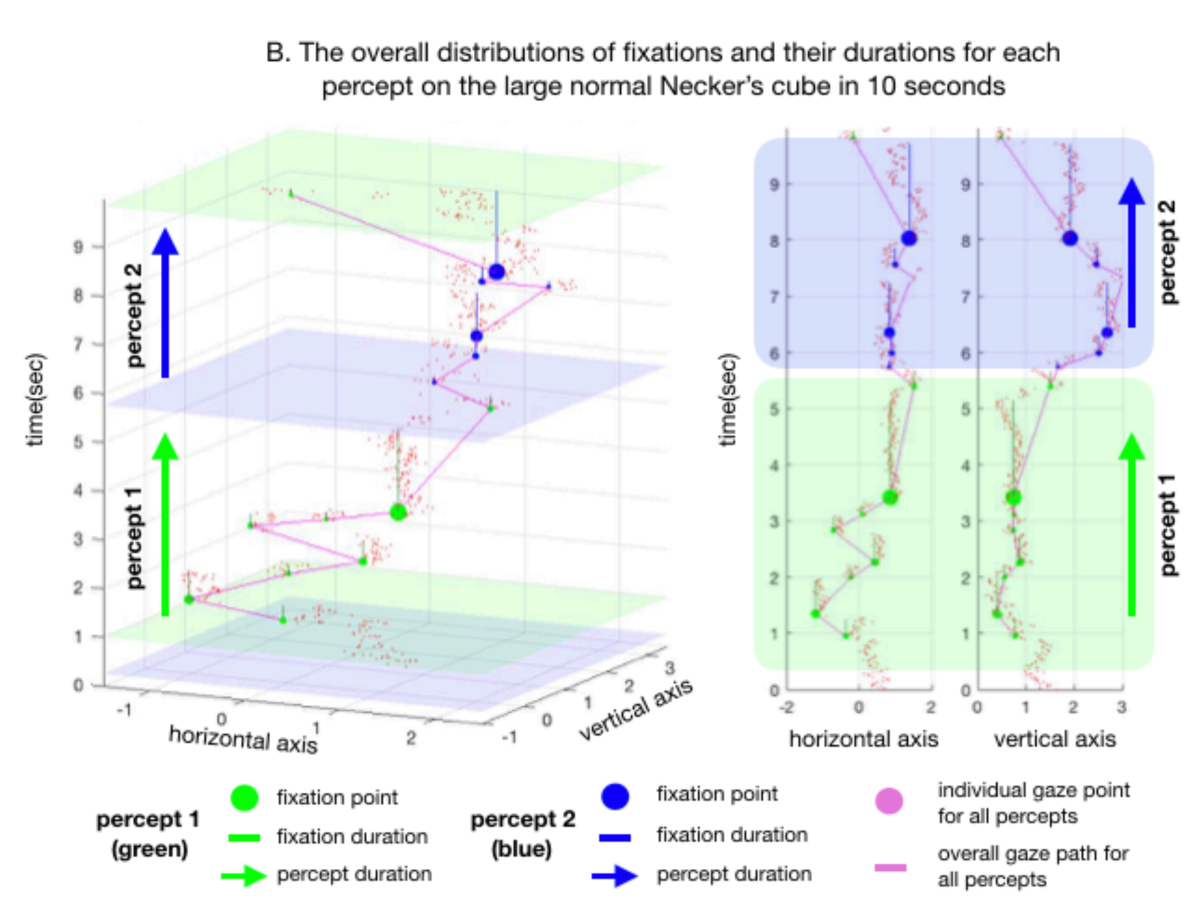
We conducted an experiment with three IR cameras to explore which gaze information and visual elements of the Necker's cube could help to distinguish a 'percept switch' better to indicate a selection. In the experiment, we found that the location of gaze points and pupil velocity are important features to distinguish the percept switch from random navigation. Larger size of the Necker's cube and biased visual cues (less transparent sides) also helped clarify the distinction between two percepts.

The environment setting of the Necker cube experiment



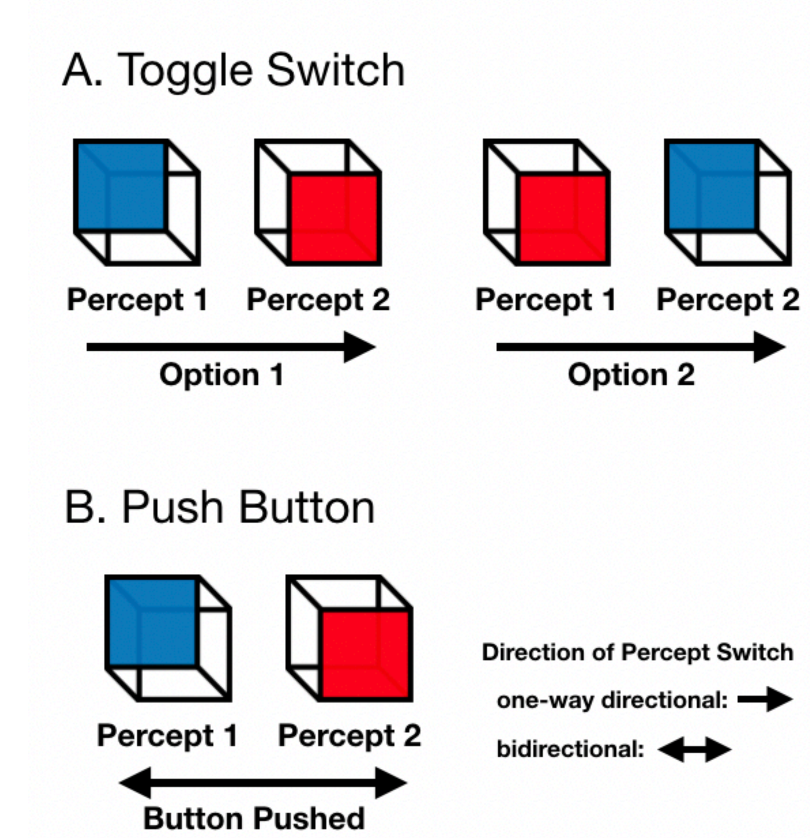
The Gaze Distribution for Percept 1 and 2 of the Subject 1





(↑ Top Figure)The fixation and saccade analysis for the subject 1 with the large normal Necker's cube during the time interval of 10 seconds. The lines represent gaze paths, and the green and blue circles indicate the individual fixation points made on the Necker's cube. The size of the circles reflect the relative durations of the fixations; Longer the fixation lasts, larger its circle gets. Percept 1 is marked with green color and percept 2 with blue color to distinguish two percepts. All of the individual gaze points are also marked with pink color. (A) and (B) show the distribution of fixations and gaze paths in the normalized unit. Overall, the fixations of the two percepts were usually clustered into two separable groups as shown in (A).

(← Left Figure) Gaze distribution of the subject 1 in three different sizes for all visual cues. Green dots represent the locations of the fixation points of percept 1 and blue dots represent the locations of the fixation points of percept 2.



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