A MASKING PROCEDURE FOR STIMULUS CONTROL ASSESSMENT

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The present series of experiments were designed to investigate the utility of the use of a masking system to assess the development of stimulus control. The first experiment compares sample observing time with response accuracy in a match-to-sample task. The second experiment more closely examines this relation by subdividing the sample stimulus mask into four quadrants. The third experiment compares sample observing time during training with accuracy during a subsequent testing condition to determine if the observed differentiation between the quadrants was correlated with the development of stimulus control.

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INTRODUCTION

What is a stimulus? In behavioral theorizing, a stimulus is that aspect of the environment, inside or outside the skin, which enters into a controlling relation with a response (Skinner, 1935; Catania, 2013). This definition of a stimulus emphasizes a functional relation between aspects of the environment and parts of an organism's behavior. Our technical and non-technical descriptions of stimuli, however, fail to emphasize the functional nature of this relation and instead focus on the structural dimensions. We often speak, for example, of lights, tones, pictures, or songs becoming discriminative stimuli. To be clear, our understanding of the controlling relation between stimulus and response is derived through a functional analysis. The description of the constituents of those functional relations, however, is typically approached structurally.

For the most part, the misalignment between our function-based conceptualization of the development of stimulus control and our structure-based descriptions of the elements of the functional relation is not problematic. In neuro-typical populations, a structural description of stimuli may suffice because the development of a controlling relation between stimulus and response entails control by many aspects of a structurally defined stimulus. When there is a failure to develop stimulus control, however, a better and more precise characterization of the actual controlling relations may be required.

A commonly found example of faulty stimulus control is found in the literature on stimulus overselectivity (Ploog, 2010). Stimulus overselectivity refers to the inability of an organism to respond to every stimulus unit present within a task due to the number of stimulus units being presented (Lovaas, Koegel, & Schreibman, 1979). In these situations, a small subset of the features of a stimulus gain exclusive control over a response to the exclusion of the other features. For example, a child learns to say “mom” to a picture of mom but the response is actually exclusively under control of the color of the shirt.

Procedures generating stimulus overselectivity may include increasing the number of stimuli being presented (Lovaas & Schreibman, 1971), the presence of distractor stimuli (McHugh & Reed, 2007), the difficulty to train using extra-stimulus prompts (Rincover, 1978), or the originally present stimuli blocking the acquisition of additional stimuli added later (Fields, Bruno, & Keller, 1976). To what extent do such overselectivity issues confront people in everyday tasks? It has been shown that with sufficient complexity added to an experiment, overselectivity may be generated even in typical functioning adults (Reed & Gibson, 2005). Such overselectivity may therefore be quite commonplace. If people are only attending to certain stimulus units, then it would be useful to be able to determine which ones exert the greatest control.

Many studies in the behavior analytic literature have investigated stimulus overselectivity using eye-tracking (Dube et al., 2006, Tomanari et al., 2007, Pessoa, Huziwara, Perez, Endemann, & Tomanari, 2009, Huziwara, de Souza, & Tomanari, 2016). The most typical eye-tracking technologies of today rely on a combination of cameras and software to measure the position of the pupil and corneal reflection in order to estimate the focal point of the eye (Holmqvist & Andersson, 2017). Such studies are important due to their potential to correlate where a subject is looking with the development of stimulus control. Eye-tracking may allow ready measurement of the stimulus units exerting control within a task.

Eye tracking studies, however, produce very complex data because the eye moves around a lot while looking at visual stimuli generating a great deal of data which then has to be analyzed. These movements include the tremor with a frequency of about 90 Hz, the microsaccades, which are short jerking movements around the focal point of a frequency of about 1 Hz, and the slower drifts which can last up to 1 second in length (Martinez-Conde, Macknik, & Hubel, 2004). Binocular coordination between the eyes will also vary (Collewijn, Erkelens, & Steinman, 1988) presenting the problem of which eye to track. Seemingly precise data will therefore often be only an estimate of a more complex process.

The main task, in the use of eye tracking technology, is to correlate a structural description of the movement of the focal point of the eye and fixations of that focal point with the functional development of stimulus control. To put the issue in more colloquial terms, the task is to correlate the subject's looking with the subject's attending. This is a difficult task because focal point fixation is not necessarily correlated with the functional development of stimulus control or attending. Longer fixations often indicate inexperience with a task such as when an unusual object is placed in a scene (de graef, chrisiaens, & d'Ydewalle, 1990), or when experienced drivers are compared with novices (Laya, 1992). But longer fixations can also indicate experience with a task as in chess (Charness, Reingold, Pomplun, & Stample, 2001) or art (Nodine, Loche, & Krupinski, 1993). When faced with a problem that is too difficult, participants may simply stare at a point without attending to it (Knoblich, Ohlsson, & Raney, 2001). Or in other circumstances, participants may continuously move their focal point around without ever responding to any individual stimulus (Ehmke & Wilson, 2007).

In the current set of studies, we explored an alternative method to measure a subject's observing responses. Rather than asking where the subject is looking at, our method allows us to ask where the subject is attending. The method involves masking visual stimuli and measuring a subject's responses to reveal stimulus features behind the mask.

The present series of experiments were designed to investigate the utility of the use of a masking system to assess the development of stimulus control. The first experiment compares sample observing time with response accuracy in a match-to-sample task. The second experiment more closely examines this relation by subdividing the sample stimulus mask into four quadrants. Would subjects respond selectively to certain quadrants? Would there be differentiation between the quadrants? The third experiment compares sample observing time during training with accuracy during a subsequent testing condition to determine if the observed differentiation between the quadrants was correlated with the development of stimulus control.

EXPERIMENT 1

Methods

Participants and Setting

Three participants were recruited from a research lab group at the University of North Texas on a volunteer basis. They were all graduate students in their twenties. The experiment was conducted in a 3m x 2m room equipped with a table and chair. A personal computer sat on the table and served as the apparatus.

Apparatus and Stimuli

Participants interacted with a custom-written computer program created using Microsoft Visual Studio. The program presented all stimuli, managed all of the contingencies and recorded data on various aspects of the subject’s responses. All data were recorded entirely through the computer program. Stimuli were created in Adobe Photoshop using the clouds filter (Filter>Render>Clouds). The contrast was then increased (Image>Adjustments>Brightness/Contrast), and the result was then posterized (Image>Adjustments>Posterize) to remove all shades of grey (see Figure 1). Stimuli A1-A3 were used as sample stimuli and B1-B3 were used as comparison stimuli in this experiment.

Procedure

At the beginning of the session, participants were presented with the instructions: “Welcome! Select the correct image. You will be given feedback whether your choice was correct or incorrect.” Participants were then trained on three conditional discriminations in a matching-to-sample task. Figure 2 presents a schematic for a trial. Each trial began with the sample stimulus being presented with a black mask covering the entire stimulus. The order of the sample stimuli was quasi-randomly selected. Participants could use their mouse to click and hold on any section of the sample stimulus to hide the black mask covering the stimulus thereby revealing the entire stimulus. They could reveal the stimulus at any time for as long as their mouse button was held down. A continue button was placed below the stimulus, and was initially disabled. After the participant had observed the stimulus for any duration of time, the continue button was enabled. Clicking on the continue button presented the comparison array on the screen. The sample stimulus remained in the exact same position and size as it had been on the previous screen. Below the sample stimulus was a comparison array of the three comparison stimuli. All three of the comparison stimuli were presented in the comparison array on every trial in a quasi-randomized order. The sample stimulus was once again covered by a black mask, and could be observing in the same manner with the mouse. When the participant clicked on a comparison stimulus, they were then taken to a feedback screen where they would be told whether their comparison array selection was "correct" or "incorrect". None of the stimuli were presented on the feedback screen. They could then click on a continue button, and the next trial would begin. Mastery criterion was whenever the participant had correctly answered 45 trials. The program would then exit.

Results

Figure 3 presents a cumulative record of correct responses (left axis) and the total time that the stimulus was observed. The data for two out of three participants show a relatively abrupt change in the sample observing times. For P3, the decrease is observed from trials 14 to 15. P5's improvement in accuracy as well as the participant's decrease in sample observing time occurred very early in the experiment; from trials 5 to 10. For P2 there was a more gradual increase in correct responding and this coincided with a more gradual change in sample observing time.

For all three participants, the drop in sample observing time was generally correlated with an increase in accuracy of responding. For two out of three participants (P2 was the exception), the drop in sample observing time was sudden and large as was the accuracy of the subjects' performance.

Discussion

The data show an apparent relation between the sample observing time and response accuracy. Previous research has shown that when learning is examined at the appropriate molecular level; it is abrupt (Skinner, 1932, Gallistel, Fairhurst, & Balsam, 2004, Sidman, 2010, Donner & Hardy, 2015). That is to say there is a clear change from chance performance to very accurate performance in discrimination training. Previous research has also shown that abrupt increases in accuracy are often correlated with abrupt decreases in reaction times (Prerau et al., 2009). A similar result was found in two out of three participants within this experiment.

These data suggest that, once the conditional relation has been acquired, subjects do not need to observe the sample stimulus for as long. It is reasonable to speculate that the decrease in sample observing time is the result of more efficient observing behavior. The subjects, may for example, become better at scanning the stimulus. Alternatively, subjects may learn to selectively respond to one or a few features of stimuli as opposed to having to respond to all of the features or dimensions of stimuli. Either of these strategies would explain the drop in sample observing times and its correlation with changes in the accuracy of MTS performance. Experiment 2 sought to investigate the second of these possibilities.

EXPERIMENT 2

The results of Study 1 showed that sample observing times were indirectly correlated with the accuracy of performance on MTS trials. One explanation for that result could have to do with changes in how the subject observes the sample stimulus. For example, the subject may learn to selectively focus on one aspect of the stimulus thereby decreasing observing time and increasing the efficiency of responding. The purpose of this study, then, was to attempt a more precise characterization of the subjects observing behavior and relate that to their performance on MTS trials.

Methods

Participants and Setting

Three participants, two female and one male, were recruited on a volunteer basis through directly speaking to them at the University of North Texas. They were all graduate students in their twenties. The experiment was conducted in the same room using the same software.

Procedure

All of the procedures were the same as in Study 1 with a few exceptions. First, the mouse button no longer had to be held down to reveal the sample stimulus. Instead, the sample stimulus could be observing with a mouse click and hidden again by moving the cursor off the sample stimulus. Second, the sample stimulus was now covered by four small masks with each mask covering one quadrant of the sample stimulus. Figure 4 displays a schematic for the sample and comparison screens. A new set of stimuli were used (A4-A6 as sample stimuli and B4-B6 as comparison stimuli as seen in Figure 1). In addition, the mastery criterion was changed to 50 correct trials in a row.

Results

Figure 5 presents a cumulative record of correct responses (left axis) and sample observing time (right axis) for each participant. There was an overall downward trend in sample observing time during training. For all three participants, there was a sharp decrease in sample observing time as well as a sharp increase in response accuracy at some point during training. For P6 and P7 the sharp decrease in sample observing time occurred several trials after the increase in accuracy. For P8 the sharp decrease in sample observing time occurred several trials before the increase in accuracy.

Figures 6-8 present data on observing times separately for each of the three sample stimuli broken down by the separate quadrants for P6, P7, and P8, respectively. Each graph presents a separate conditional relation. Observing times for each quadrant are presented in individual data paths accompanied by unique symbols. Each line represents a different quadrant. A square root transformation was applied to these data to produce a more even distribution along the y-axis for easier interpretation. Because of this transformation, the actual drop-off in times are larger than what they appear to be in the graph. The presentation method of quadrant observing time in this study is similar to proportion over time graphs often used in studies of gridded areas of interest (AOI) in eye-tracking as in Alopenna, Magnuson, and Tanenhaus (1998). Similar to the method used in this paper, visual analysis is often recommended when evaluating such data (Holmqvist & Andersson, 2017, p. 293). The trial number listed along the x-axis of the quadrant observing time graph refers to the exact trial number on which the stimulus was presented.

The data for P6 is the most complex. For P6, the observing time of sample stimulus A4 peaked in the top right quadrant before the drop-off, and then responding was longest in the top right quadrant thereafter. Observing time of sample stimulus A5 was split between the bottom left and bottom right quadrants just before acquisition, but then was almost exclusively to the bottom right thereafter. Sample stimulus A6 had the most mixed responding, however. Observing time peaked in the top left quadrant, and then there was the greatest responding in the top left thereafter. The observation time was second highest in the top right, and this was also the only other quadrant to have consistent responding for the rest of training.

For P7, the observing time of sample stimulus A4 peaked in the top left quadrant before the drop-off, and then responding was longest in the top left quadrant thereafter. Observing time of sample stimulus A5 was almost exclusively to the top left. Sample stimulus A6 also had consistent responding to the top left. Observing time peaked in the top left quadrant, and then there was the greatest responding in the top left thereafter.

For P8, the observing time of sample stimulus A4 peaked in the bottom right quadrant before the drop-off, and then responding was longest in the top right quadrant thereafter. Observing time of sample stimulus A5 also peaked in the bottom right, but then was highest in the top right later on. Sample stimulus A6 had gradually decreasing peaks in three quadrants (bottom right, top left, top right), and then was highest in the top right.

Across all stimuli, P7 had the highest peak in quadrant observing time in the top left quadrant, followed by an overall drop-off in quadrant observing time with responding thereafter being almost exclusively to the top left quadrant. Across all stimuli, P8 had more mixed responding early on to each of the quadrants, but eventually was responding almost exclusively to the top right quadrant.

Discussion

The results from Study 1 were replicated for all participants in Study 2. That is to say, learning was abrupt, and the change in sample observing time was also abrupt. Further, two out of three participants were only responding to a single quadrant by the end of the experiment. This implies stimulus control had been established to those quadrants. P6 presented a more interesting case in which there was differentiation between stimuli as well as within-stimuli in terms of which quadrant was being observed.

Importantly in this study, the responses were changing over time. True differentiation wasn’t fully established until more than halfway through the training. Also, there was often an early peak in responding around the time of acquisition to the quadrant which later had the longest duration of responding. Generally, behavior analytic studies of eye-tracking in the past have taken such Area of Interest (AOI) data and binned it into a single average. This produces a simple number for easy comparison. One major difficulty in such problems is determining the appropriate window of analysis. Should the entire data set be used across the entire session or only part of the data set, and if so, which part? As was shown in this study, there are likely to be differences between the behavior during the beginning of the discrimination training, just before the onset of acquisition of the discrimination, and after acquisition of the discrimination. A simple average cannot accommodate these differences whereas visual analysis of a graph of the time series can do so. If statistical analysis is to be used, it must be able to accommodate these factors. See Barr (2008) for one such example of statistical analysis.

One possible limitation of Study 2 might have been that the training began with the sample stimulus covered with the four masks. In this method, it is possible that the procedure itself created control by particular quadrants rather than simply assessing where the control had developed. For example, the subject may come to respond under control of the first quadrant or last quadrant they reveal. P8’s data, for example, shows that the top right quadrant gained stimulus control for all three stimuli. While it’s certainly possible that such control had developed organically, it is also possible that the procedure drove the outcome. A better method might be one that first allows the conditional relation to develop without any masking and then uses the masking procedure to assess which quadrant or quadrants have come to exert selective control. Study 3 explored this possibility.

EXPERIMENT 3

The purpose of this study was the same as Study 2 – to attempt a more precise characterization of how the subject is observing the sample stimulus when a conditional discrimination with complex visual stimuli is being acquired. A potential limitation with Study 2 was that the training procedure might guide or force the development of control by a quadrant. To address this issue, Study 3 began with the sample stimulus completely unmasked. This was so that stimulus control could be established without any potential interference from the mask. Once subjects met a training criterion, the quadrant masks were introduced to begin assessing whether certain quadrants had gained selective stimulus control.

More importantly, Study 3 sought to assess the extent to which the development of selective observing of a quadrant created functional stimulus control by the quadrant. This was accomplished by presentation of a test condition in which the subject only had visual access to one quadrant and evaluating performance accuracy. A second purpose of this study, then, was to determine the degree to which quadrant observing time during training correlated with accuracy during testing when each quadrant was tested separately.

Methods

Participants and Setting

Two additional participants were recruited on a volunteer basis. They were both male graduate students in their twenties.

Procedure

At the beginning of the experiment, no mask covered any portion of the sample stimulus. Figure 9 presents a schematic of the sample and comparison screens. The experiment would proceed as normal until the participants had gotten eight out of ten trials correct within a single block of ten trials. At that point the experiment would then proceed to masking the stimuli in the exact same manner as in Experiment 2. Once mastery had been met (8 out of 10 correct for 3 consecutive blocks), an additional testing condition was presented to the participants.

In the testing condition, the program would select the quadrant rather than the participant. The participants first received the following instructions: “Welcome! Select the correct image. You will not be given any feedback on this task.” The first trial began when the participant clicked continue. The trial began with a sample stimulus being presented in which only a single quadrant was observing with the other quadrants of the stimulus covered by a black mask. The sample stimulus presented and the quadrant revealed would be quasi-randomly selected. The quadrant revealed would not change at any point during the trial. Figure 10 presents a schematic for the testing condition. The program ended once the participant had completed 120 trials.

Results

Figure 11 presents a cumulative record of correct responses on the MTS task (left axis) and the total time spent viewing the sample (dotted line) and the time to select a comparison stimulus (dashed line) on each trial (right axis) for each participant. Reaction time measures include the time spent observing the sample as well as the time spent selecting a comparison stimulus. For P11, there was a gradual increase in response accuracy as well as a gradual decrease in reaction time. For P12, there was a sharp increase in response accuracy, and a sharp decrease in reaction time. When the masked condition was introduced, both participants had an initially sharp increase in reaction time followed by a sharp decrease in reaction time. In P11’s case the increase lasted for only a single trial. For P12, the reaction time increase remained present for seven trials. This figure also shows that sample observing times also quickly decreased to small values and remained so for the remainder of training.

Figures 12 and 13 present data for each participant's quadrant observing time broken down by both quadrant and stimulus for P11 and P12, respectively. Each of three graphs present data for a separate conditional relation. Each line represents a different quadrant. A square root transformation was applied to these data to produce a more even distribution along the y-axis for easier interpretation. Because of this transformation, the actual drop-off in times are larger than what they appear to be in the graph. The trial number listed along the x-axis of the quadrant observing time graph refers to the exact trial number on which the stimulus was selected by the quasi-random number generator.

For P11, sample stimulus A1 and sample stimulus A3 produced the longest quadrant observing time in the top left quadrant. Sample stimulus A2 produced the longest and most consistent responding in the bottom right quadrant. P12's data is more difficult to interpret. Although quadrant observing time was longest in the top left quadrant for all two out of three conditioned relations and second longest in the third, there was sustained responding to all four quadrants throughout the experiment.

Figure 14 presents the results from the testing condition. The top panel presents accuracy separated by trial types based on the quadrant that was revealed on a test trial. Each bar presents the proportion of trials with a correct response out of all the trials in which that particular quadrant was revealed to the subject. For example, the figure shows that P11 chose the correct comparison stimulus on all trials in which only the top-left quadrant of the sample stimulus was presented. The bottom panel presents the mean observing for each quadrant during the masked portion of the training condition. For example, the bottom panel shows that P11 spent more time looking at the top left quadrant relative to other quadrants when A1 was the sample.

This figure reveals some interesting relations between the time subjects spent observing various portions of the stimuli during the training condition and their performance on test trials when the quadrant revealed was chosen for them. For P11, performance accuracy on two of the three conditional relations during testing maps nicely to quadrant observing times during the training condition conditions. For sample stimuli A1 and A2 there does appear to be a strong correlation between quadrant observing time and testing accuracy. For P12, there appears to be a weak correlation between quadrant observing time and testing accuracy. No correlations were noted for sample stimuli A3 for either of the subjects.

Discussion

Similar to the relation between sample observing time and accuracy from the first two studies, a relation between reaction time and accuracy was also found in this study. In the case of P11, gradual decreases in reaction time correlated with gradual increases in accuracy. For P12, the abrupt decrease correlated with an abrupt increase in accuracy. On the other hand, the clear differentiations in quadrant observing time from Study 2 was not found in Study 3. Although there was some differentiation, it wasn’t especially consistent. This was reflected in the comparison between testing and training where, although a correlation between accuracy and quadrant observing time was found, it was a weak correlation.

GENERAL DISCUSSION

The three studies presented here represent an attempt at a more precise and functional characterization of the development of stimulus control. The results of all three studies suggest that the methods explored here may indeed allow a more precise characterization of which features of a stimulus are gaining control during the development of a discrimination or conditional relation.

Across the three studies there was general evidence of a relationship between accuracy and speed wherein abrupt increases in accuracy corresponded with abrupt decreases in sample observing time (or reaction time in the case of Experiment 3). Study 1 showed that sample observing times decrease as conditional discriminations develop. Study 2 provided suggestive evidence that this may be because the subjects are developing more efficient observing strategies. Study 3 further provides evidence of a positive correlation between time spent looking at parts of the stimuli and the control they exert on subsequent performance. These studies were primarily exploratory in nature, and as such, strong conclusions cannot be drawn. Ideally the experiments would have been conducted with naive and paid participants. Further piloting may have aided in discovering better ways to produce reliable differences between the quadrants. It is still unclear how best to resolve the problem of selecting an appropriate window of analysis as discussed at the end of Study 2, but the method of focusing on the period at the end of training appears promising. It is also possible that stimulus control is changing during the course of training, which is another potential factor. A larger sample size would be necessary in the case of Study 3 if no further changes to its design were made. However, I believe that masking is a useful tool for stimulus control assessment and conditioning, and that methods along the lines of those shown in this experiment have many possibilities.

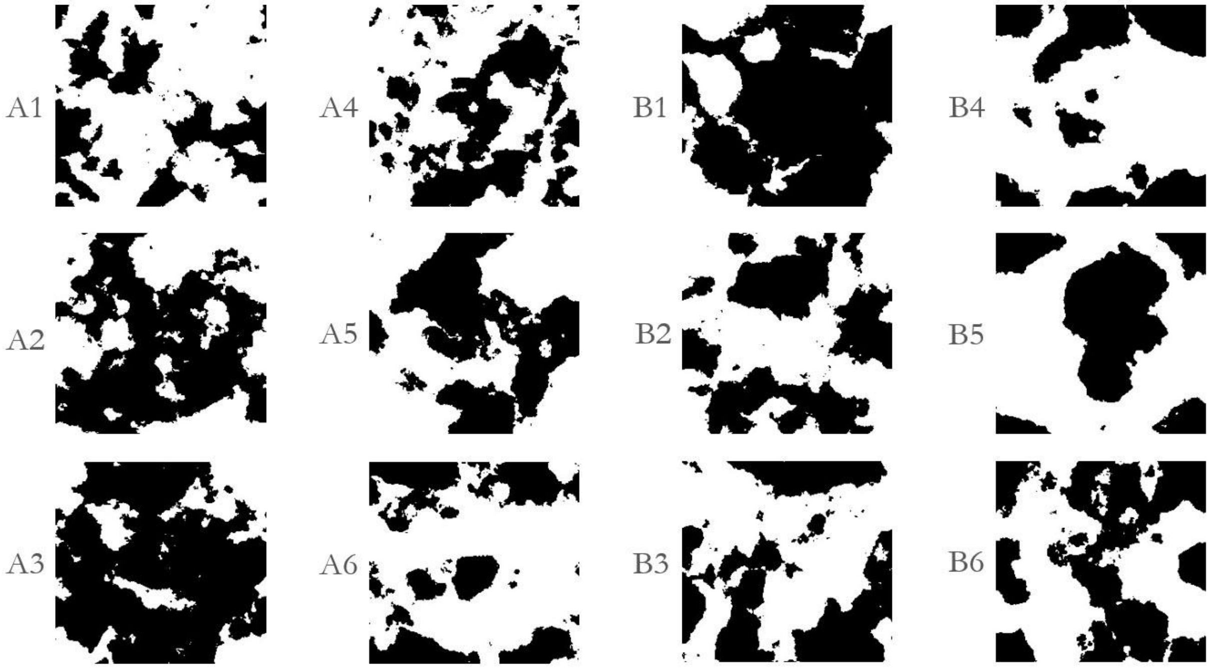

Figure 1. The stimuli used in the three experiments.

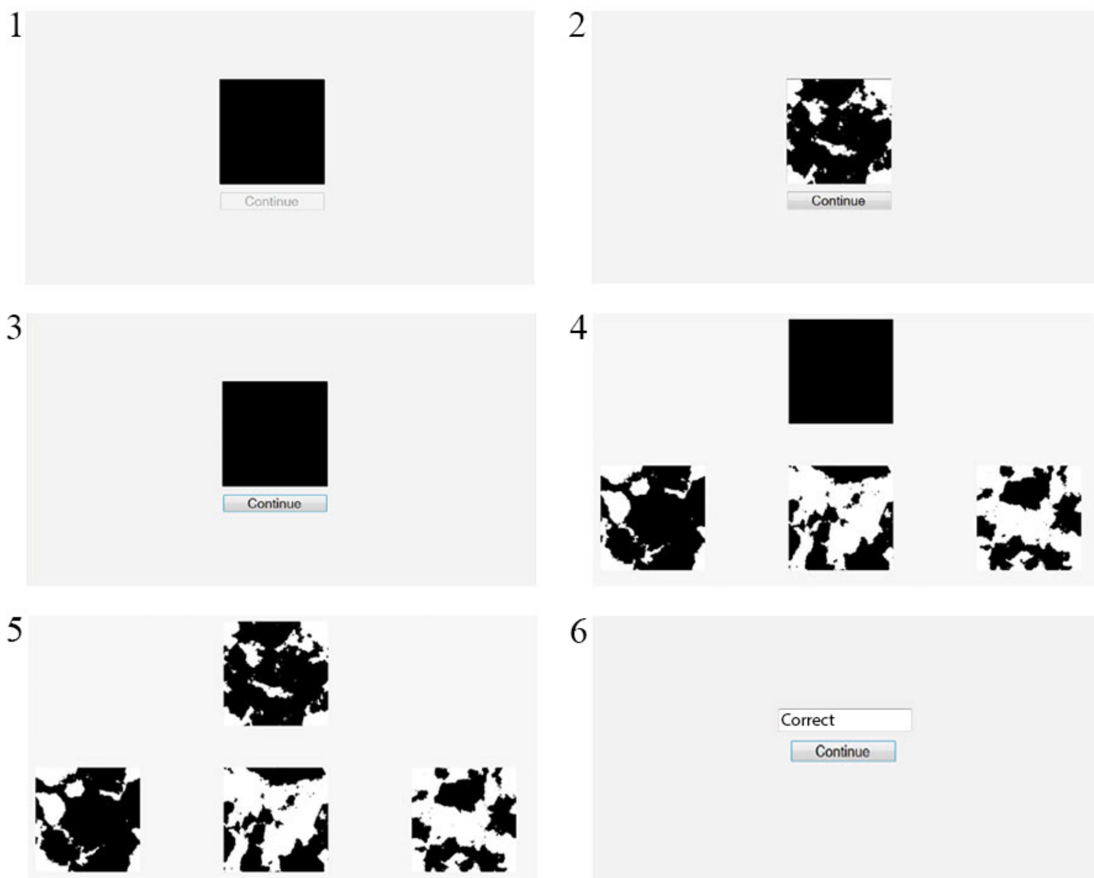

Figure 2. An example trial from Experiment 1.

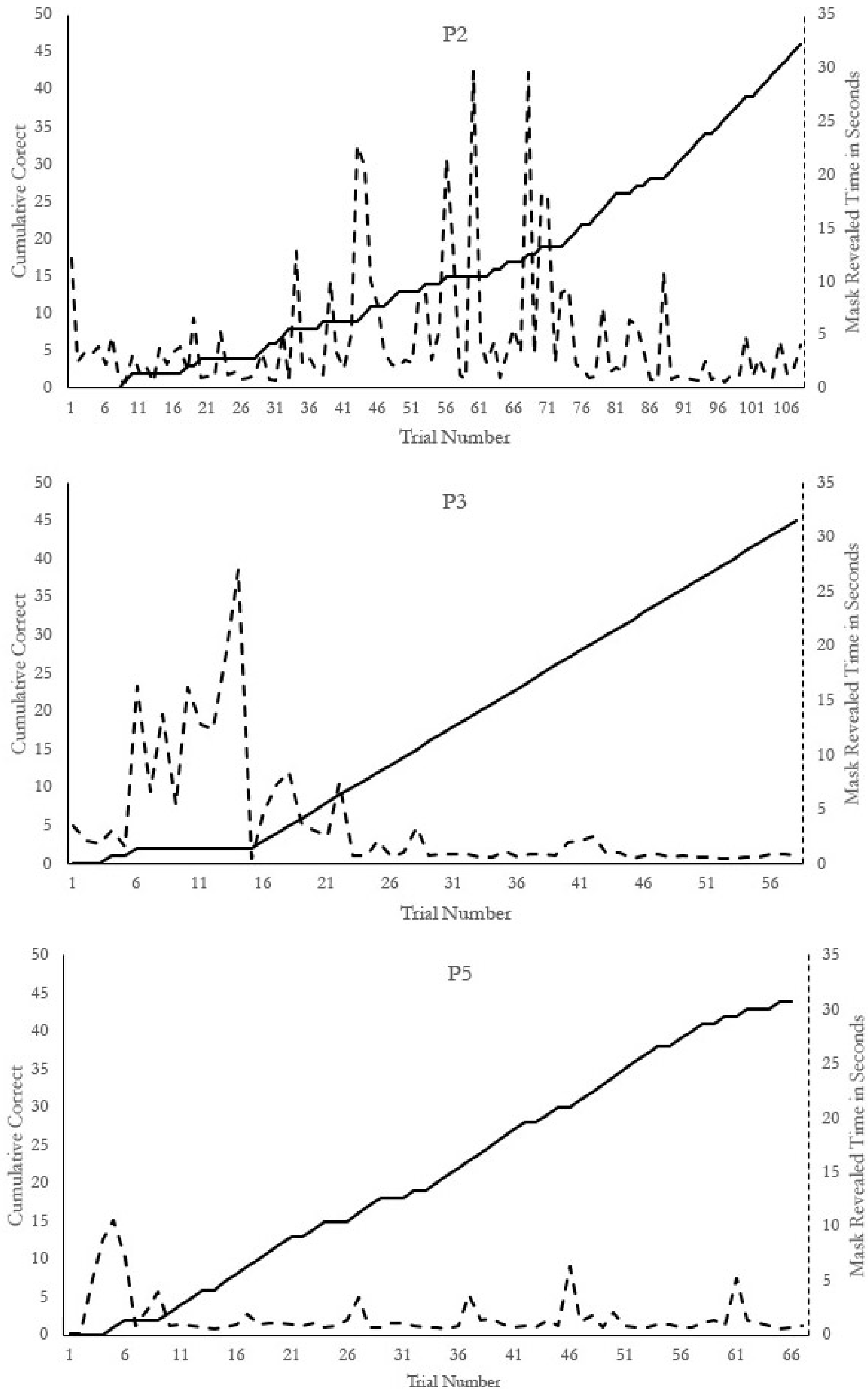

Figure 3. The solid line depicts the cumulative number of correct trials for each participant in Experiment 1. The dashed line depicts the sample observing time in seconds on every trial for each participant.

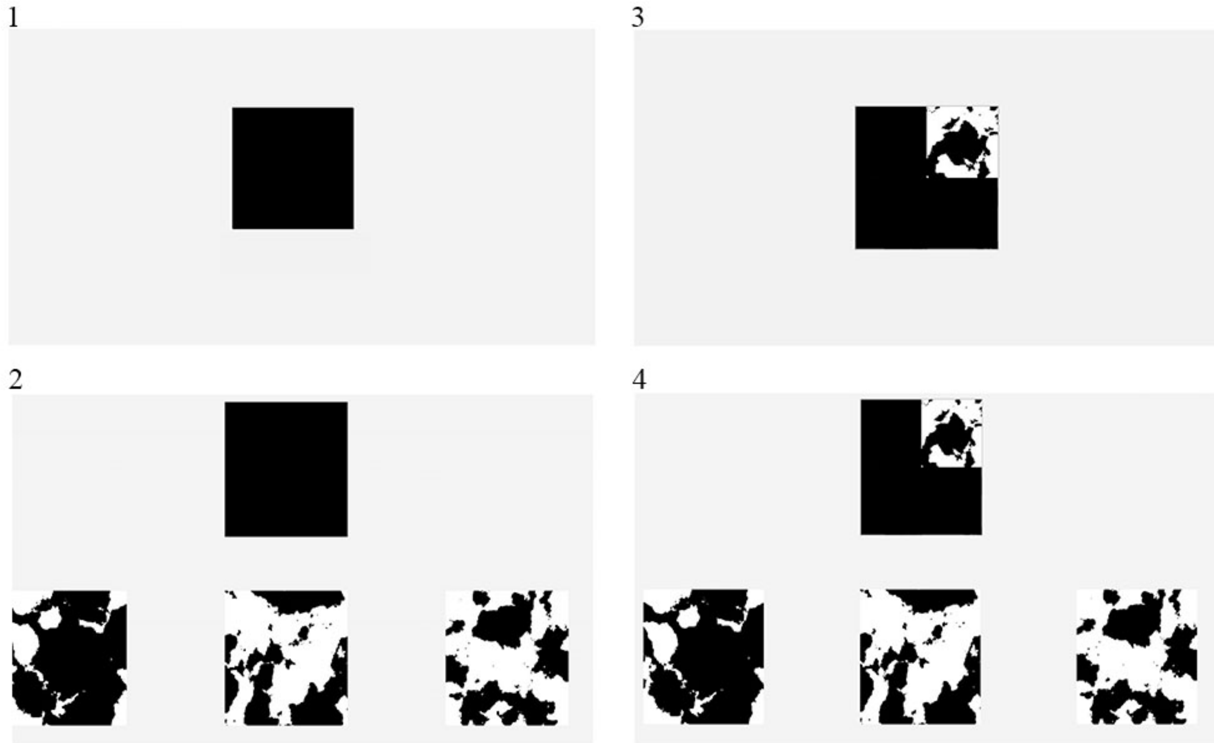

Figure 4. The sample and comparison screens from Experiment 2 are presented. Participants could reveal one quadrant at a time by clicking on that quadrant.

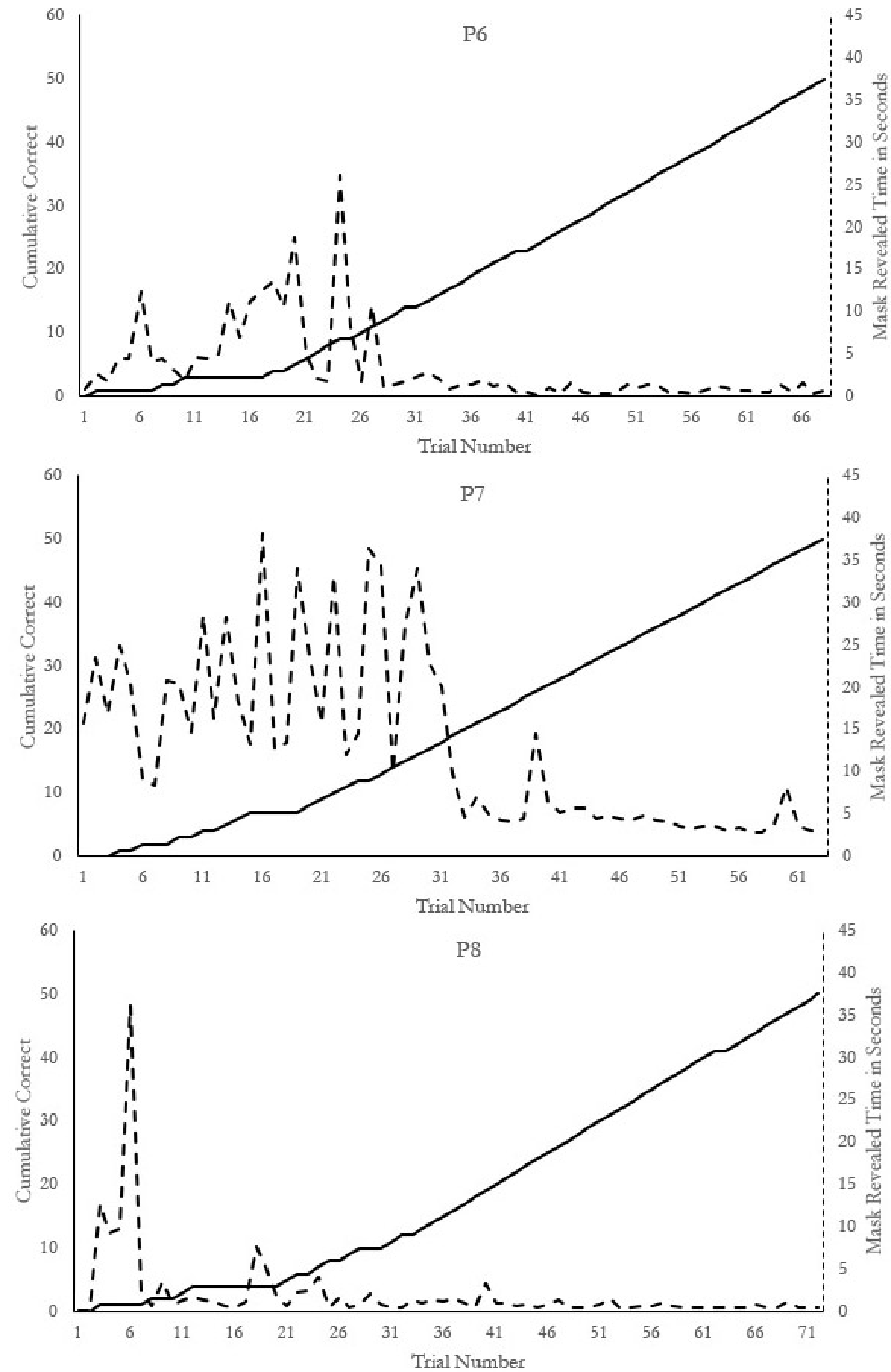

Figure 5. The solid line depicts the cumulative number of correct trials for each participant in Experiment 2. The dashed line depicts the sample observing time in seconds on every trial for each participant.

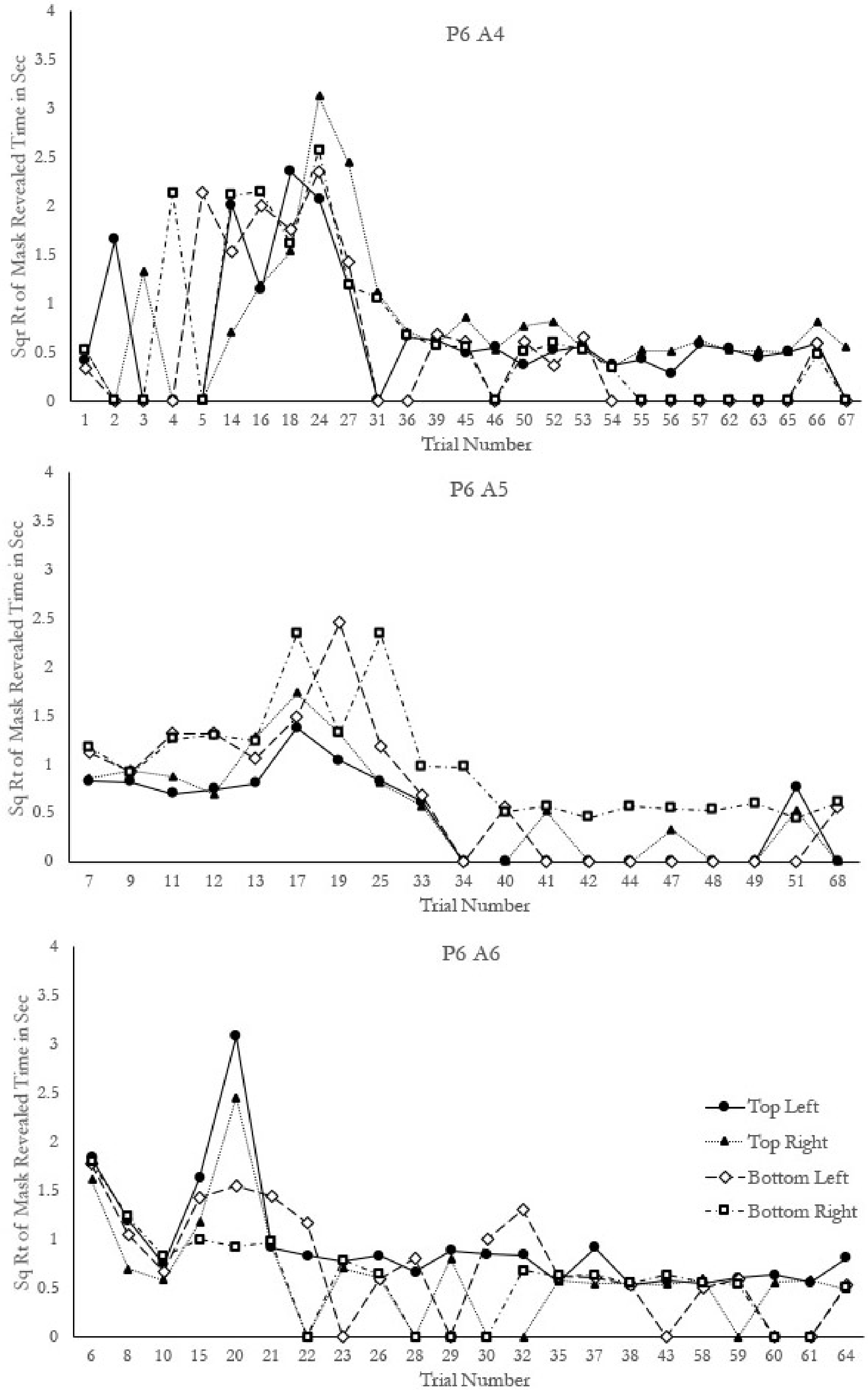

Figure 6. Each line shows the quadrant observing time from a different quadrant. The data is broken down by stimulus. The x-axis gives the exact trial number on which the stimulus appeared. The data for P6 is depicted.

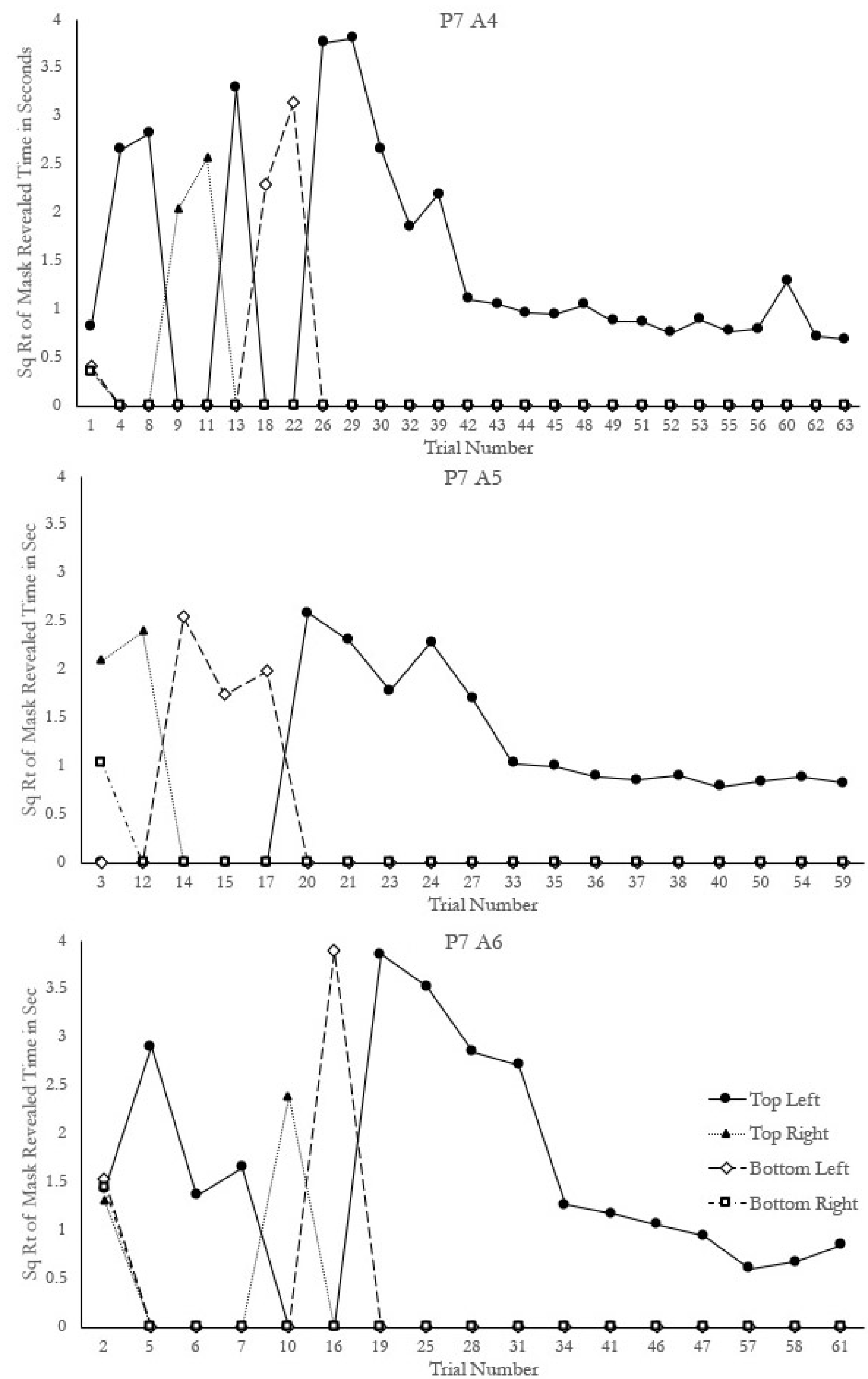

Figure 7. Each line shows the quadrant observing time from a different quadrant. The data is broken down by stimulus. The x-axis gives the exact trial number on which the stimulus appeared. The data for P7 is depicted.

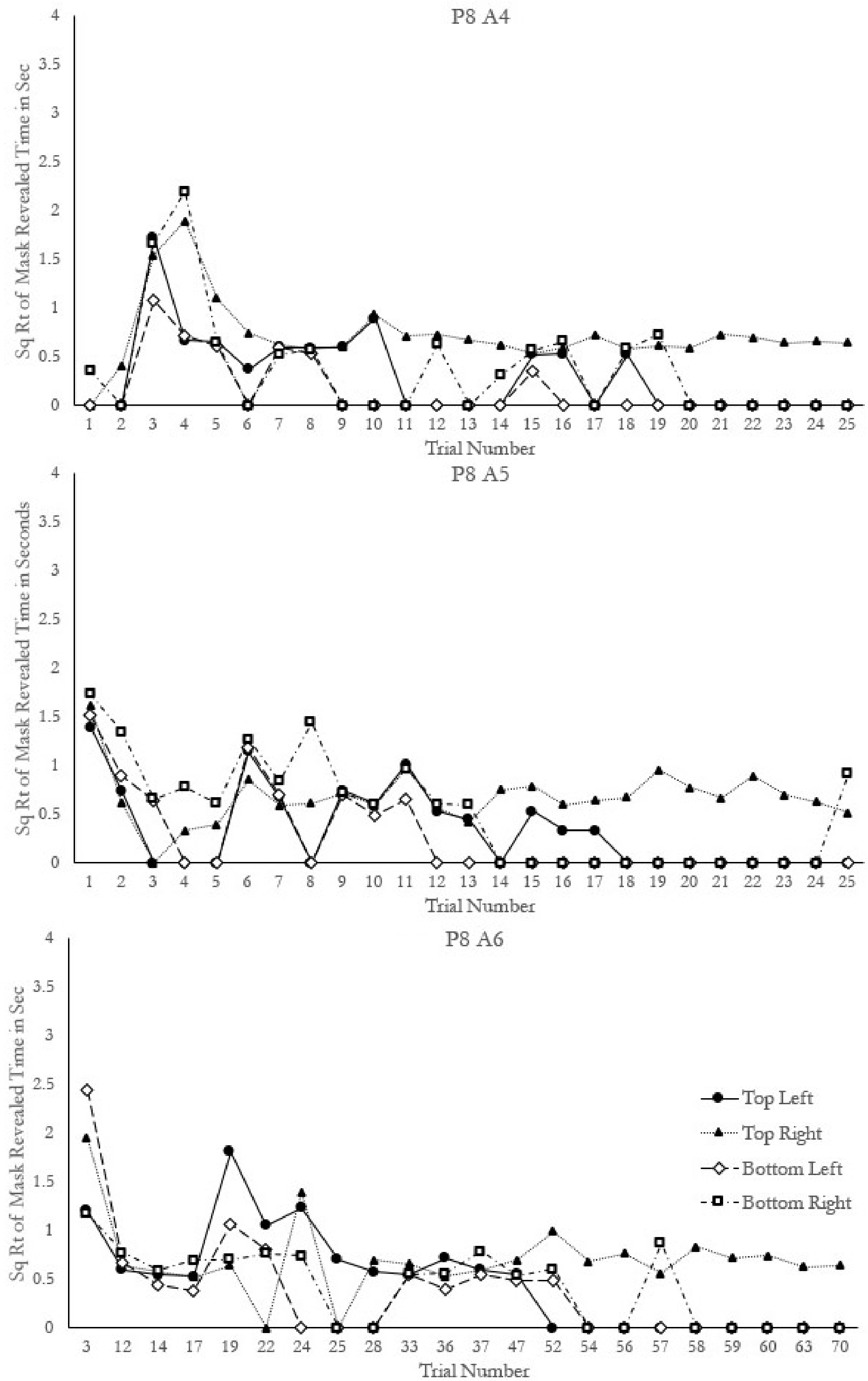

Figure 8. Each line shows the quadrant observing time from a different quadrant. The data is broken down by stimulus. The x-axis gives the exact trial number on which the stimulus appeared. The data for P8 is depicted.

Figure 9. The sample and comparison screen from the unmasked condition of Experiment 3 are shown.

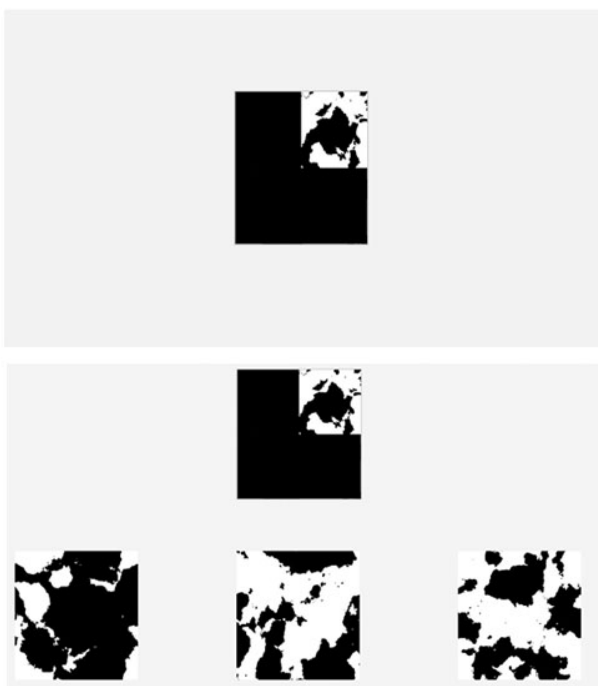

Figure 10. The sample and comparison screens from the testing condition are shown. Only one quadrant is revealed at a time, and the participant is unable to change the quadrant being revealed.

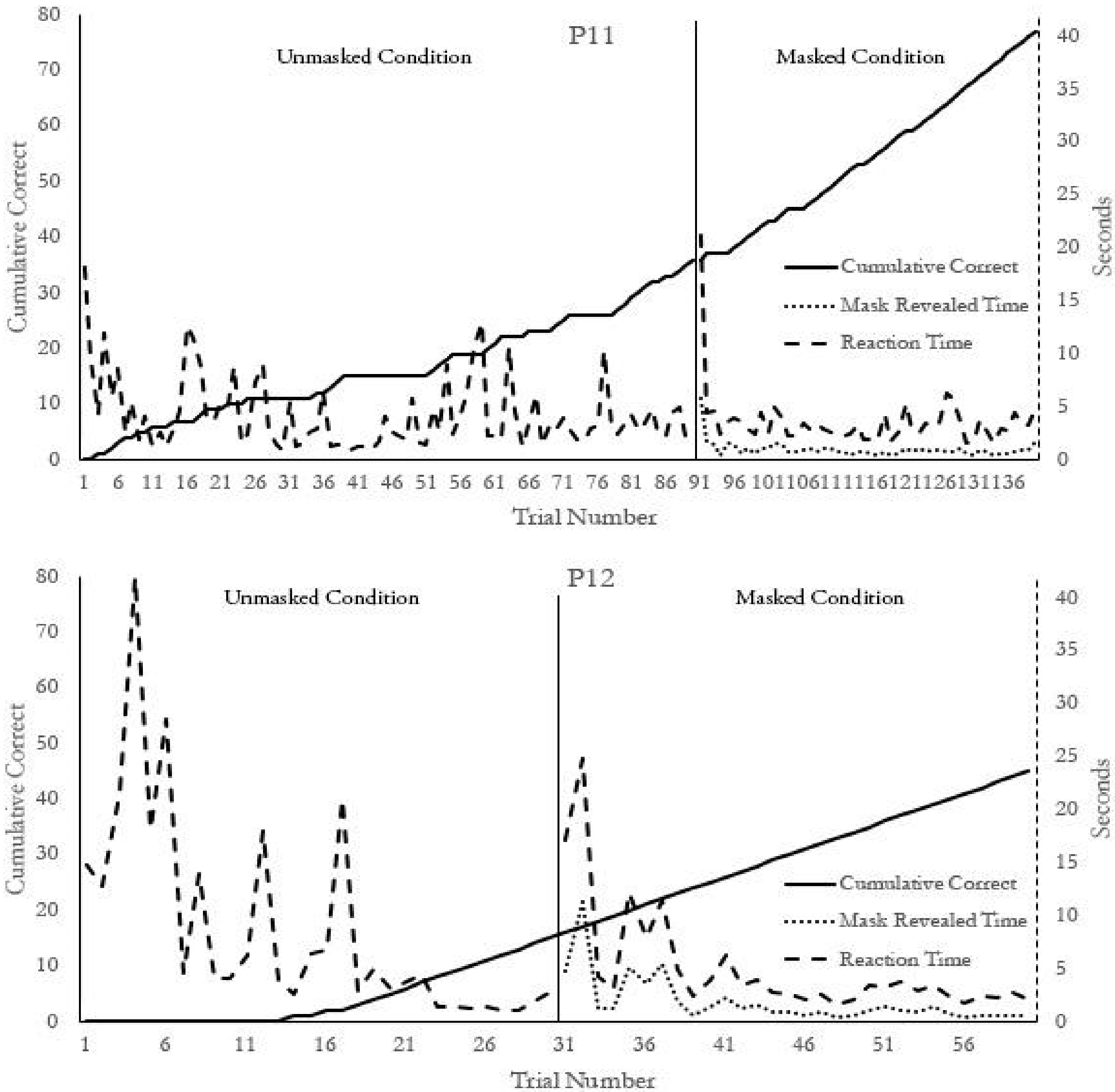

Figure 11. This shows the cumulative correct responses, the reaction times and the total sample observing times from Experiment 3.

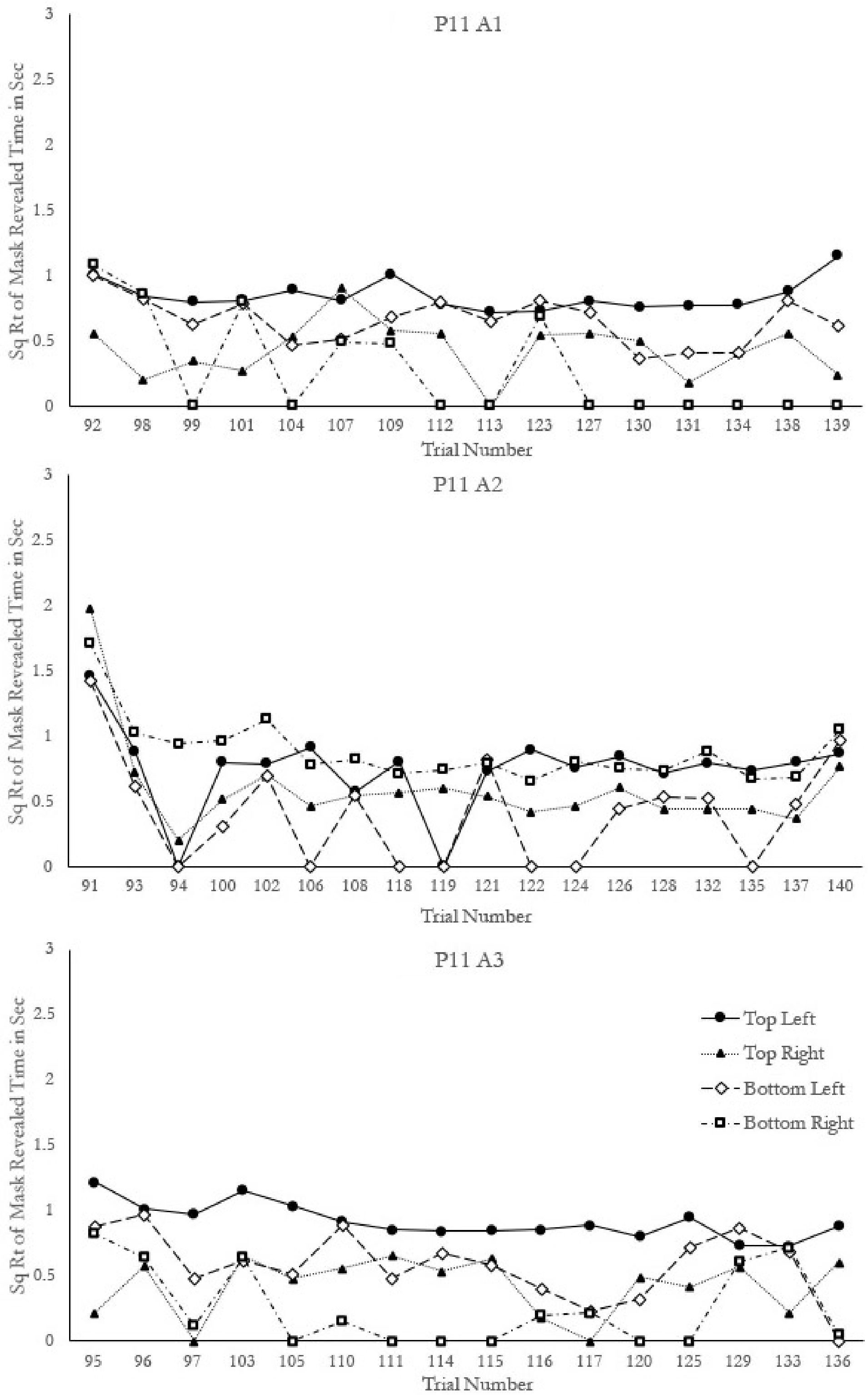

Figure 12. Each line shows the quadrant observing time from a different quadrant. The data is broken down by stimulus. The x-axis gives the exact trial number on which the stimulus appeared. The data for P11 is depicted.

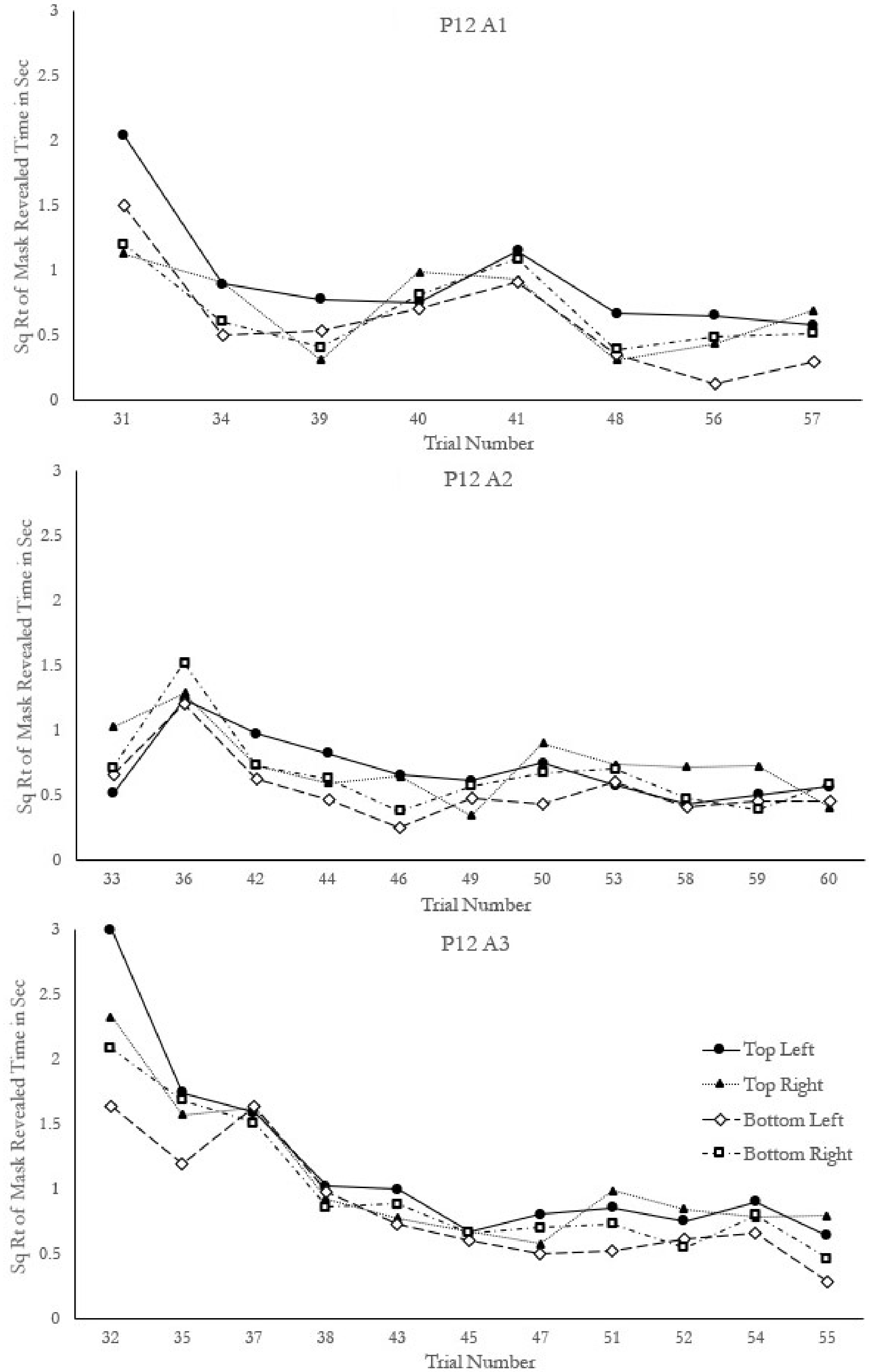

Figure 13. Each line shows the quadrant observing time from a different quadrant. The data is broken down by stimulus. The x-axis gives the exact trial number on which the stimulus appeared. The data for P12 is depicted.

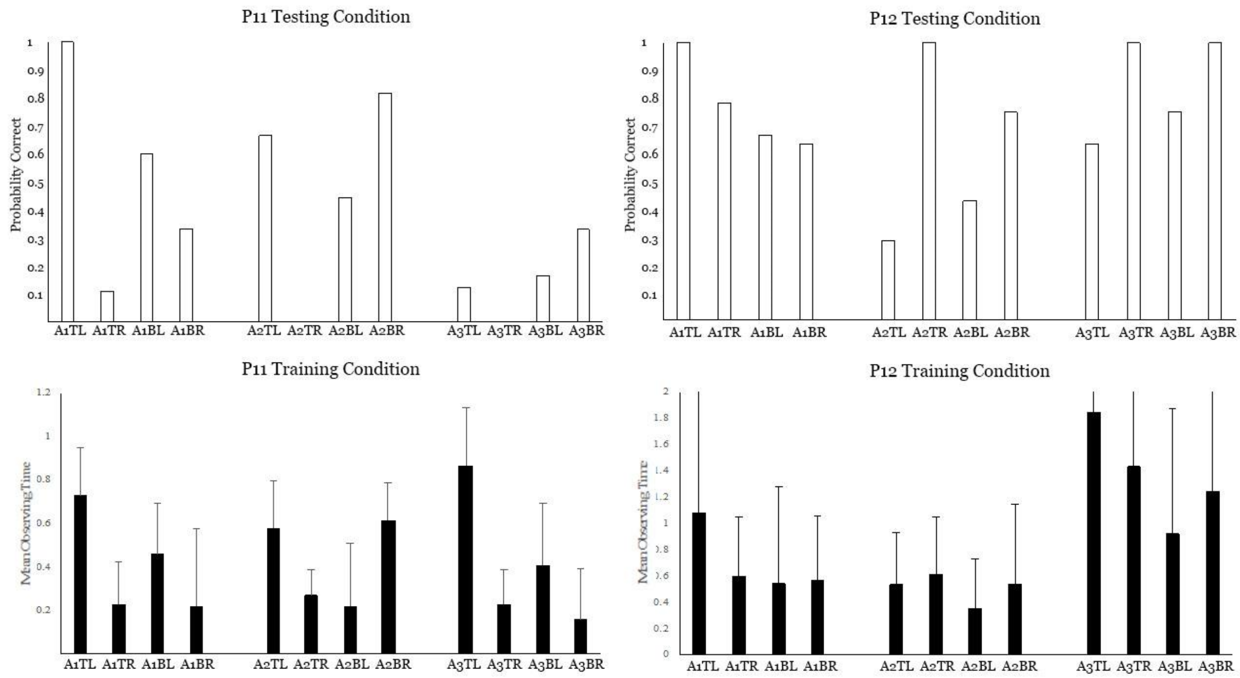

Figure 14. The top two figures depict each participant's accuracy during testing broken down by conditioned relation and quadrant. The bottom two figures depict each participant's average quadrant observing time also broken down by conditioned relation.

REFERENCES

Barr, D. J. (2008). Analyzing ‘visual world’eyetracking data using multilevel logistic regression. *Journal of memory and language*, *59*(4), 457-474.

Catania, A. C. (2013). A natural science of behavior. *Review of General Psychology*, *17*(2), 133-139.

Charness, N., Reingold, E. M., Pomplun, M., & Stampe, D. M. (2001). The perceptual aspect of skilled performance in chess: Evidence from eye movements. *Memory & cognition*, *29*(8), 1146-1152.

Collewijn, H., Erkelens, C. J., & Steinman, R. M. (1988). Binocular co-ordination of human horizontal saccadic eye movements. *The Journal of physiology*, *404*(1), 157-182.

De Graef, P., Christiaens, D., & d'Ydewalle, G. (1990). Perceptual effects of scene context on object identification. *Psychological research, 52*(4), 317-329.

Donner, Y., & Hardy, J. L. (2015). Piecewise power laws in individual learning curves. *Psychonomic bulletin & review*, *22*(5), 1308-1319.

Dube, W. V., Balsamo, L. M., Fowler, T. R., Dickson, C. A., Lombard, K. M., & Tomanari, G. Y. (2006). Observing behavior topography in delayed matching to multiple samples. *The Psychological Record*, *56*(2), 233-244.

Dube, W. V., Dickson, C. A., Balsamo, L. M., O'Donnell, K. L., Tomanari, G. Y., Farren, K. M., ... & McIlvane, W. J. (2010). Observing behavior and atypically restricted stimulus control. *Journal of the experimental analysis of behavior*, *94*(3), 297-313.

Ehmke, C., & Wilson, S. (2007). Identifying web usability problems from eye-tracking data. In *Proceedings of the 21st British HCI Group Annual Conference on People and Computers: HCI... but not as we know it-Volume 1* (pp. 119-128). British Computer Society.

Fields, L., Bruno, V., & Keller, K. (1976). The stages of acquisition in stimulus fading. *Journal of the Experimental Analysis of Behavior*, *26*(2), 295-300.

Gallistel, C. R., Fairhurst, S., & Balsam, P. (2004). The learning curve: implications of a quantitative analysis. *Proceedings of the National Academy of Sciences*, *101*(36), 13124-13131.

Holmqvist, K. & Andersson, R. (2017). *Eye tracking: A comprehensive guide to methods and measures* (2nd ed.). OUP Oxford.

Huziwara, E. M., de Souza, D. D. G., & Tomanari, G. Y. (2016). Patterns of eye movement in matching-to-sample tasks. *Psicología: Reflexão e Crítica*, *29*(1), 2.

Knoblich, G., Ohlsson, S., & Raney, G. E. (2001). An eye movement study of insight problem solving. *Memory & cognition*, *29*(7), 1000-1009.

Laya, O. (1992). Eye movements in actual and simulated curve negotiation tasks. *IATSS research*, *16*(1), 15-26.

Lovaas, O. I., Koegel, R. L., & Schreibman, L. (1979). Stimulus overselectivity in autism: a review of research. *Psychological bulletin*, *86*(6), 1236.

Lovaas, O. I., & Schreibman, L. (1971). Stimulus overselectivity of autistic children in a two stimulus situation. *Behaviour research and therapy*, *9*(4), 305-310.

McHugh, L., & Reed, P. (2007). Age trends in stimulus overselectivity. *Journal of the Experimental Analysis of Behavior*, *88*(3), 369-380.

Nodine, C. F., Locher, P. J., & Krupinski, E. A. (1993). The role of formal art training on perception and aesthetic judgment of art compositions. *Leonardo*, *26*(3), 219-227.

Pessôa, C. V. B. B., Huziwara, E., Perez, W. F., Endemann, P., & Tomanari, G. Y. (2009). Eye fixations to figures in a four-choice situation with luminance balanced areas: Evaluating practice effects. *Journal of Eye Movement Research*, *2*(5), 3.

Ploog, B. O. (2010). Stimulus overselectivity four decades later: A review of the literature and its implications for current research in autism spectrum disorder. *Journal of autism and developmental disorders*, *40*(11), 1332-1349.

Prerau, M. J., Smith, A. C., Eden, U. T., Kubota, Y., Yanike, M., Suzuki, W., Graybiel, A.M. & Brown, E. N. (2009). Characterizing learning by simultaneous analysis of continuous and binary measures of performance. *Journal of neurophysiology*.

Reed, P., & Gibson, E. (2005). The effect of concurrent task load on stimulus over-selectivity. *Journal of Autism and Developmental Disorders*, *35*(5), 601-614.

Rincover, A. (1978). Variables affecting stimulus fading and discriminative responding in psychotic children. *Journal of Abnormal Psychology*, *87*(5), 541.

Sidman, M. (2010). Errorless learning and programmed instruction: The myth of the learning curve. *European Journal of Behavior Analysis*, *11*(2), 167-180.

Skinner, B. F. (1932). On the rate of formation of a conditioned reflex. Journal of General Psychology, 7, 274-286.

Skinner, B. F. (1935). The generic nature of the concepts of stimulus and response. *The Journal of General Psychology*, *12*(1), 40-65.

Tomanari, G. Y., Balsamo, L. M., Fowler, T. R., Lombard, K. M., Farren, K. M., & Dube, W. V. (2007). Manual and ocular observing behavior in human subjects. *European Journal of Behavior Analysis*, *8*(1), 29-40.