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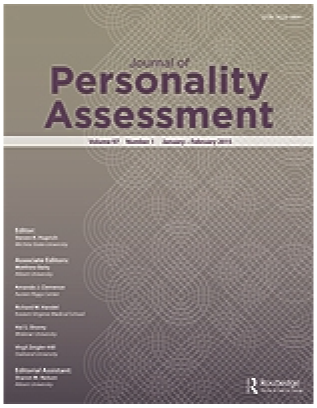

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Abstract

Recently, Ales et al. (2019) reported on an eye-tracking study showing that Complexity and other R-PAS variables located in the Engagement and Cognitive Processing domain are correlated with a proxy marker for cognitive effort and engagement. The goal of the current study was to test the robustness and validity of Ales et al.'s (2019) findings by inspecting fMRI data. We hypothesized that the greater the level of engagement and cognitive effort put in place by a Rorschach test-taker, the greater the engagement of his/her cortical areas reflecting ongoing top-down attentional processes should be. We re-analyzed archival fMRI data from 26 healthy participants exposed to the Rorschach inkblots with the instruction to think of what they might be. The association of various Engagement and Cognitive Processing R-PAS scores to increased BOLD signals in the Dorsal Attention Network of the brain was examined. As expected, Complexity showed the strongest effect size across all R-PAS variables under investigation (*d* = 0.43), followed by Synthesis (*d* = 0.32) and Human Movement (*d* = 0.21). Noteworthy, the correlation between the effect sizes found in the current fMRI study and those found in Ales et al.'s (2019) eye-tracking study consists of an impressive *r* = .80.

Keywords: Rorschach; R-PAS; Complexity; Attention; DAN; fMRI.

Complexity and Cognitive Engagement in the Rorschach Task: An fMRI Study

The Rorschach Performance Assessment System (R-PAS; Meyer et al., 2011) was introduced in 2011 to carry on the efforts initiated by the Comprehensive System (CS; Exner, 1974, 2003) to anchor Rorschach interpretations to their evidence base. A major change put in place by R-PAS, compared to CS, was the introduction of an aggregated index representing the "first factor" of the Rorschach, i.e., "the variable that defines the biggest source of variability in the test." (Meyer et al., 2011; p. 319). Originally introduced by Viglione (1999) as "the amount of productivity, precision, differentiation, and integration involved in the aggregate of all the responses" (p. 259), this variable is given primary importance in R-PAS interpretative routines.

Named Complexity, this R-PAS score serves multiple purposes, including quantifying amount of interpretatively useful information contained in a protocol. It combines three different parameters, one related to the responses' location, space and object quality, one related to their content(s), and one related to their determinant(s). A high Complexity score suggests that the test-taker has put a considerable level of psychological activity and effort to cope with the demands of the Rorschach task (Meyer et al., 2011). When that happens, one could infer that the test-taker would likely be prone to put more cognitive activity and energy when responding to real-life challenges too, outside the microcosm of the test. Particularly with individuals with mental health problems, however, a high Complexity score could also reflect less favorable psychological characteristics, such as lack of attentional control due to anxiety, agitation, mania, or trauma, confusion, rumination, and emotional overwhelming. Alternatively, low Complexity may result from an economical but sophisticated processing style in which one adroitly simplifies the task and identifies key or essential perceptual responses to the Rorschach question, "What might this be?" Regardless of these case-specific interpretive indications, higher Complexity scores represent more output and typically indicate an increased engagement with the testing situation. Because it aggregates other variables in the Engagement and Cognitive Processing domain of R-PAS interpretation, it is considered to be the most important one in the domain (Meyer et al., 2011).

Other empirically supported variables located in this same R-PAS interpretive domain include the total number of responses (R) provided by the test-taker, the percentage of responses whose sole determinant code is form (F%), the number of responses containing more than one determinant code (Blend), the number of responses in which multiple objects are meaningfully related with each other (Sy), and a few other codes related to the presence of the human movement (M) and/or chromatic color determinants (C, CF, and FC). Albeit from slightly different perspectives, all the scores in this domain characterize the level and type of engagement and cognitive processing demonstrated by the respondent while taking the Rorschach.

From another perspective, this R-PAS interpretive domain (i.e., Engagement and Cognitive Processing) conceptually relates also to the Rorschach Prognostic Rating Scale (RPRS), a composite measure with a long history in Rorschach research. Introduced in 1951 by Bruno Klopfer (Klopfer et al., 1951), the RPRS combined multiple codes with the purpose to measure ego strength and general adjustment status. In line with the hypothesis that the overall level of engagement and cognitive processing put in place by the examinees while taking the Rorschach provides useful information on their psychological resources, a meta-analytic study by Meyer and Handler (1997) strongly supported the validity of the RPRS in predicting subsequent therapeutic outcome ($\rho \geq .44$).

To investigate cognitive processes, a particularly powerful approach would be to use neuroimaging techniques. Although several empirical studies have provided data on psychophysiological measures of attentional processes related to the Rorschach response process (e.g., Kircher et al., 2001, 2005; Minassian et al., 2005; Perry et al., 1998), this type of research is still relatively scarce with regard to the R-PAS Engagement and Cognitive Processing domain variables. To our knowledge, there is one such study only: in 2019, Ales and colleagues published on an eye-tracking study ($N = 71$) testing the association of Complexity to a number of eye-tracking variables deemed to reflect cognitive effort and engagement. In that study, not only did Complexity significantly correlate with the number of fixations recorded throughout the response phase (RP) of the Rorschach administration ($r = .526$, $p < .001$), but it also explained the variance of the average number of fixations beyond the effects of each of the other R-PAS variables in the Engagement and Cognitive Processing domain entered in a series of hierarchical, multiple regressions. The authors thus concluded that their study provided some initial "psychophysiological support for the hypothesis that complexity might indeed be interpreted as an index of engagement, and possibly cognitive effort, too, as postulated by R-PAS manual" (p. 8).

To further contribute to the study of the psychophysiological foundation for interpreting Complexity as an index of engagement and cognitive effort, the current investigation used archival fMRI data and tested whether as the visual examination of the ten Rorschach inkblots became more active, complex, and articulated, the test-takers' brain activity in turn showed increased engagement in those cortical areas supposedly reflecting ongoing top-down attentional processes. More specifically, we tested whether the production of more complex Rorschach responses is associated with increased blood-oxygen-level-dependent (BOLD) signals in the Dorsal Attention Network of the brain (DAN; Corbetta & Shulman, 2002; Ptak, 2012; Vossel et al., 2014).

BOLD signal fluctuations are often used as a means to measure neural activity because of their presumed relationship with neural activity itself. As firstly argued by Ogawa (Ogawa & Lee, 1990; Ogawa, Lee, Kay, et al., 1990; Ogawa, Lee, Nayak, et al., 1990), they reflect differences in metabolic activity in brain regions involving cerebral blood flow (CBF) fluctuations. During any motor or “mental” action (such as viewing or processing a stimulus, feeling emotions, remembering facts or ideas, and so forth) the CBF increases as indicator of the functioning of those brain regions involved in the specific action (Fox & Raichle, 1986; Fox et al., 1988). The BOLD signal detects these hemodynamic fluctuations, thereby reflecting the neural activity – albeit not measuring it directly (Vul et al., 2009). Said differently, hemodynamic responses are markers of local field potentials’ activity, thereby implying a link between brain activation and local processing in that given brain region (Logothetis, 2003). Thus, the BOLD signal detection is deemed to be good measure of the strength of the neural responses elicited by a perceptual task, such as that posed by the Rorschach.

The Dorsal Attention Network (DAN) and Rorschach Complexity

Attentional processes can be divided in two categories: a goal-directed or top-down group, and a stimulus-driven or bottom-up group (Corbetta & Shulman, 2002; Posner, 1980; Vossel et al., 2014). These two systems are functionally and anatomically distinct in a dorsal pathway for top-down and a ventral pathway for bottom-up processing. The Dorsal Attention Network (DAN) comprises the intraparietal sulcus (IPS), the precuneus, the posterior cingulate cortex (PCC), the supplementary eye fields (SEF), and the frontal eye fields (FEF). The Ventral Attention Network (VAN) comprises the temporoparietal junction (TPJ) and the ventral frontal cortex (VFC) (Corbetta et al., 2000; Corbetta et al., 2008; Corbetta & Shulman, 2002; Olson & Colby, 2013). The DAN is associated to top-down control of attention, implies a voluntary orientation of the attentional focus and is activated during spatial monitoring and detection of different objects (Corbetta & Shulman, 2002; Ptak, 2012; Vossel et al., 2014). The VAN is related to bottom-up attentional processes and is activated when a behaviorally relevant stimulus appears within the attentional eye-field (Corbetta &

Shulman, 2002; Macaluso, 2010; Macaluso & Driver, 2005; Shulman et al., 2003; Vossel et al., 2014).

As suggested by Giromini et al. (2017), when a person is administered the Rorschach both the DAN and VAN are likely engaged. The DAN might be involved when the test-taker actively directs his or her attention to certain areas of the inkblot to find his or her own answer to the question, “What might this be?” Conversely, the VAN might be involved when certain features of the inkblot designs (possibly what Exner called “the critical bits”; Exner, 2003) ‘catch’ the interest of the test-taker so that he or she suddenly shifts his or her attention to an area of the stimulus he or she was not paying attention to before. Therefore, the DAN might involve a more active type of effort and engagement associated with the visual processing of the inkblot stimuli, whereas the VAN might involve a more passive approach, in which the attention of the test-taker is more stimulus-driven. Given that, one may speculate that the more the test-taker puts an active effort into attending to the stimuli to deliver a more complex and articulated response, the higher the engagement of the DAN.

Consistent with this hypothesis, Chaves et al. (2012) recently investigated the neuronal activity underlying the processes of visual exploration and visuospatial elaboration, and found that the number of fixations recorded via eye-tracking was associated with increased BOLD activity in core areas of the DAN (i.e., frontal eye fields, supplementary eye fields, and posterior cingulate cortex). This finding, together with the fact that in Ales et al.’s (2019) study Complexity strongly correlated with the number of fixations recorded during the visual examination of the Rorschach inkblot stimuli, suggests that Rorschach responses characterized by greater complexity should associate with increased activity in the DAN of the test-taker’s brain.

Method

The current study used the same database previously analyzed for three different published studies (Giromini et al., 2017; Giromini, Viglione, Pineda et al., 2019; Giromini, Viglione, Vitolo et al., 2019), encompassing fMRI data from 26 healthy participants exposed to the Rorschach inkblots with the instruction to think of what they might be. A first study investigated what brain areas are engaged, in general, when the Rorschach is administered to a person, regardless of what the test-taker sees in the inkblot designs (Giromini et al., 2017). A second study tested whether delivering a Human Movement (M) response would be associated with increased activity in mirror neuron-related areas in the brain (Giromini, Viglione, Pineda, et al., 2019). A third study examined whether delivering an Oral Dependency Language (ODL) response would be associated with increased activity in dependency-related areas in the brain (Giromini, Viglione, Vitolo, et al., 2019). These fMRI data, however, have never been analyzed to test the possible association of DAN activity to R-PAS scores reflecting cognitive engagement and processing.

In this study, we used a similar analytic approach to that used before by Giromini, Viglione, Pineda, et al. (2019) and by Giromini, Viglione, Vitolo, et al. (2019) to investigate M-related and ODL-related neural activations, respectively. First, we identified a region of interest (ROI) indicative of DAN involvement, by relying on Neurosynth (see www.neurosynth.org), an online platform for large scale, automated, meta-analytic synthesis of fMRI data (see Yarkoni et al., 2011a). Next, we split our participants' Rorschach responses into 'complex' responses versus 'non-complex' responses. This was done to maximize power and use the same analytic procedures utilized in previously published studies reporting on this same data set (Giromini, Viglione, Pineda, et al., 2019; Giromini, Viglione, Vitolo, et al., 2019). Indeed, as discussed in Giromini, Viglione, Pineda, et al. (2019), our study has fewer data points and thereby less power than the typical fMRI study, in that to preserve ecological validity we used 10 different visual stimuli only (i.e., the 10 Rorschach cards), we did not show the same stimuli more than twice. Considering that compared to more complex multivariate analyses, paired t-test comparisons require smaller sample sizes to achieve the same level of power (Cohen, 1988), dichotomizing Complexity into ‘complex’ versus ‘non-complex’ response outcomes was deemed necessary. Furthermore, this choice also allowed us to use the same approach for all variables under investigation – many of which are dichotomous in nature – and to be consistent with Giromini, Viglione, Pineda, et al. (2019) and Giromini, Viglione, Vitolo, et al. (2019), in which each dimensional code was dichotomized into “present” versus “absent” at the response-level, prior to analyzing the data. The final step of our analytic procedures consisted of computing a series of univariate ROI analyses, testing whether producing complex (versus non-complex) Rorschach responses was associated with increased (versus decreased) activity in the voxels included in the DAN ROI.

As noted above, consistent with Ales et al.’s (2019) study, in addition to testing Complexity, all other variables included in the R-PAS Engagement and Cognitive Processing domain were investigated too. This extrastep was undertaken because all of them also should inform, to some extent, on the level and type of engagement showed by the test-taker while taking the Rorschach. Additionally, it allowed us to compare the effect sizes obtained from our investigation against those found in the Ales et al. (2019) eye-tracking study, so to evaluate the replicability and generalizability of these neurophysiological findings.

The following sections summarize the key information concerning the methods used to collect and analyze our data. It should be noted that some additional details of the instructions given to the participants and of the technical fMRI methods are found in each of the three articles mentioned above, i.e., Giromini et al. (2017), Giromini, Viglione, Pineda, et al. (2019), and Giromini, Viglione, Vitolo, et al. (2019).

Participants

Twenty-six healthy volunteers (13 men; M_{age} = 21.4; SD_{age} = 2.3) took part in the study. Most of them (85%) were students recruited at the University of California, San Diego (UCSD); the remaining 15% was comprised of adult volunteers recruited by flyers posted at Alliant International University – San Diego. UCSD students received class credits and $15 cash for participation; other participants earned $18. None of the participants had a history of psychiatric or neurological illness; all were right-handed and had normal or corrected-to-normal vision. The research project was approved by the relevant institutional review boards prior to initiating participants' recruitment, and each participant gave written consent prior to being enrolled in the study.

Procedures

Upon arrival, participants were informed that during fMRI they would look at the 10 Rorschach cards, thinking of what they might be. Next, they were entered into the scanner, and a high-resolution whole-brain T1-weighted anatomical scan was obtained. Then, during the functional session, the 10 Rorschach cards were shown twice to the subject, with the instruction to think of, but not verbalize so as to minimize head movements and associated measurement error, a different response per each exposure to each card, so that a total of 20 responses per participant was obtained. Instructing participants to think of one response only per each exposure to each card aimed at making it possible to analyze fMRI activity on a response-by-response base. Prior to presenting the Rorschach cards, each of which lasted on the screen for 10 seconds, a fixation cross appeared for 16 seconds. The rest of the procedure was completed outside the scanner. As an approximation to the R-PAS Response Phase (RP), participants were first asked to verbally describe their responses, i.e., what they saw while still in the scanner. If a participant was not 100% sure about a response, that response was excluded from data analysis, which reduced the total number of responses available for the analyses from 520 to 481, which corresponds to a mean of 18.5 responses per person. Finally, the Clarification Phase (CP) was conducted following standard CP guidelines.

Imaging

Images were acquired on a 3T Siemens Trio Tim Scanner. Anatomical scanning consisted of 160 T1-weighted slices covering the whole brain. A 5-minute magnetization prepared, rapid-acquisition gradient echo image (MPRAGE) was acquired for anatomic overlays of functional data and spatial normalization. Field of view (FOV) was 240 x 240 x 160, with a voxel size of 1 mm^3.

Functional scanning consisted of 33 T2-weighted slice whole-brain, single-shot gradient echo (GE) echo-planar (EPI) sequence (TR/TR=1969/25 ms, FA = 90°, FOV = 240mm, matrix = 64x64, slice thickness/gap = 4/0 mm), with a voxel resolution of 3.75 x 3.75 x 3.75 mm. The first two volumes were excluded due to T1 equilibrium effects so that, for each subject, a total amount of 260 time points were available for data analysis.

Rorschach Variables Selection

To maximize power and be consistent with our previously adopted approach to analyze this set of fMRI data, each of the Rorschach variables to be included in data analysis first needed to be dichotomized into “target” versus “non-target” response, on a response-level basis (for additional details on this technical requirement for fMRI analyses, please see Giromini, Viglione, Pineda et al., 2019). That is, for each response from each participant, our target Rorschach variables (i.e., those located in the Engagement and Cognitive Processing domain) needed to be coded as either present or absent. Thus, a few adjustments were needed.

As for Complexity, its overall score is obtained by summing up the scores of three different subcomponents, respectively focused on (1) location, space and object qualities, (2) content(s), and (3) determinant(s). More specifically, at the response-level, i.e., response by response, each subcomponent receives a score based on a specific algorithm. For instance, let us consider the latter, i.e., the determinant(s) subcomponent: If the determinant of a response is pure form (F), then a score of zero is assigned to that response; if there is only one determinant in a response, and that determinant is not an F, then a score of one is assigned; if there is more than one determinant in a response, then the total number of determinants coded in that response represents the component score for that response. Next, these response-level scores are summed across all responses in the protocol so to obtain the protocol-level scores for each of the three Complexity subcomponents. Finally, the sum of these three subcomponents is used to indicate the overall, protocol-level, Complexity score. The higher the value of Complexity, the greater the amount of interpretatively useful information in the protocol.

At the response-level, the median Complexity value across all 481 responses from the 26 participants was 3.0 (*M* = 3.5; *SD* = 2.0). As such, we classified as "target" those responses whose response-level Complexity score was > 3 (i.e., complex responses), and as "non-target" those responses whose response-level Complexity score was ≤ 3 (i.e., non-complex responses). This choice resulted in 210 responses being classified as complex, and 271 being classified as non-complex.

As for the other R-PAS variables located in the Engagement and Cognitive Processing domain, we used the same approach adopted by Giromini, Viglione, Vitolo et al. (2019). That is, for proportional scores, the numerator was selected as the best marker of the score. For example, for the variable M Proportion, which is represented by M divided by MC, M was selected, so that a response with an M would classify M Proportion as "target," whereas a response without an M would classify M Proportion as "non-target." For sum scores, we used any variables that contributed to the relevant sum score. For instance, for MC (the sum of M and WSumC), a response with an M code and/or a color code (C, CF, or FC) would classify

MC as “target,” whereas a response with no M and no color codes would classify MC as “non-target.” For one of the variables included in the Engagement and Cognitive Processing domain we could not find an adequate marker, i.e., the variable “number of responses” (R) could not be dichotomized into “target” versus “non-target” as there would be no case in which that code (R) would be absent (“non-target”) in a response. Accordingly, R was not included in our analyses. Table 1 and Table 2 detail all of these coding adjustments.

Furthermore, based on fMRI literature recommending a minimum sample size of N = 16 (Friston, 2012), and consistent with Giromini, Viglione, Vitolo et al. (2019), to include a selected Rorschach variable in our analyses, we also decided that the relevant code needed to be “present/target” in some responses and “absent/non-target’ in other responses for at least 16 participants. This additional step excluded from the analyses another small set of four potentially interesting variables. More specifically, for the variable CFC Proportion, which is calculated as the proportion of color-dominated color responses divided by the total number of color responses (i.e., (CF+C) / SumC), the numerator of the proportion score was initially selected as the best marker of the variable, consistent with the methodological approach described in the previous paragraph. However, because 11 of the 26 participants included in this study had zero color-dominated color responses (i.e., C or CF), the comparison between the presence versus absence of this variable would be possible for 15 cases only. Hence, because the sample size of this analysis would be $N < 16$, the variable CFC Proportion was not further retained for data analysis. In addition to CFC Proportion, the other three variables excluded from the analyses based on the $N < 16$ criterion were Vagueness (Vg), Vista (V) and Pure C (C). For these variables, the total number of cases with valid data were 8, 12, and 2, respectively (for additional details and descriptive statistics, please see Giromini, Viglione, Vitolo, et al., 2019).

Reliability Check

An expert Rorschach user, with a certificate of proficiency in R-PAS coding (see www.r-pas.org) initially coded all Rorschach responses blind to the fMRI results. Next, to test R-PAS scores' interrater reliability, a group of six independent raters provided a second set of codes for 16 of the 26 records. For the variables included in the Engagement and Cognitive Processing domain, absolute agreement one-way random effect intraclass correlation coefficients (ICCs) ranged from .77 (IntCont) to 1.00 (R8910%), thus demonstrating excellent interrater reliability (Shrout & Fleiss, 1979). In particular, interrater reliability of Complexity was nearly perfect, ICC = .92, consistent with other published literature (Pignolo et al., 2017; Viglione et al., 2012).

Data Analysis

Before analyzing the data, we identified brain areas associated with the DAN using Neurosynth, a freely available online platform that produces meta-analytically derived brain maps, based on keywords (Yarkoni et al., 2011b). For the current study, we used the keyword "dorsal attention" and obtained results from 65 published studies encompassing 2,552 locations of activation. To create our region of interest (ROI), we relied on what was previously referred to as the "reverse inference" approach and is now called the "association test" (www.neurosynth.org). Briefly, rather than simply testing whether a given region is active in studies including a given keyword, association test derived maps evaluate whether the activation of a given region occurs more consistently for studies that mention such keyword compared to studies that do not mention it. This approach thus ensures a greater specificity in the creation of voxel-based meta-analytic maps (Poldrack, 2011; Yarkoni et al., 2011a). The resultant DAN ROI, which was then used for our Rorschach-related analyses, included seven clusters with contiguous voxels[1] (Figure 1).

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[1] A cluster threshold of 300 VMR voxels was used to create the clusters.

As for our imaging data, they were preprocessed, analyzed and visualized using BrainVoyager QX, version 2.6 (Brain Innovation, Maastricht, the Netherlands). We performed mean intensity adjustment, head motion correction, 3D spatial smoothing with full width half-maximum (FWHM) of 6mm, high pass filtering with a cutoff of 0.004 Hz, and temporal smoothing with FWHM of 2.8 seconds. For each participant, data were coregistered with their 3D high-resolution anatomical scan, and then converted from MNI to Talairach space (Talairach & Tournoux, 1988) using a homemade Matlab script that performs a ICBM2TAL transformation (for more details, visit http://www.brainmap.org/icbm2tal/).

Consistent with previous studies using this same fMRI data set (i.e., Giromini, Viglione, Pineda, et al., 2019; Giromini, Viglione, Vitolo, et al., 2019), to analyze possible activation differences between presence and absence of the selected Rorschach variables in our DAN ROI, univariate-ROI analyses were next performed. Initially, a first-level, within-subject, analysis was performed using a ROI-based general linear model (GLM) with blocked design to model BOLD signal fluctuations. With regard to the experimental conditions (e.g., complex > fixation, non-complex > fixation), BOLD signal changes were analyzed by averaging all available data for each condition. Subsequently, results from this first-level analysis were subject to a second-level analysis (between subjects), treating participants as a random effect. Specifically, a random effect GLM was used to evaluate the differences between the mean contrast values of the voxels inside the DAN ROI associated with the presence versus absence of each of the target Rorschach variables under investigation. It should be pointed out that in fMRI research it is a standard practice to implement a two-level model in which a first level of analyses deals with data from individual subjects and a second level deals with groups of subjects. In the first level, the data come from individual subjects and are autocorrelated with a relatively large number of observations; in the second level, a smaller set of independent and identically distributed data are analyzed (Friston et al., 1994).

Because these same analyses were applied to multiple Rorschach codes, in addition to inspecting uncorrected *p*-values, Bonferroni adjusted *p*-values were examined too. As 14 variables were investigated, a *p*-value ≤ .00071 was set to indicate a statistically significant finding at a Bonferroni-corrected alpha of .01, a *p*-value ≤ .00357 was set to indicate a significant finding at a Bonferroni-corrected alpha of .05, and a *p*-value ≤ .00714 was set to indicate a significant finding at a Bonferroni-corrected alpha of .10. Lastly, it should be pointed out that all variables included in the analyses had an absolute skew value ≤ 1.21 and an absolute kurtosis value ≤ 2.31, so they no mathematical transformations to account for possible nonnormality issues was deemed necessary (see West, Finch & Curran, 1995).

Results

As shown in Table 3, four statistically significant findings were observed: Complexity, Sy, MC and M were positively associated with BOLD activity in the DAN ROI, whereas W was negatively associated with it (*uncorrected p's* < .05). Additionally, F was associated with a marginally significant (*uncorrected p* =.08) decreased activation of the DAN ROI. It should be pointed out, however, that only two findings, i.e., those related to Complexity and Sy, remain statistically significant after applying a Bonferroni correction, and only if using a non-conservative, corrected alpha of .10. In terms of effect sizes, Complexity generated the highest absolute Cohen's *d* value of 0.43, followed by Sy (*d* = 0.32), F (*d* = -0.23), and M (*d* = 0.21). All other effect sizes were very small, with *d* lower than .20 in absolute value (for characterization of *d* effect sizes, please see Cohen, 1988).[2]

Table 3 also presents the effect size values found in Ales et al.'s (2019) eye-tracking study when considering the average number of fixations (see the last column). The correlation between the effect sizes found in the two studies, i.e., ours and Ales et al.'s, is

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[2] In line with Dunlap et al.'s (1996) recommendations, because we were more interested in calculating the actual effect size, rather than in determining the power that would be needed to detect an a priori established effect size, Cohen's d values were calculated using standard independent samples d formula.

impressively high, $r = .80$, $p < .001$. As graphically represented in Figure 2, the variables that produced the largest effect sizes in both studies are Complexity and Sy, with F% at very end of the opposite direction. However, the effect sizes observed in our study were notably lower than those reported in Ales et al. (2019). Just as an example, Ales et al.'s (2019) effect size for Complexity, i.e., $r = .53$, corresponds to a Cohen's d value of 1.25; a much higher value than the $d = 0.43$ found in our study.

Additional Analyses

The fact that Complexity, Sy, MC, and M were associated with increased activity in the DAN, and that F was associated with a marginally significant decreased activity in that same ROI is consistent with extant literature postulating that Complexity, Sy, MC, and M reflect increased whereas F reflects decreased engagement and cognitive processing (Meyer et al., 2011; Mihura et al., 2013). Conversely, the negative association between W and DAN activity is somehow in contrast with the traditional interpretation of W as an index of a sophisticated cognitive effort (Exner, 2003; Meyer et al., 2011).

To better understand the relationship of W responses to DAN activity, we performed additional analyses. More specifically, the R-PAS manual (Meyer et al., 2011) states that "for the cohesive or intact cards (e.g., I, IV, and V), the simplest solution is to use the whole blot" (p. 332). On this basis, we examined the degree to which the DAN was activated by W responses delivered to different Rorschach cards. More specifically, two additional univariate ROI comparisons were computed. First, DAN activity for W responses given to cards I, IV, V, and VI ("Intact Cards – W") was compared against DAN activity for any non-W responses to these same cards. Next, DAN activity for W responses given to cards II, III, VII, VIII, IX, and X ("Segmented Cards – W") was compared against DAN activity for any non-W responses to these same cards.

None of these two univariate ROI analyses produced statistically significant results. However, a trend was observed for "Intact Cards – W" responses, suggesting that delivering a W to a cohesive or intact card might be associated with a slight decreased activity of the DAN, t (25) = -1.66, p = .11, d = -0.21. Conversely, "Segmented Cards – W" and non-W responses yielded virtually the same activity in our DAN ROI, t (25) = 0.26, p = .80, d = 0.03. Taken together, these findings suggest that the significant decreased activity of the DAN observed for W responses (Table 3) is likely driven by "Intact Cards – W" responses.

Discussion

This fMRI study tested the role of the Dorsal Attention Network (DAN; Vossel et al., 2014) in the production of more versus less complex Rorschach responses. By re-analyzing archival fMRI data from 26 healthy participants exposed to the Rorschach inkblots with the instruction to think of what they might be, we found that delivering Rorschach responses characterized by higher-than-average Complexity was associated with increased activity in the DAN. Additionally, we observed that Sy, M, and MC responses were associated with increased DAN activity too, whereas W – and to a lesser extent F – responses was associated with decreased activity in that same network. Noteworthy, this pattern of findings is remarkably similar to that reported by Ales et al. (2019) when investigating the association of the number of fixations recorded during the response phase of the Rorschach with all R-PAS variables located in the Engagement and Cognitive Processing domain (Meyer et al., 2011). Indeed, the correlation between the effect sizes found in the current fMRI study and those found in Ales et al.'s (2019) eye-tracking study consists of an impressive r = .80.

A first conclusion that may be drawn from this study is that the variable Complexity does seem to be a highly valuable marker of engagement and effort in the Rorschach task, as postulated in the R-PAS manual (Meyer et al., 2011). Indeed, the DAN likely represents the chief neural network underlying those active, top-down attentional processes in which the person orients his or her attentional focus voluntarily, e.g., during spatial monitoring or while detecting different objects in the visual field (Corbetta & Shulman, 2002; Ptak, 2012; Vossel et al., 2014). That is, the higher the activity of the DAN, the higher the level of engagement and cognitive effort likely put in place by the test-taker. The association between Complexity and DAN activity hence provides some neurophysiological support to its postulated interpretative meaning. For a similar reason, our study also supports the hypothesis that Sy, M, and MC reflect increased, whereas W – and to a lesser extent F – reflect decreased engagement and cognitive effort. From an interpretive standpoint, thus, these six variables should be looked at with particular attention to assess the level of engagement and effort demonstrated by the test-taker during the administration of the Rorschach.

The strong convergence between our findings and those reported by Ales et al. (2019) is particularly impressive if one considers the numerous methodological differences across the two studies. Ales et al. (2019) tested eye tracking variables, and conducted their analyses at the protocol-level. Conversely, we examined fMRI data, and performed response-level analyses. Besides, Ales et al.'s (2019) participants were Italian volunteers who had been instructed to provide "two…or three responses per card," whereas our participants were American volunteers, who had been instructed to think of one response per each exposure to each card. Thus, although the tested R-PAS variables obviously share some common variance, because they all belong to the Engagement and Cognitive Processing domain, the remarkable convergence of the findings observed in the two studies is promising in terms of future replicability and generalizability.

The reduced size of our effects, compared to Ales et al. (2019), may likely be ascribed to several technical limitations associated with our fMRI study. Indeed, as elaborately discussed in Giromini, Viglione, Pineda, et al. (2019), because we could not present the same visual stimuli (i.e., the 10 Rorschach cards) more than two times each, our analyses used fewer data points than typical fMRI studies. As a result, our statistical power was notably reduced and a number of potential confounds (e.g., the possible presence of repetition suppression effects in BOLD signals during the second presentation of the stimuli) could have masked or altered our findings. This methodological weakness probably explains why none of the findings presented in Table 3 remain statistically significant at $p < .05$ after a Bonferroni correction (albeit two variables, i.e., Complexity and Sy, did yield a statistically significant result at a liberal Bonferroni-corrected alpha of .10, which was inspected given the exploratory nature of the study).

Another factor that could potentially explain the reduced size of the effects obtained in this study, compared to Ales et al. (2019), is that our analyses essentially removed from each of the tested R-PAS scores the influence of productivity. As detailed in Meyer et al. (2011), the number of responses, or R, measures the level of productivity demonstrated by the test-taker while engaged in the Rorschach task, and, thus, it correlates with most of the R-PAS variables included in the Engagement and Cognitive Processing domain. For instance, R contributes to Complexity in that the three subcomponents of Complexity (see Introduction) are summed across all the responses in the protocol, so to generate the overall Complexity score. In Ales et al. (2019), R correlated at $r = .369$ with the number of fixations recorded during the visual exploration of the Rorschach cards. Thus, it likely did play a role, in that study, in the association of many R-PAS Engagement and Cognitive Processing variables to the average fixations number. Conversely, in our study all variables were analyzed at the response-level, so that the impact of R on each of the R-PAS scores under investigation was partialed out. Differently put, in our study Complexity could not benefit from the possible association of productivity to DAN activity in that the level of Complexity was measured at the response-level, i.e., response by response, thus holding R constant. One might say that we tested the original response level version of the variable, that is equivalent to Complexity divided by R, as originally developed by Viglione and colleagues and first published by Morgan and Viglione (1992) and Viglione (1999), and modified by Dean and colleagues (2007). Accordingly, while the effect sizes observed by Ales et al. (2019) were likely inflated by the fact that all R-PAS scores located in the Engagement and Cognitive Processing correlated with R and R correlated with the target criterion variable, this could not happen in our study because our analyses were performed at the response-level so that R was obviously equal to one in each response. Consistent with this hypothesis, in Ales et al. (2019) the association of Complexity to average number of fixations decreased from β = .526 to β = .478, when R was controlled for via hierarchical multiple regression.

An interesting insight for future research comes from our additional analyses on the relationship between the activity of the DAN and the production of W responses given to intact versus segmented Rorschach inkblots. When we started this study, we anticipated that W would perhaps be associated with increased DAN activity, because of the extra cognitive effort required to account for the whole visual stimulus when delivering a response. As reviewed in our Additional Analyses section, this hypothesis would be in line also with CS tradition, according to which W may be interpreted as an index of the test-taker's ambitiousness or achievement goals. Contrary to our expectations, our findings showed that W responses were associated with a weak (d = -0.19) but statistically significant (p = .04) *decreased activity* of the DAN. As R-PAS authors pointed out that delivering a W might be particularly easy in cohesive inkblots such as Card I or Card V (Meyer et al., 2011), we thus performed additional analyses testing the activation of the DAN for W responses delivered to intact/cohesive versus segmented/fragmented cards. Interestingly, the results of these additional analyses suggested that the decreased activity of the DAN only occurred in the first case only (i.e., intact cards), and not in the second (i.e., segmented cards). We thus encourage future studies to investigate whether there would be any interpretative value in differentiating W responses provided to intact versus segmented cards.

Amongst the limitations to keep in mind when considering the results of this study, we would like to highlight the four most relevant ones. First, taking the Rorschach while in an fMRI scanner is evidently different from taking it in a standard evaluation context. Related to that, differently from standard, real-life Rorschach administrations, in this study several methodological adjustments were needed (e.g., the participant could not speak while looking at the inkblots for the first time, etc.). As such, the ecological validity of our findings might be questioned. Second, as this study was conceived of as a block-design(-like) paradigm, with each fMRI event being linked to each Rorschach response produced by the test-taker, our analyses could only compare BOLD functions were associated with the presence versus absence of any specific events. Given that, all our Rorschach variables needed to be dichotomized into present versus absent, prior to analyzing the extent to which they associated with any given BOLD functions (for additional details, please see Giromini, Viglione, Pineda et al., 2019). To test the association of Complexity to DAN activity, we thus artificially dichotomized each response into “complex” versus “non-complex” based on the median Complexity value observed across all 481 responses from the 26 participants who took part in the study. The choice of using the median value aimed at maximizing the amount of fMRI data points available for our statistical analyses, i.e., to maximize power. However, other solutions would be possible too (e.g., considering as “complex” those responses with a response-level Complexity score located in the first tercile and as “non-complex” those whose response-level Complexity score located in the third tercile), so that future research might try using different approaches to analyze the data. Third, our relying on Neurosynth to derive our DAN ROI might be questioned too. Although its accuracy has been demonstrated by several studies (de la Verga et al., 2016; Poldrack, 2011; Yarkoni et al., 2011a), one might wonder whether using a different approach to generate our ROI would or would not lead to the same results we obtained in this investigation. In particular, because our study did not have adequate power to perform whole-brain analyses (for details, please see Giromini, Viglione, Pineda et al., 2019), our reliance on Neurosynth to define the ROI to be examined may have led to the exclusion from the analysis of some other potentially relevant frontocortical regions. Fourth, though fMRI is known to yield excellent spatial precision, it has difficulties in creating fine-grained time series analyses of brain activity, which is clearly important when addressing attentional processes. As such, although before showing each inkblot a neutral visual stimulus appeared on the screen for 16 seconds, we cannot rule out that some carryover effects from one Rorschach card to another could have occurred.

Despite these limitations, the fact that our findings replicate so closely those presented by Ales et al. (2019), with the correlation between the effect sizes coming from the two studies consisting of an impressive $r = .80$, suggests that the Rorschach Complexity variables are indeed related to attentional processes and the degree of cognitive processing effort by the test-taker. In our opinion, one may conclude that at this point, Complexity, as well as a couple of other R-PAS variables located in the Engagement and Cognitive Processing interpretative domain, i.e., Sy and F%, have now demonstrated to possess some psychophysiological support so that they may be considered to be particularly useful in both clinical and forensic contexts.

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Table 1. Variables Selection: R-PAS Engagement and Cognitive Processing Domain, Page 1

Target Variable	**Variable Description**	**Adjustment for fMRI Analyses**	**Selected Code(s)**
Complexity	A dimensional measure of differentiation, integration, and productivity	We used the median of the composite score to dichotomize the variable into high versus low	Complexity
Number of responses, R	Number of responses given by the respondent to the question "What might this be?"	We could not dichotomize R into present versus absent, so R was not included	-
Form%, F%	The proportion of pure form responses out of all responses	At the response-level, Pure Form (F) is the best marker of F%	F
Blend	Number of responses in which more than one determinant are used in the same response	Blends are coded at the response-level	Blend
Synthesis, Sy	Number of responses in which different objects described in relation to each other	Synthesis is coded at the responses-level	Sy
Human Movement and Weighted Color, MC	The sum of Human Movement responses plus a weighted sum of any color responses	At the response-level, the most representative markers are responses involving M and/or any color determinants (C, FC, or CF)	M or Any C
Human Movement, M	Number of responses in which human activities or movements are seen	M is coded at the response-level	M
M Proportion, M/MC	The proportion of M to MC responses	For difference or proportion scores, the numerator is selected as the best marker of the score. In this case, M is selected	M
CFC Proportion, (CF+C)/SumC	The number of color responses in which the color has more importance than the form, divided by the total number of color responses	For difference or proportion scores, the numerator is selected as the best marker of the score. In this case, the most representative markers at the response-level are responses involving CF or C	CF or C

Table 2. Variables Selection: R-PAS Engagement and Cognitive Processing Domain, Page 2

Target Variable	**Variable Description**	**Adjustment for fMRI Analyses**	**Selected Code(s)**
W%	Proportion of responses in which the whole inkblot is used to respond	At the response-level, Whole (W) is the most representative marker of W%	W
Dd%	Proportion of responses in which an unusual inkblot area is used to respond	At the response-level, Unusual detail is the most representative marker of Dd%	Dd
Space Integration, SI	Number of responses in which the white background is identified as a distinct perceptual element and then integrated with the inkblot in the response	Space integration is coded at the response-level	SI
Intellectualized Content, IntCont	Number of responses in which an abstract or symbolic intellectualized style of information processing is present	For this score, the presence versus absence of any of Art, Ay or ABS at the response-level is considered	Art or Ay or ABS
Vagueness%, Vg%	Proportion of responses with formless objects or images	At the response-level, Vague is the most representative marker of Vg%	Vg
Dimensional variables, V & FD	Number of responses in which some inkblot features (shade or form) are used to confer dimensionality to the percepts	Vista and Form Dimension are coded at response-level	V FD
R8910%	Proportion between the number of responses given to colored Cards (i.e., VIII, IX, and X) and the total number of responses	Responses given to the last three cards are considered as presence of R8910, responses given in any other cards are considered as absence of R8910	R8910

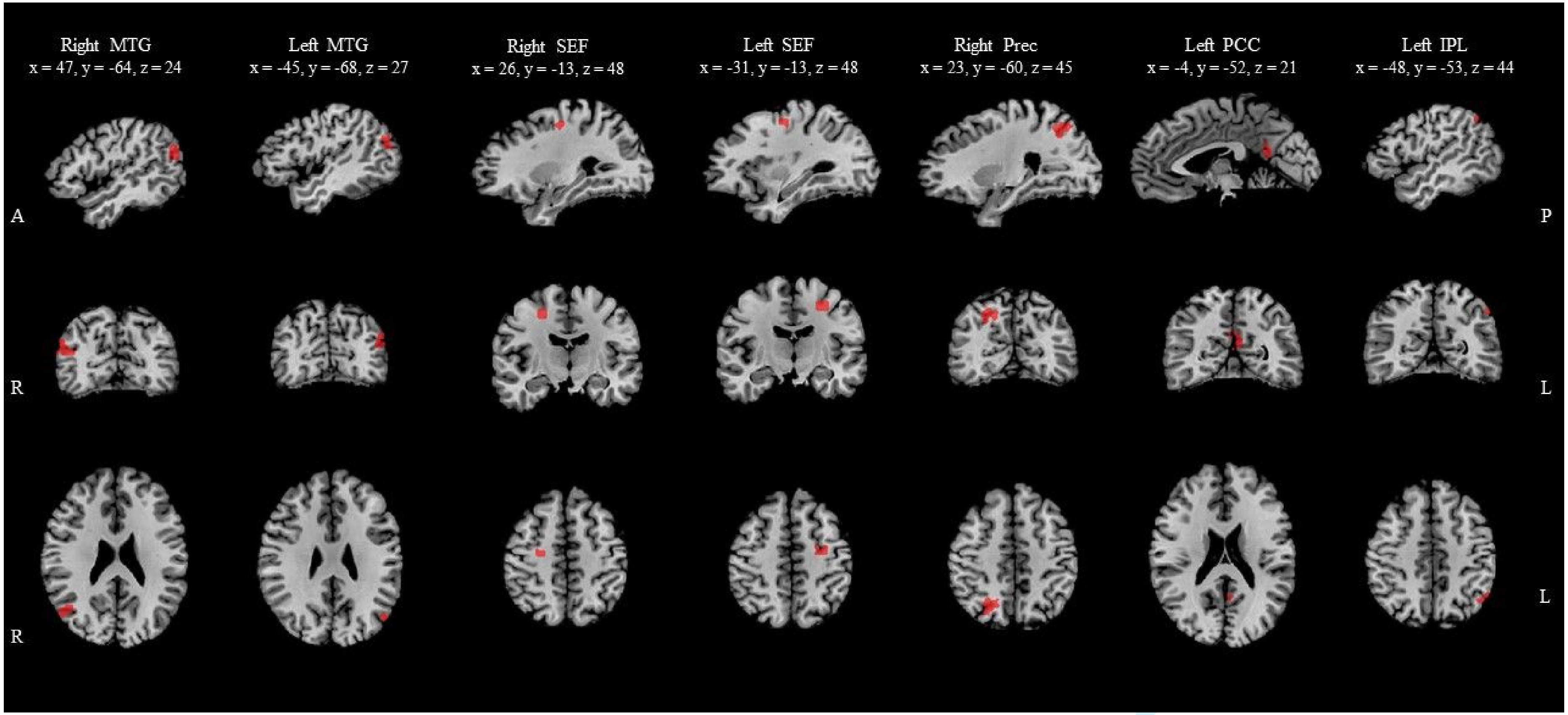
Weighted Sum of Color responses, WSumC	Weighted sum of any color responses	At the response-level, the most representative markers of WSumC are responses involving any color-related codes, i.e., any C, CF or FC	Any C
Pure Color, C	Number of responses in which the response is based on the color of the inkblot and the form has no importance	Pure Color is coded at the response-level	C
Mp Proportion	Proportion of passive M responses to all M responses	For difference or proportion scores, the numerator is selected as the best marker of the score. In this case, Passive Human Movement is selected	Mp

Table 3. Results of Univariate ROI Analyses Comparing DAN ROI Activity for the Presence versus Absence of Selected Rorschach Codes

R-PAS Variable	***The Current Study*** [a]						***Ales et al.'s (2019) Study*** [b]
	Selected Code	***N***	***t***	***df***	***p***	***d***	***r***
Page 1 Variables							
Complexity	Complexity	25	3.05	24	.006	0.43	.53
F%	F	26	-1.84	25	.08	-0.23	-.26
Blend	Blend	25	0.08	24	.94	0.01	.31
Sy	Sy	26	3.15	25	.004	0.32	.48
MC	MC	26	2.17	25	.04	0.18	.37
M	M	26	2.29	25	.03	0.21	.33
Page 2 Variables							
W%	W	26	-2.20	25	.04	-0.19	-.01
Dd%	Dd	18	-0.76	17	.46	-0.13	.13
SI	SI	20	-1.44	19	.17	-0.18	.25
IntCont	Art or Ay or ABS	23	-0.27	22	.79	-0.04	.24
FD	FD	24	0.36	23	.72	0.05	.11
R8910%	R8910	26	0.47	25	.64	0.04	.10
WSumC	Any C	23	0.55	22	.59	0.08	.22
Mp	Mp	22	-0.51	21	.60	-0.06	-.13

[a] In line with Dunlap et al.'s (1996) recommendations, as we were more interested in calculating the actual effect size, rather than in determining the power that would be needed to detect an a priori established effect size, Cohen's *d* values were calculated using standard independent samples *d* formula. [b] These *r* effect sizes, reported in Ales et al. (2019), refer to the correlations of R-PAS scores to the average number of fixations recorded during the response phase.

Figure 1. Graphical Representation of the Seven Clusters with Contiguous Voxels Included in our DAN ROI.



Note: MTG: middle temporal gyrus; SEF: supplementary eye field; Prec: precuneus; PCC: posterior cingulate cortex; IPL: inferior parietal lobule; A: anterior; P: posterior; R: right; L: left.

Figure 2. Graphical Representation of the Correlation between the Effect Sizes found in the Current fMRI Study and those Reported in Ales et al.'s (2019) Eye-Tracking Study

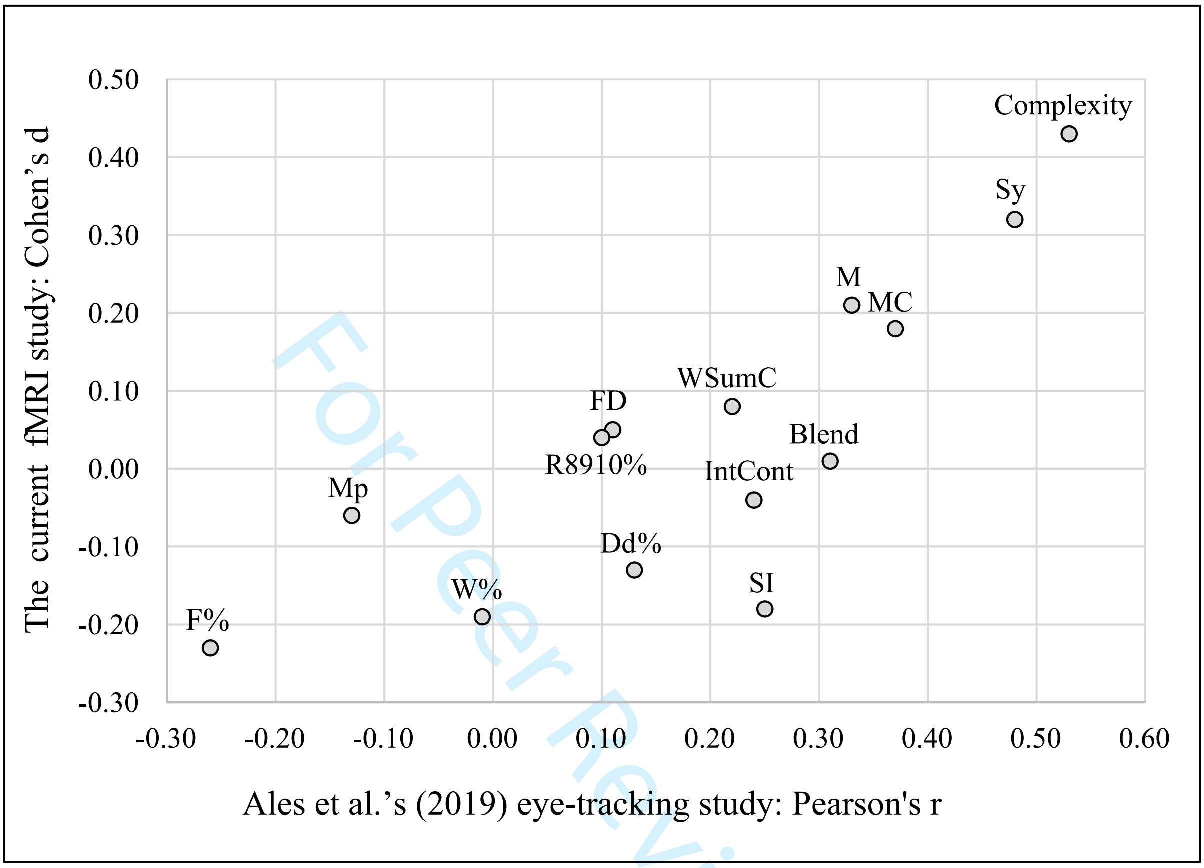


Table 3. Results of Univariate ROI Analyses Comparing DAN ROI Activity for the Presence versus Absence of Selected Rorschach Codes

R-PAS Variable	**Selected Code**	***N***	**Presence of the Code**				**Absence of the Code**				***t***	***df***	***p***	***d***	**Ales et al.'s (2019) Study** [b]
			M	***SD***	***Skew***	***Kurtosis***	***M***	***SD***	***Skew***	***Kurtosis***					***r***
Page 1 Variables															
Complexity	Complexity	25	0.29	0.99	-0.26	-0.06	-0.11	0.90	-0.10	-0.94	3.05	24	0.006	0.43	0.53
F%	F	26	-0.15	0.89	-0.46	-0.18	0.07	1.06	-0.33	-0.43	-1.84	25	0.08	-0.23	-0.26
Blend	Blend	25	-0.05	1.15	-0.10	-0.56	-0.06	0.98	-0.29	-0.70	0.08	24	0.94	0.01	0.31
Sy	Sy	26	0.23	1.21	-0.43	-0.63	-0.11	0.91	-0.22	-0.90	3.15	25	0.004	0.32	0.48
MC	MC	26	0.13	1.01	-0.42	-0.64	-0.06	1.04	-0.28	-0.52	2.17	25	0.04	0.18	0.37
M	M	26	0.17	1.06	-0.47	-0.46	-0.04	1.01	-0.26	-0.82	2.29	25	0.03	0.21	0.33
Page 2 Variables															
W%	W	26	-0.08	1.03	0.16	-0.66	0.12	1.02	-0.82	-0.34	-2.20	25	0.04	-0.19	-0.01
Dd%	Dd	18	0.06	1.30	-1.21	2.31	0.21	0.96	-0.17	-0.33	-0.76	17	0.46	-0.13	0.13
SI	SI	20	-0.38	1.03	-0.31	-0.62	-0.19	1.00	-0.25	-1.04	-1.44	19	0.17	-0.18	0.25
IntCont	Art or Ay or ABS	23	0.02	1.34	-0.54	1.61	0.07	0.97	-0.21	-0.58	-0.27	22	0.79	-0.04	0.24
FD	FD	24	0.00	0.84	0.43	-0.57	-0.05	1.05	-0.23	-0.69	0.36	23	0.72	0.05	0.11
R8910%	R8910	26	0.04	1.09	-0.08	-0.64	0.01	1.03	-0.33	-0.56	0.47	25	0.64	0.04	0.10
WSumC	Any C	23	0.00	1.25	0.25	-0.29	-0.09	1.04	-0.22	-0.70	0.55	22	0.59	0.08	0.22
Mp	Mp	22	-0.28	1.30	-1.01	0.50	-0.21	1.01	-0.50	0.22	-0.51	21	0.60	-0.06	-0.13

[a] In line with Dunlap et al.'s (1996) recommendations, as we were more interested in calculating the actual effect size, rather than in determining the power that would be needed to detect an a priori established effect size, Cohen's *d* values were calculated using standard independent samples *d* formula. [b] These *r* effect sizes, reported in Ales et al. (2019), refer to the correlations of R-PAS scores to the average number of fixations recorded during the response phase.