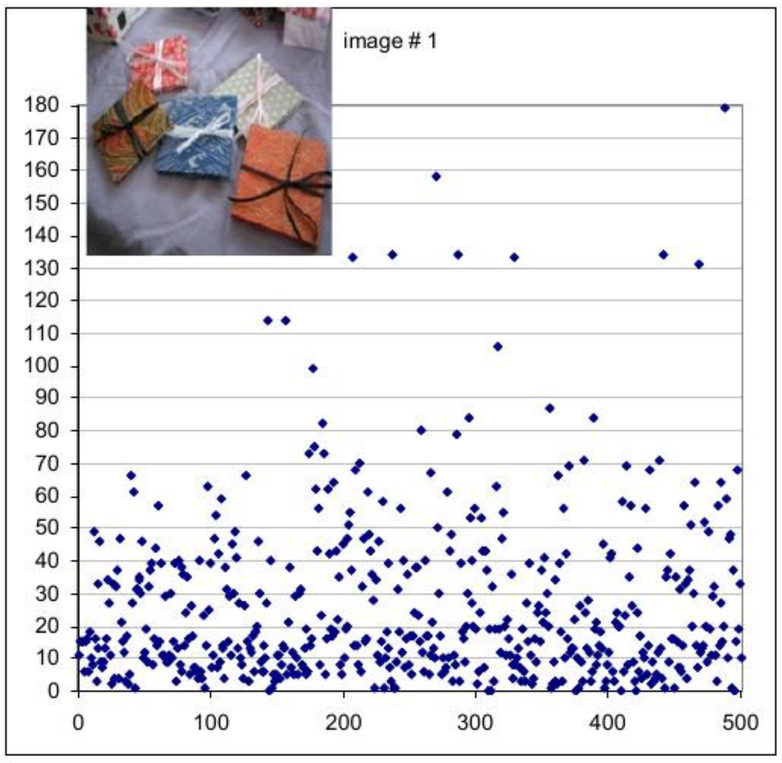

Figure 8: An image with large distribution of orientations.

2. Some images' default upright orientation may not correspond to the users' view of their natural upright orientation. We designate the default upright orientation as the angle at which the image was taken originally. This is illustrated in the picture of the toy car (image #3). Figure 9 shows the original orientation of the image, in contrast to the orientation of the image which most users thought was "natural", shown in the graph. Based on the low deviation in responses, this image is a good candidate for being "socially corrected". If this image was used after the social correction phase, the "upright" orientation would be changed to approximately 60° from the shown orientation.

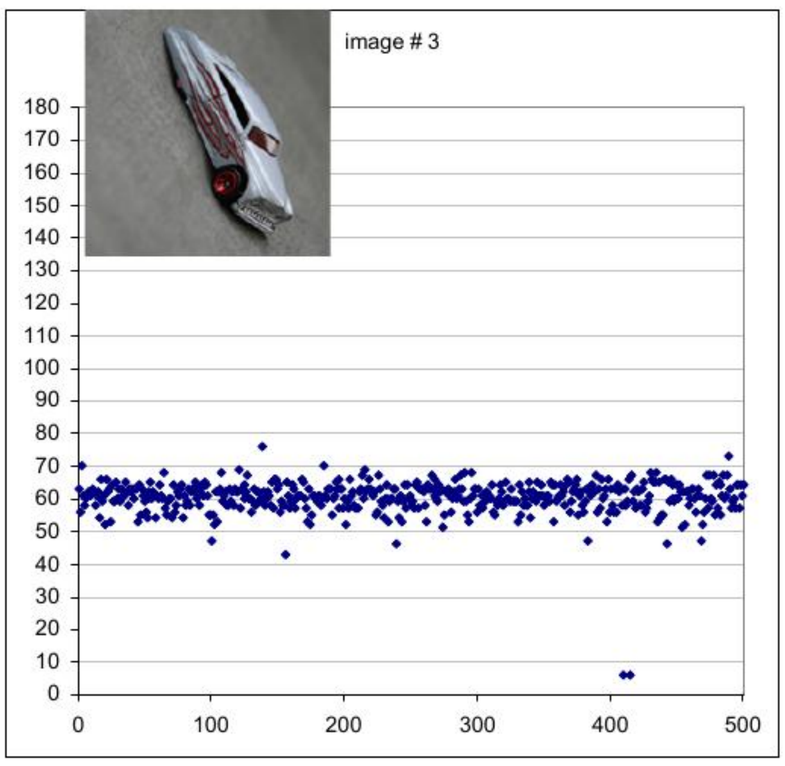

Figure 9: An image requiring social correction.

3. Some images have multiple "natural" upright positions. Figure 10 shows various orientations of the guitar image which could be considered upright. In our analysis we rejected any image which had multiple upright orientations (indicated by a large standard deviation in image rotation results). However, future versions of this CAPTCHA system may choose to allow for multiple orientations, if there is a multi-modal clustering around a small number of orientations.

Figure 10: Two possible natural orientations of the image.

It is important to note that the decisions about whether an image falls into one of the above categories can be made in real time by a system that presents a user a "candidate" image in addition to the CAPTCHA images. The "candidate" image need not be used to influence the user's success at solving the CAPTCHA, but is simply used to gather information. The user is not informed of which image is a candidate image.

In our analysis, the human success rate is determined by the average probability that a user can rotate an image correctly. However, we exclude any images which fall into case 1 or case 3 outlined above. Those images would be identified and subsequently rejected from the dataset by our social-feedback mechanism. If an image falls in case 2, we corrected the upright orientation based on the mode of the users' final rotation, as this could be similarly determined by the correction aspect of our social-feedback mechanism.

Human success rates are influenced by two factors: the size of the error window and the number of images needed to rotate. Table 1 shows the effect on human success, as the size of the error window and number of images we require a user to successfully orient vary. The configurations which have a success rate of greater than 80% are highlighted in green.

Table 1: Human-success rates (%), as number of images shown and size of acceptable error window varies.

number of images	size of acceptable error window: 6 degrees	8 degrees	10 degrees	12 degrees	14 degrees	16 degrees
1	**66.10**	**75.20**	91.50	93.10	93.50	94.40
2	**43.69**	**56.55**	83.72	86.68	87.42	89.11
3	28.88	42.53	76.61	80.70	81.74	84.12
4	19.09	31.98	70.09	75.13	76.43	79.41
5	12.62	24.05	64.14	69.94	71.46	74.97
6	8.34	18.08	58.68	65.12	66.81	70.77

The viability of a CAPTCHA is not only dependent on how easy it is to solve by humans, but it is also dependent on how difficult it is to solve by computers. Computer success rate is the probability that a machine can solve the CAPTCHA. No algorithm has yet been developed to successfully rotate the set of images used in our CAPTCHA system. A first pass at estimating