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Cognitive Information Processing in Borderline Personality Disorder: A Neuropsychiatric Hypothesis

J. Wesley Burgess, Ph.D., M.D.

Abstract

Neurocognitive information processing was compared in 18 borderline subjects and 14 controls of similar age and gender. An 11-item screening examination significantly differentiated the two groups ($P < 0.001$). Significant differences were found on Delayed Memory, Serial Sevens, Rhythm Reproduction, and Perseveration subtests ($P < 0.05$). The results are interpreted as evidence for mild frontotemporal brain deficits. The findings support a developmental model of borderline disorder where early stress/injury during the childhood period of frontotemporal vulnerability results in failure to negotiate developmental landmarks and adult deficits in cognition, emotion/behavior modulation, and insight.

INTRODUCTION

Much of the contemporary interest in neurophysiological and neuropsychological information processing was influenced by the work of Luria (1,2), who correlated aberrant patterns of thought and behavior with the location of specific brain lesions in hospitalized neuropsychiatric patients. The notion that the brain acts as a processor of exogenous information provides one theoretical framework to bridge biological, psychological and behavioral viewpoints of brain injury and mental illness (1,2). Alterations in the processing of incoming sensory information are thought to play important roles in schizophrenia, mental retardation and learning disabilities (e.g., 3-17). However, the role of brain information processing in characterological disorders is unclear, and has received little clinical or research attention.

There are some suggestions of an organic component to characterologic disorders, particularly in borderline personality disorder, which could provide a substrate for altered neurocognitive processing. Adrionis and colleagues (18,19)

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have found a disproportionate percentage of head trauma, encephalitis, epilepsy and learning disabilities in some subgroups including borderline disordered persons, suggesting they may have suffered lesions placing them at risk for neurocognitive dysfunctions.

There is also circumstantial evidence suggesting a role of organic dysfunction in the similarity between the symptoms of borderline personality disorder and the symptoms of acute, diffuse brain injury. The Diagnostic and Statistical Manual III-Revised (DSM-III-R) lists the following symptoms of borderline personality disorder: chronic depression, mood instability, poor control of anger, relationship instability and impulsivity with impulsive sexual and violent acts (20). In patients with diffuse cortical injury secondary to closed head trauma, the most frequently reported behavioral symptoms include: chronic depression, mood instability, irritability with temper outbursts, and poor impulse control with sexual and aggressive acts (21–25). Obviously there is a strong convergence between the chronic symptoms of borderline personality disorder and the acute symptoms following adult frontal brain injury. Moreover, research studies and clinical impressions have associated characterological disorders with parental deprivation and abuse (26); conditions which could result in possible early brain injury. Overall, this circumstantial evidence suggests that a theory of aberrant brain processing could explain aspects of characterologic behavioral dysfunction occurring after early neuropsychiatric trauma.

Studies of endogenously depressed patients have revealed deficiencies in standardized tests of cognition and information processing, including information coding, apprehension span, logical operations, and abstract functions (27–34). These findings have been explained as a reversible impairment in cortical information processing accompanying affective changes (31). Although borderline personality disorder characteristically manifests marked affective changes, the demonstration of an equivalent neurocognitive deficit in borderline disorder is as yet unknown.

Assumptions of Neurocognitive Testing

The disciplines of neuropsychology/neuropsychiatry are concerned with the mechanisms and measurement of functional brain processes (35,36). Typically, these include assessment of integrity of such brain functions as attention, memory, language, abstraction, and motor behavior (37). These general functional may be combined or separated into other derivative functional categories, depending on the theoretical stance of the author. Confirmation of localization site can come from anatomical measures such as imaging studies, physiological measures including EEG, evoked potentials or radioisotopic labeling metabolic studies. Importantly, certain neuropsychological subtests are thought to assess mental functions which localize more or less specifically to areas of the brain and can therefore be used as behavioral measures of organic or functional impairment (37). An outline of commonly presented mental functions, together with

their associated brain mechanisms and subtests which are thought to localize to them is presented below.

Attention. The control of attention is intimately associated with corticoreticular, reticulocortical and thalamic projections and posterior internal capsule pathways, as well as other brainstem and midbrain structures (38–42). It can be measured by such subtests as Double Simultaneous Stimulation (43,44), or vigilance subtests (37).

Memory. Recent memory is dependent on intact functioning of limbic system structures, particularly the bilateral hippocampus, dorsomedial thalamic nuclei, and mammillary bodies (45–48). Memory can be tested by repetition of digits (4,10,14,49), delayed recall or free recall from a story (2,37), or such batteries as the Wechsler Memory Scale (50).

Language. Functions of language are associated with temporal and parieto-temporal cortical and subcortical language areas (51,52). Classical dysfunctions include Broca's, Wernicke's, conduction, transcortical and subcortical aphasia (52). Expressive language functions are classically associated with anterior or Broca's area (53), whereas receptive language functions are classically associated with the posterior or Wernicke's area (54). Tests such as the Boston Naming Test (55), the FAS Controlled Oral Word Association Test (54), or the Animal Naming Test (56) particularly assess naming processes deficient in expressive aphasia.

Abstraction. Higher cognitive functions, including abstract operations, are associated with many areas of the brain, especially the parietal lobes (57–59). Operations of abstraction and generalization can be measured by standardized versions of the proverbs interpretation task (37,61), the WAIS Similarities subscale (62), Raven Progressive Matrices (64), the Category Test (63), the nonverbal half of the Shipley Hartford Scale (60), and other tests.

Computations may be disrupted by dominant parietal lesions, as well as other lesions (57,55,56). Arithmetic operations can be measured by the serial sevens task (37), the WAIS Arithmetic subscale (62), and other tasks.

Constructions. Constructions are nonverbal performance tasks relying on abstract, visuospatial and motor operations, which appear to overlap functions of abstraction and behavioral sequencing. These functions can be assessed by drawing to command, figure reproduction and copying tasks (37,67,68). Unfortunately, the most widely used construction tests also include the additional confounding dimension of visuospatial memory, such as the Bender Visual Motor Gestalt (69,70), the Graham and Kendall Memory for Designs Test (71), and the Benton Visual Retention Test (67).

Behavioral Sequence. Organization of behaviors, and the ability to switch motor activities or mental sets is associated with the frontal cortex (1,2,37). Perseveration errors are a hallmark of frontal damage (72), as are other errors in ordering. Behavioral sequencing is important in the execution of Luria's alternating movements task (1,2), Luria's rhythm reproduction task (1,2), Reitan's

Trail Making Test (73), or the Proteus Maze Test (74). The Wisconsin Card Sorting Test (75), provides one measure of ability to switch mental sets without a strong loading for motor abilities.

Successive and Simultaneous Processing. Based on the work of Luria, Das and colleagues (76) have taken another approach to functional localization, by proposing that certain tasks represent a specialization in "successive" information processing operations. According to Das (76) these include WAIS Digit Span and Digit Symbol subscales (62), free recall from a story (1,2,37), Reitan's Trail Making Test (73), and other tasks where information is presented in serial, sequential fashion. Impairment in successive processing tasks is generally associated with deficits of frontotemporal neocortical function (76). Conversely, other tasks involve more "simultaneous" information processing operations, including the Graham and Kendall Memory for Designs Test (71), the Raven Progressive Matrices (64), and the Bender Visual Motor Gestalt (69,70). Impairment in these tasks is generally associated with deficits of parietoccipital neocortical function (70,73,76).

Research Hypothesis and Experimental Model

We were impressed by the circumstantial evidence linking organic dysfunction and borderline personality disorder, and decided to test this relationship using the neuropsychiatric tools described above. As an initial step, we proposed a testable model of organic dysfunction leading to cognitive information processing defects in borderline personality disorder. This became the basis of a research hypothesis which was tested in a clinical population sample.

Developmental Model. We propose that certain developing brain areas, particularly frontal and temporal neocortex (which are at risk during early development (1) sustain injury during childhood trauma in persons who will later be diagnosed with borderline personality disorder. Although grossly focal neurological signs are absent, a chronic deficit in cognitive information processing localizing to the frontotemporal cortex remains. This early, generalized, subclinical insult results in difficulty negotiating developmental landmarks, with consequent personal and interpersonal problems during late childhood and adulthood. Initial behavioral deficits in childhood are partially compensated during personality development, but there remains a pattern of affective instability, relationship dysfunction, and impulsive thought and action in regard to both self and others. This pattern of behavioral impulsivity, emotional instability, and insight impairment may appear mild or severe, depending on the individual and the degree of stress in the environment.

Experimental Hypothesis. Based on the developmental model above, we hypothesize that a battery of neurocognitive screening tests will show measurably greater neurocognitive dysfunction in a sample population of individuals with borderline personality disorder than in a comparable population of individ-

uals without this diagnosis. We would expect that the most deficient tests would localize to the frontal and temporal regions of the cortex.

METHODS

Subjects

Subjects were drawn from successive presentation for psychiatric evaluation, and neurocognitive function was tested in the overall context of comprehensive mental status evaluation. The borderline group was comprised of 18 patients with an independent diagnosis of borderline personality disorder by DSM-III-R criteria from at least two clinicians. Subjects had no Axis I diagnosis, no history of neurological disorders, neurosurgery, or focal brain injury. All subjects denied the use of drugs for the week preceding evaluation. In this group, mean age was 32.61 years (S.E. = 2.23), and gender was 33% female (S.E. = 12.1; the high proportion of males reflects the overall hospital population).

The control group was comprised of 14 persons with no current history of psychiatric hospitalization, Axis I or II diagnosis, history of neurological disorders, neurosurgery, or focal brain injury. The average age was 31.36 years (S.E. = 1.21), and gender was 43% female (S.E. = 12.8).

11-Item Screening Examination

All patients were given an 11-question neurocognitive screening examination (see the Appendix), administered by the author, who was blind to the diagnosis of borderline personality disorder. Tests were drawn from the work cited above, particularly from the examination of Luria (1973). Two subtests were used to evaluate each of the functional categories of memory, language, abstract operations, and behavioral sequence, and three types of errors of order and sequencing were scored separately. Because all patients presented in a normal waking state of consciousness, no assessment of attention was provided. The entire examination required less than 10 minutes to administer and is therefore appropriate for clinical screening purposes. The examination is reproduced verbatim in the Appendix. The following outline describes the tests administered, and our understanding of the functions they measure.

Memory

1. Digit Span was the ability to repeat 6–7 digits in two presentations of 7-digits each, adapted from WAIS Digit Span Subtest (4,10,14,49,62).

2. Delayed Memory for 3 objects was the ability to repeat the 3 associated word pairs first presented in Question #3 after 10 minutes of distraction; our version of this subtest in common use was adapted from Strub and Black (37).

Language

3. Immediate Repetition was the ability to repeat the following 6 associated words after presentation at a rate of one per second: "red ball, blue car, city of Chicago" (51,77).

4. Object Naming was the ability to name common objects and their parts when presented visually: pen, cap, cover, clip, point, watch, band; (37,77).

Abstract Operations

5. Serial Sevens tested the ability to serially subtract 7 from 100 five times with minimal help from the investigator (57,65,66,78).

6. Proverb Interpretation tested the ability to interpret the proverb "Don't cry over spilt milk" abstractly, according to criteria adapted from Gorham (37,61).

Behavior Sequencing

7. Luria Movements tested the ability to reproduce with either hand the following three sequential movements after seeing them performed by the investigator: clenched fist; outstretched palm & fingers; thumb & forefinger ring. This task was adapted from Luria (1,2).

8. Rhythm Reproduction was the ability to reproduce with either hand the following three rhythms comprised of hard [T] and soft [t] taps presented at one per second: TTTtttTTT; tttTTTttt; ttTTtt. This task was also adapted from Luria (1,2).

General Errors of Ordering and Sequencing

9. Slowing Errors were scored when at least one response to a subtest was delayed for 4 seconds or more.

10. Perseveration Errors were scored when at least one response to a subtest was repeated more than once (37,72).

11. Inversion Errors were scored when parts of at least one subtest response were reversed in order.

Total Sum of Failed Subtests

The total sum of failed subtests, ranging from 0–11 was recorded for all the subtests listed above.

Statistical Analysis

Group Comparisons. Neurocognitive measures from the borderline and control subject groups were compared using Multifactorial Analyses of Variance

(MANOVA: 79,80). Statistical analysis was performed with the Statistical Analysis System (81). The MANOVA was a mixed design with the following model: [Diagnosis $\times$ (Measures $\times$ Subjects)], see Winer (82). The between subjects factor (Diagnosis) had 2 levels (Borderline Personality Disorder, Control). The within subjects factor (Measures) had 11 levels (Digit Span, Delayed Memory, Immediate Repetition, Object Naming, Serial Sevens, Proverb Interpretation, Luria Movements, Rhythm Reproduction, Slowing Errors, Perseveration Errors and Inversion Errors).

The MANOVA generated omnibus comparison (F-tests) for between subjects factors (82,83) and multivariate tests (Hotelling Trace) with F-Test equivalents for within subjects factors (79,80). Multiple comparisons testing allowed statistical comparisons to be made between the subject groups on specific subtests without violating Type I or Type II error assumptions by repeated individual tests. Multiple comparisons were made using Tukey's all-pairs test with appropriate error terms for a posteriori contrasts between borderline and control for each of the 11 subtests (84).

In addition to the above mixed, repeated measures design, one-factor analyses of variance (ANOVAs) were used to compare the subject groups for age and gender distribution. One-factor ANOVAs were also used to compare total sum of test performance between the subject groups (82,83).

RESULTS

Subject Groups

The average age of the borderline and control subject groups was not significantly different, as shown by one-factor ANOVA [Age $F(1,30) = 0.22$; $P = \text{NS}$]. Similarly, gender distribution in the borderline and control subject groups was not significantly different [Gender $F(1,30) = 0.29$; $P = \text{NS}$].

Neurocognitive Tests

Omnibus Tests. Borderline and control groups showed a significant difference in performance across the 11 subtests of the neurocognitive screening examination [Diagnosis $F(1,30) = 14.180$; $P = 0.0007$]. Overall performance differed significantly according to subtest [Measures Hotelling Trace = 3.435; $F(10,21) = 7.214$; $P < 0.0001$], and an interaction comparison revealed that a significant component of this resulted from differential performance by the two subject groups across the 11 subtests [Measures $\times$ Diagnosis Hotelling Trace = 1.449; $F(10,21) = 3.043$; $P = 0.015$].

Multiple Comparisons. As shown in Table 1, multiple comparisons testing revealed significant impairment in the borderline group on subtests of Delayed Memory (Tukey test, $P < 0.05$), Serial Sevens (Tukey test, $P < 0.05$), Rhythm Reproduction (Tukey test, $P < 0.05$), and Perseveration Errors (Tukey test,

TABLE 1.

Neurocognitive Screening Measures in 2 Groups¹

Function =	<u>MEMORY</u>		<u>LANGUAGE</u>		<u>ABSTRACT</u>		<u>BEHAVIOR</u>		<u>GENERAL ERRORS</u>		
TEST =	<u>SPAN</u>	<u>MEM3</u>	<u>REPT</u>	<u>NAME</u>	<u>SER7</u>	<u>PROV</u>	<u>LURI</u>	<u>RHTM</u>	<u>SLOW</u>	<u>PERS</u>	<u>INVT</u>
BORDERLINE GROUP											
% Errors =	5.6	36.1	0.0	16.7	55.6	5.6	61.1	77.8	50.0	27.8	50.0
±S.E. =	5.9	10.3	0.0	9.6	12.8	5.9	12.5	10.7	12.8	11.5	12.9
CONTROL GROUP											
% Errors =	0.0	7.1	7.1	0.0	7.1	0.0	28.6	35.7	35.7	0.0	35.7
±S.E. =	0.0	6.7	6.7	0.0	6.7	0.0	11.7	12.4	12.4	0.0	12.4
SIGNIFICANCE =	—	**	—	—	**	—	—	**	—	**	—
	<u>SPAN</u>	<u>MEM3</u>	<u>REPT</u>	<u>NAME</u>	<u>SER7</u>	<u>PROV</u>	<u>LURI</u>	<u>RHTM</u>	<u>SLOW</u>	<u>PERS</u>	<u>INVT</u>

¹Differences are significant at $P < 0.05$ by Tuken's multiple comparisons test, from MANOVA results. KEY: SPAN = Digit Span, MEM3 = Delayed Memory, REPT = Immediate Repetition, NAME = Object Naming, SER7 = Serial Sevens, PROV = Proverb Interpretation, LURI = Luria Movements, RHTM = Rhythm Reproduction, SLOW = Slowing Errors, PERS = Perseveration Errors, INVT = Inversion Errors.

$P < 0.05$). There was no significant difference between performance of the two groups on subtests of Digit Span, Immediate Repetition, Object Naming, Proverb Interpretation, Luria Movements, Slowing Errors, or Inversion Errors ($P = NS$).

Total Sum of Failed Subtests

Across the entire screening examination, the borderline group had an average of 3.86 errors (S.E. = 0.47), whereas the control group had an average of 1.57 errors (S.E. = 2.22). This difference was significant, as described above for between subjects comparisons [$\text{Diagnosis } F(1,30) = 14.180$; $P = 0.0007$].

DISCUSSION

In summarizing the findings, it was shown that groups of borderline and control subjects of equivalent age and gender could be significantly discriminated by their performance on a screening neurocognitive examination. Deficits were most pronounced on subtests of Delayed Memory, Serial Sevens, Rhythm Reproduction, and Perseveration Errors.

Implications of the Findings

The finding that borderlines can be discriminated from controls by their performance on a screening neurocognitive examination provides evidence that that borderline thought processes differ from nonborderlines on a basic, measurable, neuropsychological level.

These findings support our research hypothesis that borderline individuals show a significant neurocognitive deficit. This hypothesis is based on a hypothetical developmental model, where stress, abuse or deprivation during vulnerable stages of early development result in chronic cognitive information processing errors. These errors impair the ability to negotiate formative developmental stages in childhood, and interfere with social/interpersonal relationships throughout adulthood, contributing to the characteristics diagnosed as borderline personality disorder (see Introduction).

Interpretation of the Findings

Contrary to our predictions, there was no concentration of deficits in a single functional category. Instead, poor performance was found in subtests measuring diverse functions of memory, abstract operations, behavioral sequencing and general errors of order and sequence, overlapping all neurocognitive functions except language. To find out the nature of the borderline dysfunction, we must look at the pattern of cognitive errors.

The pattern of deficient subtests appear to best fit the Das (76) model of deficient sequential information processing, since deficits were found in subtests of Delayed Memory, Serial Sevens, Rhythm Reproduction, and Perseveration Errors, which all involve information that is presented in serial, sequential fashion, and where a string of stimuli must be sequentially memorized or manipulated. According to the model of Das and colleagues (76), errors in sequential information processing suggest involvement of the frontotemporal pole. Unfortunately, we did not have a way of formally testing the significance of this relationship in our borderline population.

Another way of explaining the findings is to look for similarities between the deficient subtests of delayed memory, serial subtraction, rhythm reproduction and perseveration. All these tests require planning, multiple operations, and the maintenance of a prolonged response over time; thus, all the subtests are particularly subject to distraction or intrusion from exogenous or endogenous stimulation. This is similar to the pattern of errors which Teuber (58) associates with frontal brain injury, and is similar to the dimension of "planning" which Luria (1,2) associates with frontal and prefrontal injuries.

Thus, the results of our study can be interpreted as supporting our hypothesis of mild injury to the frontal and temporal brain regions, which are particularly vulnerable during early childhood (1).

Limitations of the Study

The current methodology does not rule out effects of incidental variables like apathy, depression, anxiety or environmental stressors known to be common in borderline disordered persons lives. An explanation of our results based entirely on exogenous stressors cannot account for the magnitude of difference between borderline and control performance, nor can it explain how borderlines could perform well on such difficult subtests as Proverb Interpretation, while failing simpler tasks like Delayed Memory or Serial Sevens.

However, we suggest that future research employ tests for attentional/motivational variables, if only to dispel the notion that subjects were inattentive or unmotivated. Although the 11-item screening examination is convenient to use, the use of additional tests for each neurocognitive function would provide a much stronger picture of neurocognitive deficits. Power of the examination would also be increased by exchanging the current pass/fail scoring system for an interval or continuous measurement scale (85). Additional tests with standardized, interval scoring are available (1,2,37,62,70,73).

CONCLUSIONS

The present study is an attempt to provide a broader, multidisciplinary viewpoint on borderline personality disorder by evaluating cognitive information processing. The importance of the findings, which support a neurocognitive

deficit in borderline frontotemporal processes, will depend on the results of future studies confirming and expanding the current results.

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APPENDIX

Cognitive Screening Test

MEMORY

1. Digit Span: (Say at rate of one number per second. Record performance.)

"I'll say some numbers and you repeat them when I'm done."

"3-2-6-0-9-1-0" (Record answers): _ _ _ _ _

"8-1-5-3-7-2-9" (Record answers): _ _ _ _ _

SCORE: ≤ 5 either trial, score 1

Score: ____

(Record slowing/hesitation, perseveration, inversion below.)

2. Verbal Delayed Memory: (See below).

LANGUAGE

3. Repetition: "I'll say three things and you repeat them when I'm done."

"A red ball, a blue car, and the city of Chicago."

"Now see if you can remember them when I ask you again later."

SCORE: unless repetition is perfect, score 1

Score: ____

(Record slowing/hesitation, perseveration, inversion below.)

4. Naming: (Hold up item and point to part. Correct answers underlined.)

"What's this thing?" (point to pen; record answer): ____

"What's this thing?" (Point to cap/cover; record answer): ____

"What's this thing?" (Point to clip; record answer): ____

"What's this thing?" (Point to point/tip; record answer): ____

"What's this thing?" (Point to watch; record answer): ____

"What's this thing?" (Point to band; bracelet; record answer): ____

SCORE: if any errors in naming, score 1

Score: ____

(Record slowing/hesitation, perseveration, inversion below.)

ABSTRACTION

5. Serial 7's: (Check if correct or record errors.)

"What's 100 minus 7?" ____ (93) "And 7 from that?" ____ (86)

"Keep taking 7 away." ____ (79) ____ (72) ____ (65)

SCORE: if subject misses or unable to complete, score 1

Score: ____

(Record slowing/hesitation, perseveration, inversion below.)

6. Proverbs: (Record full answer).

"What does it mean to you when people say 'Don't cry over spilt milk?' "

Score: ____

SCORE: use scoring key below; unless matches abstract, score 1

(Abstract: Don't worry about mistakes in the past. When something's gone, don't be concerned about it. What's done is done; don't brood. It's gone, don't worry. Don't cry when something goes wrong.

Concrete: Just clean it up. The milk's gone, you can't use it.)

(Record slowing/hesitation, perseveration, inversion below.)

BEHAVIORAL SEQUENCE

7. Luria Movements: "I'll do something with my hand and you try to repeat the same thing when I'm done."

(Tap your right knee 3 times with the right hand in these 3 positions):

FIST: (make a fist and strike the knee with the heel of the hand)

PALM: (extend fingers out flat and strike the knee with the palm)

RING: (make 'OK' sign with the thumb and forefinger together in a ring; extend the other fingers and strike the knee with the heel of the hand) "Now you try it."

SCORE: if subject cannot reproduce in first trial, score 1

Score: ____

(Record slowing/hesitation, perseveration, inversion below.)

APPENDIX (CONTINUED)

Cognitive Screening Test

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8. Rhythms Reproduction: 'I'll tap a little rhythm on my knee. Watch carefully and try to repeat it when I'm done.'
 (Tap on right knee with right hand in following sequence where (*) equals a brisk (1-sec) tap and (-) equals a slow (2-sec) tap):
 * * * - - * * * "Now you try." (Record response): _____
 "Now try this one." (Tap out following sequence):
 - - - * * * - - - "Now you try." (Record response): _____
 "Now try this one." (Tap out following sequence):
 - - * * - - "Now you try." (Record response): _____
 SCORE: if subject misses or unable to complete, score 1 Score: _____
 (Record slowing/hesitation, perseveration, inversion below.)

DELAYED MEMORY

2. Verbal Delayed Memory: (Record full answer).
 "Now tell me the 3 things I asked you to remember earlier."
-

(Correct = Red Ball, Blue Car, City of Chicago)

SCORE: if subject misses any or unable to complete, score 1
 (Record slowing/hesitation, perseveration, inversion below.)

Score: _____

9. Slowing/Hesitation: (>3 sec delay on any question. Record times): _____
 SCORE: if subject hesitates on any question, score 1 Score: _____
10. Perseveration: (Repeats response on any question. Record times): _____
 SCORE: if subject perseverates on any question, score 1 Score: _____
11. Inversion: (Inverts/reverses response on any question. Record times): _____
 SCORE: if subject inverts on any question, score 1 Score: _____
- TOTAL (add together all points from 0-11).....TOTAL: _____
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