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Eye Movements During Pareidolia: Exploring Biomarkers for Thinking and Perception Problems on the Rorschach

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Abstract: Eye movements (EMs) offer valuable insights into cognitive and perceptual processes, serving as potential biomarkers for disordered thinking. This study explores the relationship between EM indices and perception and thinking problems in the Rorschach Performance Assessment System (R-PAS). Sixty non-clinical participants underwent eye-tracking while completing the Rorschach test, focusing on variables from the Perception and Thinking Problems Domain (e.g., WSumCog, SevCog, FQo%). Results revealed that increased cognitive disturbances were associated with greater exploratory activity but reduced processing efficiency. Regression analyses highlighted the strong predictive role of cognitive variables (e.g., WSumCog) over perceptual ones (e.g., FQo%). Minimal overlap was observed between performance-based (R-PAS) and self-report measures (BSI), underscoring the need for multi-method approaches. Findings suggest that EM patterns could serve as biomarkers for early detection and intervention, offering a foundation for future research on psychotic-spectrum processes in clinical and non-clinical populations.

Keywords: eye movements; eye tracking; pareidolia; perception and thinking problems; rorschach

1. Introduction

Eye movements (EMs) are promising behavioral correlates of cognitive, social, and emotional functioning as they are sophisticated processes controlled by the brain, and due to their low cost, non-invasive nature, and objectivity in measurement [1]. When responding to the Rorschach, individuals visually scan the blots to identify features that align with familiar objects, essentially constructing recognizable objects from the variations in shading and form. This is commonly known as the process of pareidolia [2].

Recent studies by [3] and [4] have shown the value of EMs in understanding processing strategies during the Rorschach by establishing associations between EM indices and variables from the Rorschach Performance Assessment System (R-PAS) [5]. These studies found that participants with higher Complexity scores exhibited more fixations while scanning the blots, indicating higher levels of cognitive engagement, consistent with the R-PAS interpretation of Complexity. Additionally, participants showed shorter fixation durations as their Vague Percent (Vg%) increased, suggesting shallower information processing. These findings demonstrate the usefulness of R-PAS variables as correlates to EMs for understanding how pareidolic processing strategies are associated with implicit personality characteristics in the Engagement and Cognitive Processing Domain [5].

The current study aims to explore eye movement correlates of the Perception and Thinking Problems Domain of the R-PAS [5], which largely represents issues in thinking, judgment, or perception. Variables such as Fo%, POP codes, WSumCog, SevCog, EII-3, and TP-Comp are related

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to conventionality, reality testing, thought disorganization, and disturbing thought content, involving both thinking and perceptual aspects [5]. The goal is to understand options for detecting disordered thinking and the utility of methods for doing so. While some research has investigated features of disordered thinking in non-clinical individuals, most attention has been given to clinically diagnosed individuals. Using non-clinical populations can be valuable, as many current models propose a continuum of psychotic experiences in the population [6–8]. Investigating non-clinical populations can also contribute to using EMs in early detection and prevention and improving the specificity of EMs as biomarkers of psychosis. This exploratory study aims to establish strong behavioral biomarker candidates for predictive hypotheses in future studies of clinical and non-clinical samples.

2. Materials and Methods

2.1. Participants

Sixty individuals (18 males) from a Midwestern University's undergraduate participant pool and the surrounding community participated in this study (age range 18 to 60 years, mean = 25.73, S.D. = 8.72). All participants had normal or corrected-to-normal visual acuity, and color blindness was an exclusion criterion. Participants were paid $30 for their time in the laboratory (2-2 1/2 hours). The study was approved by the university's Institutional Review Board (Protocol #1314-41) and conducted in accordance with the Belmont Principles (1978), with all participants providing informed consent.

2.2. Stimuli & Apparatus

The 10 Rorschach inkblots [9] were digitized for presentation on a 17-inch color monitor. Eye movement characteristics were recorded using an Eyelink-II Eye-Tracking system with head-mounted video cameras sampling pupil position at 500 Hz as participants engaged in visual tasks. An eye movement was detected when eye velocity exceeded 30° s–1 or eye accelera-tion exceeded 8000° s–2. After a 9-point calibration, the reported gaze position accuracy on the Rorschach images was 0.5° -1.0° of visual angle and was not hindered by minor head movements less than ±15° of visual angle (e.g., from uttering verbal responses during the Rorschach test). The eye tracker was controlled by EYETRACK software (http://www.umass.edu/psychology/div2/eyelab/).

2.3. Measures

Eye movement indices used in this study and their definitions are provided in Table 1. The focus of the current study is the R-PAS Perception and Thinking Problems Domain. Page 1 and Page 2 variables and brief descriptions of their interpretive significance can be found in Table 2.

Table 1. Definitions of Eye-Tracking Variables used in the Present Study.

Eye Tracking Measure	Definition
NF	The number of fixations used to scan the images.
FD	The mean duration of the time the eye is still while a participant acquires information from these images.
SA	The mean distance the eye travel travels in search of information.
ISA	The eye distance traveled at the onset of each image.
ISL	The reaction time at the onset of each image.
URV	Method of dividing the stimulus field into non-overlapping regions of equal size which receive at least one fixation.
URV/NF	Number of unique regions visited per number of fixations
NF/sec	Number of fixations per second.
URV/sec	Number of unique regions visited per second

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Table 2. Page 1 and Page 2 R-PAS variables from the Perception and Thinking Problems Domain.

Variable	Name	Brief Interpretation
Page 1		
EII-3	Ego Impairment Index	Thinking disturbance and how severe the psychopathology (if present) is.
TP-Comp	Thought and Perception Composite	Reality testing; disorganized thinking.
WSumCog	Weighted Sum of the Six Cognitive Codes	Disordered and disturbing thinking.
SevCog	Severe Cognitive Codes	Evidence of severe problems with thinking.
FQ–%	Form Quality–%	Distortions of reality; not perceiving the world as others do.
WD–%	Percent of W's and D's that have minus form quality	Distortions of reality are present, even in conventional or common situations.
FQo%	Ordinary Form Quality Percentage	Seeing the world in the ways that others do.
P	Popular	Seeing the world in the ways others do, but also in highly conventional ways.
Page 2		
FQu%	Unusual Form Quality Percentage	Sees the world in a somewhat different way than others do and, as a result, has a tendency to engage in more individualistic behaviors.

In addition, the Brief Symptom Inventory [10] was administered to participants. The scales of Paranoid Ideation (Pa), Psychoticism (Py), Global Severity Index (GSI), Positive Symptom Index (PSI), and the Positive Symptom Distress Index (PSDI) were the focus of analyses to understand perception and thinking problems and compare self-report measures with performance-based measures.

2.4. Procedure

Participants completed a demographic questionnaire, self-report measures, and a performance-based measure (not in the scope of the present study). The Eyelink II eye-tracking cameras were fitted for comfort during extended use. Participants sat 55 cm from the monitor, with Rorschach images subtending visual angles of approximately 6° by 6°. Viewing was binocular, but recording was monocular, measuring only right eye movements [1].

The R-PAS administration of the Rorschach [5] was utilized with minor modifications to account for viewing the images on a computer screen. The images were presented sequentially (Cards I-X), and a trial was terminated when the participant indicated completion. The Clarification phase was completed with physical cards, according to the standardized R-PAS procedure, after removing the eye tracker. Rorschach verbal responses were coded and scored according to R-PAS criteria [5]. Each participant's responses were coded by the second and fourth authors to consensus, both of whom have extensive R-PAS training, teaching, and supervision of students learning the R-PAS. Following the initial scoring, the authors met to compare their scores and resolve any discrepancies through discussion and reference to the R-PAS manual. This collaborative process allowed the scorers to share their rationales, ensuring a thorough examination of each protocol and a comprehensive

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understanding of the scoring criteria. The consensus scoring approach was chosen to ensure the highest level of accuracy and consistency in the scoring of the Rorschach protocols.

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. R-PAS and BSI

The first aspect to consider is the correspondence between the performance measures (R-PAS) and self-report measures (BSI). Table 3 illustrates the correlations between these two sets of variables measuring disturbances of thinking and reality testing. Psychoticism was inversely correlated with FQo%, indicating that higher Psychoticism scores are associated with lower levels of ordinary form quality on the Rorschach. The GSI was correlated with FQu%, suggesting that higher Global Severity of self-reported symptoms was related to more unusual form quality in the participant's Rorschach protocol. No other relationships were statistically significant.

Table 3. Intercorrelations between Perception and Thinking Problems Domain and BSI variables.

Perception and Thinking Problems	Paranoid Ideation	Psychoticism	GSI	PST	PSDI
Page 1					
EII_3	.053	.113	-.038	-.046	.012
TP_Comp	.010	.150	-.030	-.035	.038
WSumCog	-.002	.091	-.006	-.017	.057
SevCog	.001	.115	.006	.001	.100
FQm_Per	.062	.122	-.023	-.008	-.059
WDm_Per	.095	.090	.087	.063	.124
FQo_Per	-.146	-.312*	-.233	-.231	-.121
Popular	-.032	-.020	-.100	-.085	.017
Page 2					
FQu%	.121	.226	.270*	.252	.173

* p<.05 GSI (Global Severity Index); PST (Positive Symptom Total); PSDI (Positive Symptom Distress Index).

Next, we examine the relationships between the EM variables, R-PAS variables, and BSI variables in Table 4. Overall, there were several significant correlations between R-PAS variables of Perception and Thinking Problems and NF, URV, and URV/NF. NF, URV, and URV/sec were correlated with EII-3, TP_Comp, WSumCog, Sev Cog, and FQo%. URVV/NF was correlated with EII-3, TP_Comp, WSumCog, and Sev Cog. In contrast, there were several significant correlations between BSI variables and FD (Pa, PY, GSI, and PSI), indicating that the two different methods of assessing psychotic or psychotic-spectrum processes are related to different facets of the allocation of attention and information processing.

Table 4. Correlations between EM variables, R-PAS Thinking and Perception Problems Domain.

Eye-Tracking	EII_3	TPComp	WSumCog	SevCog	FQm%	WDm%	FQo%	P	FQu%+	BSIPA	BSIPY	BSIGSI	BSIPST	BSIPDI
NF	.455**	.401**	.370**	.310*	.202	.120	-.261*	-.110	.160	-.004	-.180	-.114	-.140	-.093
FD	.027	.065	-.084	-.087	.175	.178	.007	-.145	-.121	-.260*	-.264*	-.255*	-.268*	-.228
URV	.337**	.313*	.311*	.261*	.177	.109	-.290*	-.144	.190	.026	-.094	-.051	-.070	.002
SA	-.008	.030	.039	.002	.070	.216	-.221	-.125	.179	-.005	.086	-.028	-.034	-.106
URV/NF	-.395**	-.319*	-.302*	-.249	-.115	-.050	.220	.035	-.197	-.071	.150	.017	.034	.159
NF/sec	-.004	-.119	.032	.022	-.222	-.262*	.088	.290*	.058	.080	.071	.138	.145	.063
URV/sec	-.370**	-.392**	-.257*	-.208	-.267*	-.235	.267*	.227	.140	-.011	.177	.096	.115	.175

* $p<.05$
** $p<.01$
+ Page 2 variable

3.2. Cognitive and Perceptual variables

Given the relationships between several R-PAS variables and EM indices, it is useful to gain more insight into the findings. The Perception and Thinking Problems Domain contains variables that are more sensitive to perception (e.g., FQo%, FQu%, FQ-%) and others more sensitive to thinking or cognitive aspects (e.g., WSumCog and SevCog). To address whether the variation associated with EMs can be accounted for by perceptually relevant variables, cognitively relevant variables, or both, simple regressions were run with each of the significant EM variables (i.e., NF, URV, URV/NF). A perceptually related variable (FQo%) and a cognitively related variable (WSumCog) were selected as predictor variables.

The first regression analysis revealed the relationship between the dependent variable, NF, and two predictors: WSumCog and FQo%. The model summary indicated an R^2 of .171, suggesting that approximately 17.1% of the variance in NF was explained by the predictors. The adjusted R^2 value was slightly lower at .142, accounting for the number of predictors in the model. The F-statistic for the change in R^2 was significant $F(2, 57) = 5.880$, $p = .005$, indicating that the mod-el significantly predicts the dependent variable.

The coefficients table shows that WSumCog had a positive relationship with NF ($B = 9.657$, $p = .010$), whereas FQo% showed a negative relationship, though not statistically significant ($B = -10.808$, $p = .131$). The constant term is significantly different from zero ($B = 1638.297$, $p < .001$). Table 5 summarizes the regression analysis.

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Table 5. Regression analysis for the dependent variable of NF and independent variables of WSumCog and FQ0Per.

Predictor	B	SE	β	t	p
Constant	1638.297	404.964		4.046	<.001
WSumCog	9.657	3.635	.328	2.657	.010
FQo_Per	-10.808	7.056	-.189	-1.532	.131

The second regression analysis shows how the dependent variable URV was influenced by two predictors: WSumCog and FQo%. The model summary revealed an R^2 value of .148, indicating that about 14.8% of the variance in URV was explained by these predictors. The adjusted R^2 is .119, which adjusts for the number of predictors. The model's change in R^2 was statistically sig-nificant F (2, 57) = 4.969, p = .010, affirming that the model is a good fit for the data.

From the coefficients table, WSumCog exhibits a positive association with URV (B = 1.296, p = .043), while FQo% showed a negative association, which was not statistically significant (B = -2.259, p = .068). The intercept was significantly different from zero (B = 462.253, p < .001). Table 6 summarizes the regression analysis.

Table 6. Regression analysis for the dependent variable of URV and independent variables of WSumCog and FQ0Per.

Predictor	B	SE	β	t	p
Constant	462.253	69.643		6.637	<.001
WSumCog	1.296	.625	.260	2.073	.043
FQo_Per	-2.259	1.214	-.233	-1.861	.068

The third regression analysis examined the relationship between the dependent variable URV/NF and two predictors: WSumCog and FQo%. The model summary showed an R^2 of .116, indicating that approximately 11.6% of the variance in the dependent variable was explained by these predictors. The adjusted R^2 was lower at .085, reflecting the adjustment for the number of predictors. The model's R^2 change was statistically significant F (2, 57) = 3.731, p = .030, sug-gesting that the model provides a significant fit to the data.

In the coefficients table, WSumCog was negatively associated with the dependent variable (B = -.001, p = .042), while FQo% showed a positive but not statistically significant association (B = .001, p = .211). The intercept was significantly different from zero (B = .281, p < .001). Table 7 summarizes the regression analysis.

Table 7. Regression analysis for the dependent variable of URV/NF and independent variables of WSumCog and FQoPer.

Predictor	B	SE	β	t	p
Constant	.281	.057		4.962	<.001
WSumCog	-.001	.001	-.266	-2.084	.042

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Predictor	B	SE	β	t	p
FQo_Per	.001	.001	.162	1.265	.211

The fourth regression analysis examined the relationship between the dependent variable URV/sec and two predictors: WSumCog and FQo%. The model achieved an R^2 of .112, suggest-ing that approximately 11.2% of the variance in the dependent variable was explained by these predictors. The adjusted R^2 lowers slightly to .081, considering the number of predictors. The model's change in R^2 was statistically significant $F (2, 57) = 3.605$, $p = .034$), indicating a signif-icant predictive capability.

From the coefficients table, WSumCog shows a negative association with URV/sec (B = -.002, p = .109), although this effect is not statistically significant. FQo% exhibits a positive association with URV/sec (B = .005, p = .090), also not reaching statistical significance. Table 8 summarizes the regression analysis.

Table 8. Regression analysis for the dependent variable of URV/sec and independent variables of WSumCog and FQo%.

Predictor	B	SE	β	t	p
Constant	.610	.155		3.925	<.001
WSumCog	-.002	.001	-.208	-1.627	.109
FQo_Per	.005	.003	.221	1.726	.090

4. Discussion

The results show several significant relationships between R-PAS variables and EM indices, suggesting different levels of pareidolic processing for individuals experiencing varying levels of thinking and perception problems. Both cognitive and perceptual variables indicated that increasing levels of difficulty are associated with more fixations and visiting more regions of the inkblots, suggesting a more exhaustive and possibly scattered search pattern. This pattern could indicate a higher cognitive load (Rayner, 1998; 2009) as individuals struggle to make sense of the stimuli, potentially reflecting their efforts to impose structure or find meaning in ambiguous situations. At the same time, higher degrees of thinking disturbance are associated with generally less efficient processing, as higher levels of scores for EII-3, TP_Comp, WSumCog, and FQ-% are inversely correlated to URV/NF. The increased cognitive load could lead to less efficient processing for individuals with greater difficulties in thinking and reality testing, as they might revisit the same concepts or struggle with integrating information cohesively.

The regression analyses indicated that the cognitive variables likely contribute more to the variance compared to the perceptual variables. WSumCog, which measures thinking disturbance, predicted a significant amount of variance for EM indices of NF, URV, and URV/NF, while FQo% failed to reach significance. As thinking disturbance increases, participants showed greater exploratory activity but exhibited less efficient processing, suggesting that participants with higher degrees of thinking disturbance might utilize more effort to perform the task. It is possible that even subclinical thinking disturbances could lead to this loss of efficiency.

There was very little overlap between R-PAS and BSI, with a small degree of convergence between self-report and performance measures, consistent with research. This finding argues for the use of multiple methods in research studies.

The current study's findings have several implications for understanding the relationship between eye movements, pareidolic perception, and thinking problems. Eye movements have been

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used as behavioral biomarkers for disordered thinking in schizophrenia, with a well-established body of literature documenting abnormalities in individuals with schizophrenia diagnoses (Miassian et a., 2005; W. A. Phillips & Silverstein, 2013; Silverstein et al., 2015; Yoon et al., 2013). Eye movement methodology can help overcome methodological issues related to generalized performance deficits in perception and thinking disturbances by measuring task performance variability across group comparisons, manipulating visual stimuli independently of cognitive demands, and controlling for differences in stimulus detection and orientation (Yoon et al., 2013). This research aimed to establish biophysiologic models of cognition (Daskalakis, 2012) and provide information for future clinical and research applications. Understanding how eye movement behavior varies with stimulus type, task, and features of information processing disturbance is crucial for elucidating the clinical relevance of eye movement behavior as a biomarker for disordered thinking.

The present study focused on extending knowledge of relationships between EMs as bio-behavioral markers and cognitive dysfunctions seen in psychotic disorders, particularly in non-clinical individuals who, to varying degrees, report or perform in ways that deviate from typical perception and thinking. The results suggest that eye movement indices can serve as valuable bio-behavioral markers for detecting and characterizing cognitive dysfunctions associated with psychotic disorders, even in non-clinical populations. The use of eye tracking technology in conjunction with the Rorschach test may provide a more comprehensive assessment of an individual's cognitive and perceptual functioning, potentially aiding in early detection and prevention efforts.

Furthermore, the study highlights the importance of considering both cognitive and perceptual aspects when investigating thinking and perception problems. The findings indicate that cognitive variables, such as thinking disturbance measured by WSumCog, may have a greater influence on eye movement patterns compared to perceptual variables. This insight can guide future research efforts and inform the development of targeted interventions for individuals experiencing cognitive difficulties.

Limitations and Future Directions

While the current study provides valuable insights, it is important to acknowledge its limitations. The sample size of 60 participants, although sufficient for exploratory analyses, may limit the generalizability of the findings. Future research should aim to replicate these results with larger and more diverse samples, including both clinical and non-clinical populations.

Additionally, the study relied on a single performance-based measure (Rorschach) and a single self-report measure (BSI) to assess perception and thinking problems. Incorporating a broader range of assessment tools, such as cognitive tasks and neuroimaging techniques, could provide a more comprehensive understanding of the relationship between eye movements and cognitive dysfunctions.

Future research should also explore the potential of using eye movement indices as predictive markers for the development of psychotic disorders. Longitudinal studies following individuals with subclinical thinking disturbances could help establish the predictive value of eye movement patterns in identifying those at risk for developing more severe psychopathology.

Moreover, investigating the neural correlates of eye movement abnormalities in individuals with perception and thinking problems could provide valuable insights into the underlying mechanisms of these dysfunctions. Combining eye tracking with neuroimaging techniques, such as functional magnetic resonance imaging (fMRI; e.g. Akdeniz, Toker, & Atli 2018) or electroencephalography (EEG), could help elucidate the brain regions and networks involved in aberrant cognitive processing.

In conclusion, the current study demonstrates the value of using eye movement indices as bio-behavioral markers for understanding perception and thinking problems in non-clinical populations. The findings highlight the importance of considering both cognitive and perceptual aspects when investigating these dysfunctions and provide a foundation for future research aimed at improving early detection, prevention, and intervention efforts for individuals at risk of developing psychotic disorders. [1] Binocular recording of eye movements is only of concern during some reading studies where very fine spatial resolution is of importance (e.g., Liversedge et al., 2006, 2013), and do not outweigh the set-up convenience and cost-savings to researchers or the comfort of participants offered by monocular recording of eye movements.

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Conflicts of Interest: The authors declare no conflicts of interest.

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