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Incongruity, Incongruity Resolution, and Mental States: The Measure and Modification of Situational Awareness and Control

by

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Incongruity, Incongruity Resolution, and Mental State: The Measure and Modification of Situational Awareness and Control - Final Report.[1]

Cognition and emotion combine to define mental states. Situational awareness depends on both knowledge of the environment and the mood of the individual. Cognitive scientists from William James and Sigmond Freud to contemporary theorists in artificial intelligence and neuropsychology have acknowledged the critical role of subjective state in determining the efficiency and flexibility of information processing.

One of the most explicit computational models of mental states to incorporate both knowledge and arousal has been described by Gerlernter (1994). Knowledge is carried in a typical neural net with categorical nodes and probabilistic links. Arousal determines the focus among these nodes and links. High arousal results in a restricted range of activation. Low arousal causes a wider range of stimulation and a broader linking of categories or "ideas." From this model Gerlernter generates "creativity" in problem solving from a network that is widely active and the possibility of "fixation" from a highly aroused system. Figure 1 illustrates this model.

Pope and Bogart (1992) have drawn similar conclusions from research on individuals monitoring simulated situations. Their mental states have been labeled and operationally defined as "focused, attentive, complacent, and preoccupied." To illustrate the use of these target-background manipulations in the study of pattern recognition and situational awareness, four specific paradigms are offered. These paradigms have been proposed as relevant to the four mental states that have been found to be critical in situational cognizance (Pope, 1990). The quotations below are taken from pilots involved in air traffic incidents (Pantine and Mellone, 1989). They are chosen to illustrate the mental states and a possible experimental analog from pattern recognition is given to illustrate how each mental state might be replicated in the laboratory.

1. Attentive - A vigilant pilot monitors changes in the instruments available for observation, anticipating their future states: "Pay close attention to clearances, question unusual clearances...pilots and controllers can make mistakes, and last and certainly the main concern is be alert." (#89626).

Pattern Recognition: Target has intermediate complexity and is stochastic. Prediction accuracy is potentially above chance but uncertain.

2. Focused - A pilot monitors a single important aspect of the situation with less awareness of other aspects: "I was concentrating on the captain's use of new equipment...new electronic gadgetry." (#68957). "I was flying with a new F/O and I was paying more attention to the pre-takeoff checklist and briefing him, than I normally would have, rather than thinking about where I was taxiing." (#49738)

Pattern Recognition: Target has intermediate complexity and is stochastic. Prediction accuracy is potentially above chance and consistent.

3. Complacent - A pilot is not challenged and does not attend an automatic system, leading to errors when something goes wrong: "I still do not know what caused the map display to be off course. The entire system usually performs so magnificently that I may be becoming complacent and totally relying on its accuracy." (#39567) " in flying for a commuter airline, we fly to many airports many times a day, as many as 10 in one day. We seem to be complacent about these airports. As is said, flying is hours and hours of pure boredom, but with a few moments of pure excitement." (#44065)

Pattern Recognition: A relatively simple, recursive target is interrupted by an uncertain, stochastic element.

4. Preoccupied - A pilot becomes involved in thinking about events outside the immediate situation, without attending to the task at hand: "I feel a major cause of this incident was a preoccupation by the captain caused by the crisis situation of our airline, leaving all our futures in serious doubt. The previous two-three hours of conversation were totally devoted to what was happening and conjecture on what might happen... He was worrying about his career and the fate of our airline.: (#49963)

Pattern Recognition: A simple recursive target is learned, until no errors are made.

As shown in Fig. 1 each of these states can be mapped into the cognitive surface - emotional cone model. This mapping indicates the continuous nature of mental states and the ease with which a person or pilot can slip into a dangerous one.

A computational model such as this has corollaries in neural activation. In the broadest sense low arousal is indicated by slow waves of electrocortical activity (alpha and delta). Higher arousal is shown by disorganized, relatively chaotic activity. Also relevant here is the cortical response to particular environmental stimuli, i.e. event-related potential (ERP).

Of particular interest is the occurrence of an ERP to incongruity. Kutas and her associates (Kutas and Hillyard, 1980, Van Petten and Kutas, 1990) have measured ERPs and found a negative-going cortical change at 400 milliseconds (ms) that corresponds to an incongruous word in a sentence. This "N400" followed a positive-going wave at 300 ms (P300) that indicated initial categorization of the stimulus. This response to verbal materials shows the "setting up" of an incongruity (Coles et al., 1990). The initial demonstration of the N400 depended on anomalous sentence completions (Kutas and Hillyard, 1980). Even slightly unexpected verbal stimuli have been found to elicit the N400, though not to the same amplitude (Kutas and Hillyard, 1984; Van Petten and Kutas, 1990). Nigam et al. (1992) have proposed that the N400 is more consistently related to any activation of conceptual memory. At least one study has reported that the amplitude of the N400 was related to the storage load in a memory search task (Mecklinger et al., 1992). Chwilla et al., (1995) found that the N400 was limited to a semantic task. Another study, however, has presented ERPs that seem to show the N400 when errors in a simple discrimination task occur under instructions to be accurate rather than fast (Gehring et al., 1993). In any case, the N400 may be described as occurring when categorization, usually semantic, is relatively unsuccessful and a search is initiated for better alternatives.

Earlier research in this project has indicated that the monitoring of ambiguous words, an active task, always elicited an N400 even for some of the material that was non-ambiguous (Derks, Gillikin, Bartolome, and Bogart, 1994). A more passive task, however, only produced an N400 when the material was incongruous (Derks, Gillikin, Bartolome-Rull, and Bogart, 1997). These separate studies suggested that the emotional focus might play a role in cognitive selection (Derks and Gillikin, 1993).

The present series of experiments was designed to examine brain states and ERP's under various conditions of arousal and several degrees of mental involvement. (1.) The mental state tasks of Pope and Bogart were compared with imaginal techniques for manipulating positive and negative arousal. (2.) The word monitoring task was replicated with the addition of a non-ambiguous condition. (3.) A complex binary pattern prediction task was designed to require varying degrees of attention and, possibly, different levels of arousal. (4.) The judgement of ambiguous figures was examined to compare cortical activity in visual vs. more verbal decision making. (5.) An anomalous clock reading task was employed to generalize these procedures to a more instrumental, aviation-like task.

Methods

Pre-test - One of the primary problems with the earlier research was the loss of data from many participants due to muscular tension in the forehead and scalp and excessive blinking. Such peripheral activities causes artifactual readings in the EEG patterns of individuals engaged in these experimental tasks. Therefore an off-base pre-testing procedure was used to select participants in the main research activity.

Twenty-two individuals were given pre-testing with the Autogenic Systems Biolab. During approximately a twenty-minute period they were asked questions about themselves and instructed to think about a pleasant and an unpleasant time in their lives. The muscular tension in the forehead was recorded at three intervals and their eye blinks were counted continuously. They were paid $3.00 for their participation in this test.

In spite of the different activities performed during the test, forehead tension was highly correlated within subjects. The first measure matched the second, $r=.912$, The second matched the third, $r=.929$, and the first and third matched, $r=.897$. The actual values of these readings were not meaningful as they were based on a clinical base line and did not give absolute measures.

The eye blinks on the other hand were quite variable, ranging from one to twenty-three per minute and averaging 9.32

with SD=6.20. Furthermore, eye blinking did not correlate with forehead tension. For the three tension measures eye blinks correlated, - .117, - .097, and - .073 respectively. Eye blinking was seen as the greater problem, but the initial participants in the main research were selected to be both low in eye blinking and forehead tension.

Arousal Induction

For comparison with the arousal induction manipulation the four mental state induction proceedings of Pope and Bogart (1992) were performed at the beginning of the session and again after lunch. For the "attentive" state events on the CRT screen were monitored. "Focused" was induced by monitoring a specific event. An event off the screen was monitored for the "absorbed" state. Thinking of some current problem induced the "preoccupied" state.

Counterbalanced between morning and afternoon, a positive and negative arousal induction was performed. For the positive induction the participant was instructed to "think about a time in your life when you were really happy. Make it as specific as possible. Try to remember a time or situation when everything worked out right and you were really in control. Imagine that time as clearly as you can. Try to feel the same elation you felt then." The negative induction was "Think about a time in your life when you were really sad. Make it as specific as possible. Try to remember a time or situation when things were not going well and you lost something or someone very important to you. Imagine that time as clearly as you can. Try to feel the same depression you felt then." Following induction the participants were asked to assess their arousal. The form to aid this assessment is included in appendix 1.

Word Categorization

The ambiguous word task from Derks, Gillikin, Bartolome, and Bogart (1994) was presented to these participants to replicate the earlier findings. A list of 105 words, nouns and verbs, was presented visually. The words chosen had been judged as either obviously a noun, obviously a verb, or ambiguous by 15 college students in a class on cognition and thinking during the section on psycholinguistics. Typical nouns were "cat, pie, tin" and verbs "think, fail, reach." Ambiguous words included "load, hope, slide." The subjects' task was to count the number of either nouns or verbs. The target to be counted was counterbalanced over sessions. A list of the stimuli is included in appendix 2.

The non-ambiguous word task was similar in format to the ambiguous word task except that the 88 stimuli were either cities or animals taken from Battig and Montague (1969). This decision was obvious and easy except for "Buffalo" that was introduced late in the list as a possible ambiguous judgement in the midst of certainty. These stimuli are also included in appendix 2.

Binary Prediction

In an effort to model states of mental awareness in a controlled information processing task two sets of sequences of binary stimuli (X's and O's) were designed. One set of stimuli was composed of repeating patterns. For example, an X would appear on the computer screen then disappear and be followed by an O. The O would then disappear and be followed by an X. The pattern would continue to repeat X followed by O followed by X for five cycles or 10 stimuli. Then the participant was required to predict the next event, X or O, by pressing the appropriate key on the key board. These recursive sequences were simple enough to be learned by college students and it was assumed that no errors would be made in the task (Derks and House, 1965). The cognitive demand was low and the emotional involvement was minimal. Thus the task was expected to lead to preoccupation or complacence. The recursive sequences are included in appendix 3.

A more difficult binary prediction task was generated stochastically, or probabilistically. In other words, the occurrence of an X or an O could not be predicted from the preceding sequence. There was, however, a bias in favor of one stimulus or the other. One of the stimuli would occur about three times more often than the other. Thus a prediction could be right more often than wrong by choosing the more frequent event but this strategy would not lead to perfect performance. Predictors in such situations have been found to gamble and match the sequence probability as if playing a cognitive game (Derks, 1962, 1963). This task was expected to increase involvement and be more arousing leading to a focused or attentive mental state. These sequences are also included in appendix 3. For a computational discussion of the cognitive components of recursive and stochastic prediction see Hofstadter (1995).

In order to increase arousal still further another manipulation was performed on each sequence. On a certain proportion of the trials the individual's guess was wrong no matter what the sequence predicted or what response the individual made. This forced error was expected to lead to more negative arousal and move preoccupation or complacence to attention on the recursive sequence. On the stochastic sequence false error feedback was expected to enhance attention to focus, or possibly move focus into preoccupation. Event-related potentials in these various situations were expected to reflect these changes in mental state. Specifically the N400 wave was predicted to increase in magnitude as the cognitive involvement and emotional arousal increased. The participants were asked about their "mood" following the completion of each of the four sets of sequences. The form for recording their arousal is included in appendix 1.

Ambiguous Figures

Each participant was shown ambiguous or reversible figures, such the Necker cube or the young girl-old lady. Examples are presented in appendix 4. They were instructed to press a button "when the stimulus changes." Event related potential measures were taken from the button press.

Clock Reading

An on screen comparison between digital and analogue clocks was made by the participants. One version would appear followed by a comparison version for a same-different judgement. All possible comparisons, digital-digital, analogue-analogue, and digital-analogue were made. Of primary interest, however, were digital-analogue comparisons when the digital reading was impossible, i.e. 2:30 analog and 37:98 digital. ERP measures were taken from the appearance of the anomalous reading as well as accuracy and latency. Ray Comstock was instrumental in the design and performance of this experiment.

Overview

A typical research session lasted from about 8:30 in the morning till after 2:30 in the afternoon, with about 30 minutes for lunch. The tasks described here were counterbalanced across participants. A typical session schedule is given in appendix 5. The participants remained connected to the electrodes (but not necessarily the computer) for this whole time. The trip from William and Mary to the Langley Research Facility took about 45 min. or an hour and a half total travel time. The participants were reimbursed $40 for their day of research. They were informed about the general nature of the tasks and given a complete debriefing at the end of the day. In every case the participants were treated according to the ethical standards of the APA.

Results

Word Categorization

The clearest and most completely analyzed results are for the replication and extension of the word categorization experiment. Figure 3 a & b shows the ERP brain map for nouns (14 participants with sufficient artifact free data), 2 a & b for ambiguous (15 participants artifact free). Only three participants had sufficient usable data for verbs so they are not presented.

Generally the brain maps show a position wave at approximately 175-200 ms. This positive potential is a bit early for a P300 but it compares well with the previous study (Derks, Gillikin, Bartolome, and Bogart, 1994). Also similar is the negative potential at 325-400 ms. The first study was replicated in this respect as well.

For the city-animal judgements, shown in figure 4 a & b and 5 a & b respectively, a clear positive wave occurs at 175 ms. An unpredicted negative wave appears in both judgements at around 350-375 ms. Although this is somewhat earlier than the ambiguous judgements it is still an "incongruity" wave in a non-ambiguous task.

As for judgements on "Buffalo" only three observers had latencies of over two sec indicating an awareness of the ambiguity. Two of these judgements were "city." Of the others with less than two sec latency, seven were "animal" and ten were "city." The cortical EGG were not sufficiently error free to produce a mapping, but given the other data, N400's probably occurred here too.

Binary Prediction

As a technique for inducing particular mental states, the binary prediction task was unsuccessful. "Bored" was the most frequent response overall, occurring for recursive, accurate feedback for 40% of the participants. For recursive with false feedback, 60% said they were bored. When the sequences were stochastic, 50% were bored for accurate feedback and 65% for false feedback. Focused also received some votes, 60% for recursive accurate, 45% for recursive false, 30% for stochastic accurate, and 15% for stochastic false. The regularity of this decline in focus is appealing, but contrary to prediction.

As for EGG recordings, in spite of pretesting the regular occurrence of X's and O's on the screen prompted a reflex blink from all participants. Consequently no brain maps could be produced.

Arousal Induction, Ambiguous Figures , and Clock Reading

The arousal manipulation was more successful. On the response sheet the positive induction resulted in 50% of the participants reporting "happy" feelings and 40% were "cheerful." The negative induction produced 65% "sad" and 45% "depressed." Unfortunately, the comparison between these brain maps and those of the other mental states has not been made. The difficulties involved in this data analysis have also prevented further work on Clock Reading and Ambiguous Figures. Early analysis, however, has suggested that N400 appears under most circumstances where artifacts are not so extensive as to prevent examination.[2]

Ray Comstock has performed some behavioral analysis on the clock reading task. Table 1 presents response latencies for decisions in the various conditions. Digital - digital latencies were shorter than analog - analog, $F(1, 18) = 13.49$, $p < .01$.

Different display readings resulted in longer latencies, $F(1,18) = 10.87$, $p < .01$. Analog - digital comparisons were slowest, $F(1,18) = 33.91$, $p < .01$ (cf. Miller & Pennengroth, 1997). After an initial response of over four seconds, impossible digital readings were made as quickly. Incongruity and surprize were quickly resolved.

Discussion

Although artifacts and limited data analysis reduced the significance of this project, some conclusions can be drawn and suggestions made for future research. Of primary interest, participants in the categorization tasks, both in the original study and the replication, showed the N400 ERP when making active decisions. The majority of research projects have reported the N400 to be related to the violation of some expectation, usually semantic (Coles, Gratton, and Fabiani, 1990).

The participants in this research did not have a frame in which to build up an expectation. Instead, each word, noun, verb, city, or animal, not to mention clock reading and ambiguous figure, came in an unspecified context and led to the incongruity response.

On the other hand, when participants were in a passive, story completion task in the original series of studies they showed a distinction between recognized and unrecognized incongruities (Derks, Gillikin, Bartolome, and Bogart, 1997). In effect, decision making became active when an incongruity was recognized. From this perspective, the N400 depends on active processing and uncertain context. When the context is certain and processing is passive, no N400 occurs.

This distinction is reminiscent of the definition of consciousness proposed by Tolman (1932). Consciousness is the active comparison of alternatives, a search for a response to fit a need. Hardcastle (1996) has given a similar analysis of the N400 in recognition tasks. Indeed, this was the rational of the binary prediction task in the present project.

This emotional-cognitive interaction warrants continued evaluation, both behavioral and neurophysiological. Patterns of a more engaging kind, both verbal and imaginal, could be presented under different levels of arousal. The imagery technique for manipulative arousal was successful. The story completion procedure did distinguish congruent from incongruent overt and ERP reactions. A combination of these methods could lead to a better understanding of the effects of cognition and emotion on the awareness and control of situational incongruities and emergencies.

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Footnotes

1. Thanks to Alan Pope, Ed Bogart, Ray Comstock, Dan Burdette, and Debbie Bartolome-Rull for their help and expertise. Also thanks to Martie Haselton and Robert Shulz for their careful and intelligent data analysis.

2. When this project was originally proposed, three years and approximately $300,000 were requested. The initial award was for nine months and $60,000. During that period we became involved in a cooperative venture with other NASA projects going on at the time. We gladly donated time, expertise, and funds to these projects with the expectation (but no guarantee) that the contributions would balance out.

Since that time we have received time extensions that have given a full three years to the project. No additional funding has accompanied these extensions. Nevertheless, thanks to time contributed by Robert Shulz and Debbie Bartolome-Rull over what they were reimbursed to do, some of the data were analyzed and some tentative conclusions and suggestions for further research could be made. Unfortunately, without additional volunteer effort or supplemental funding, these data must remain in the HEM lab's archives.

Table 1

Mean Latency (and SD) for Clock Comparison: Analog (A), Digital(D), and Impossible Reading(I).

	A-A	D-D	A-D	D-D:I	A-D:I
Same	1.50	1.08	2.66		
(SD)	(.64)	(.27)	(1.01)		
Diff	1.74	1.39	2.58	1.37	2.54
(SD)	(.97)	(.39)	(1.08)	(.38)	(1.34)

Figure Captions

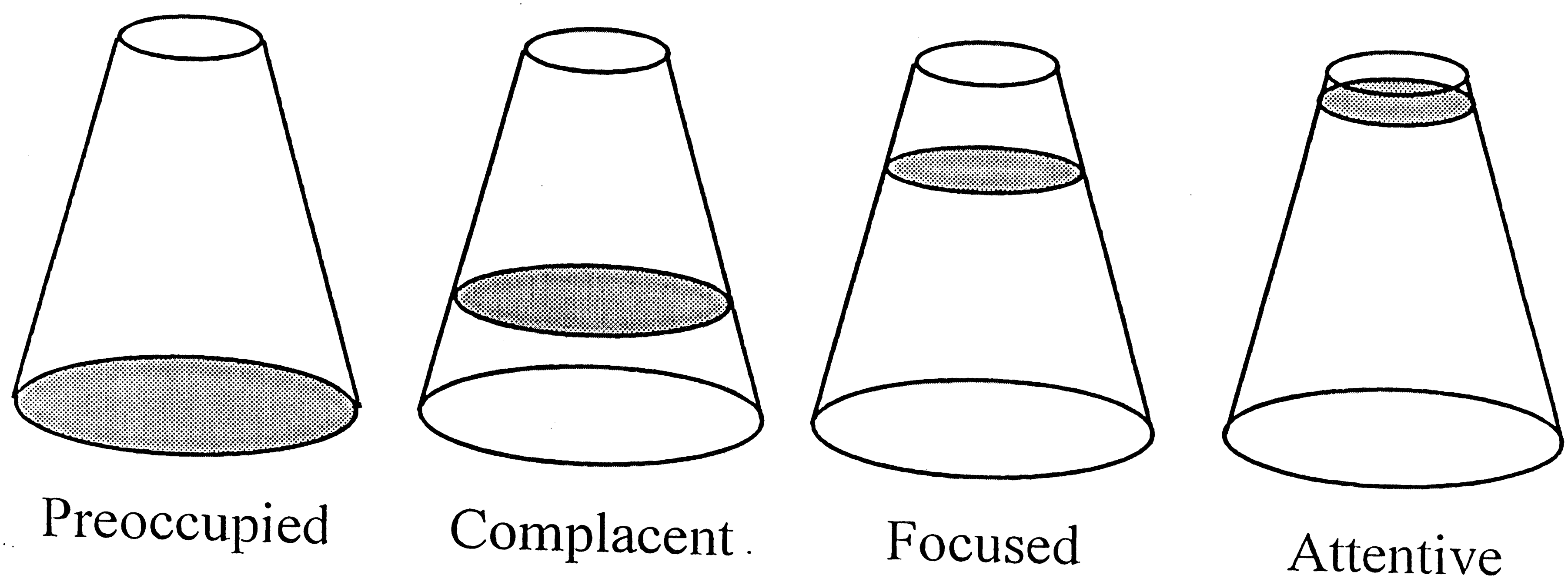
Figure 1. A computational model of the interaction between knowledge and emotion with four mental states indicated, based on Gerlernter (1994), courtesy of Alan Pope.

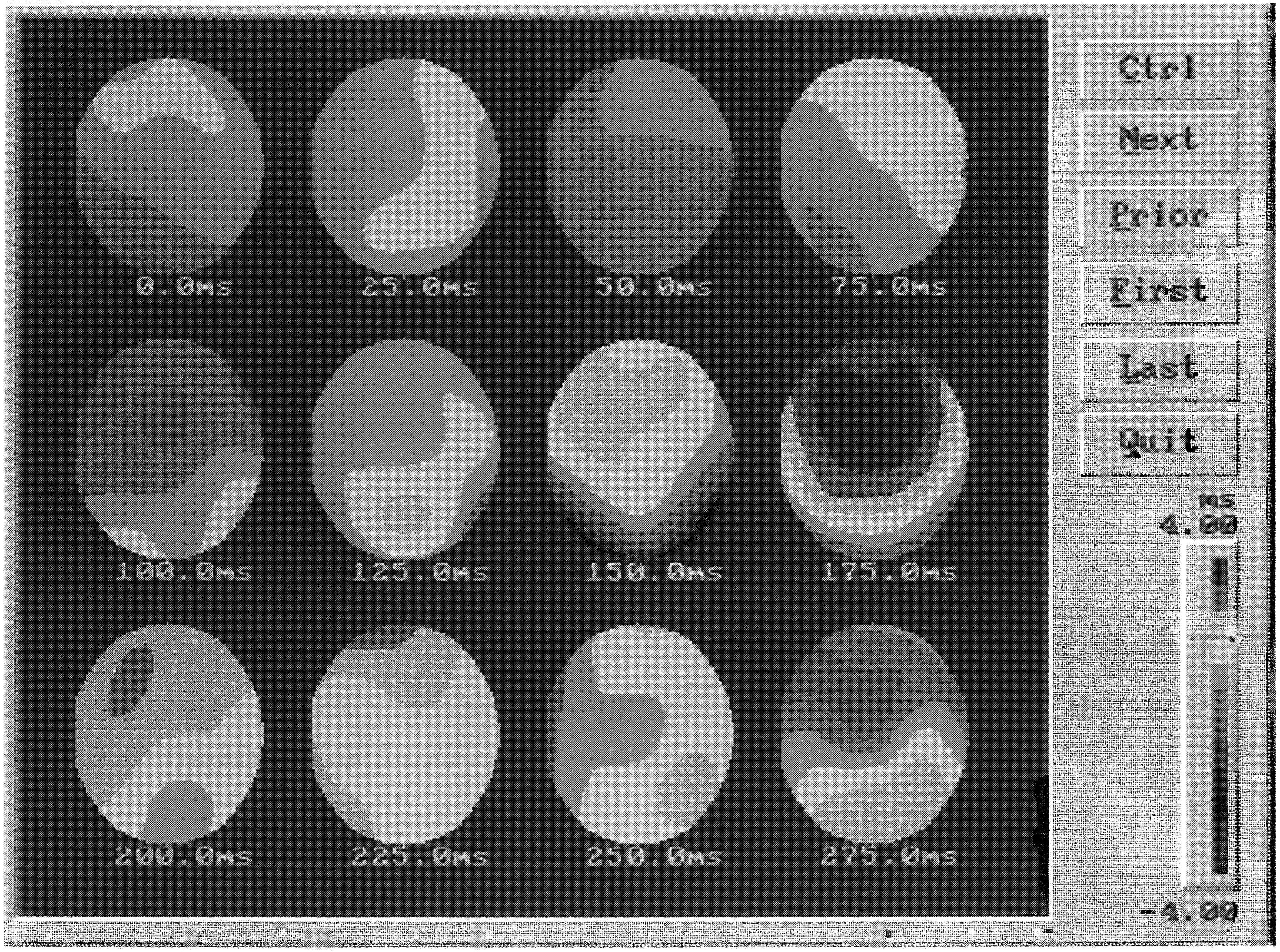
Figure 2. ERP spatio-temporal brain maps for judgement of nouns.

Figure 3. ERP spatio-temporal brain maps for judgement of ambiguous words.

Figure 4. ERP spatio-temporal brain maps for judgement of city names.

Figure 5. ERP spatio-temporal brain maps for judgement of animal names.


Preoccupied
Complacent
Focused
Attentive



Page 1 Grand average Ambiguous Words NV

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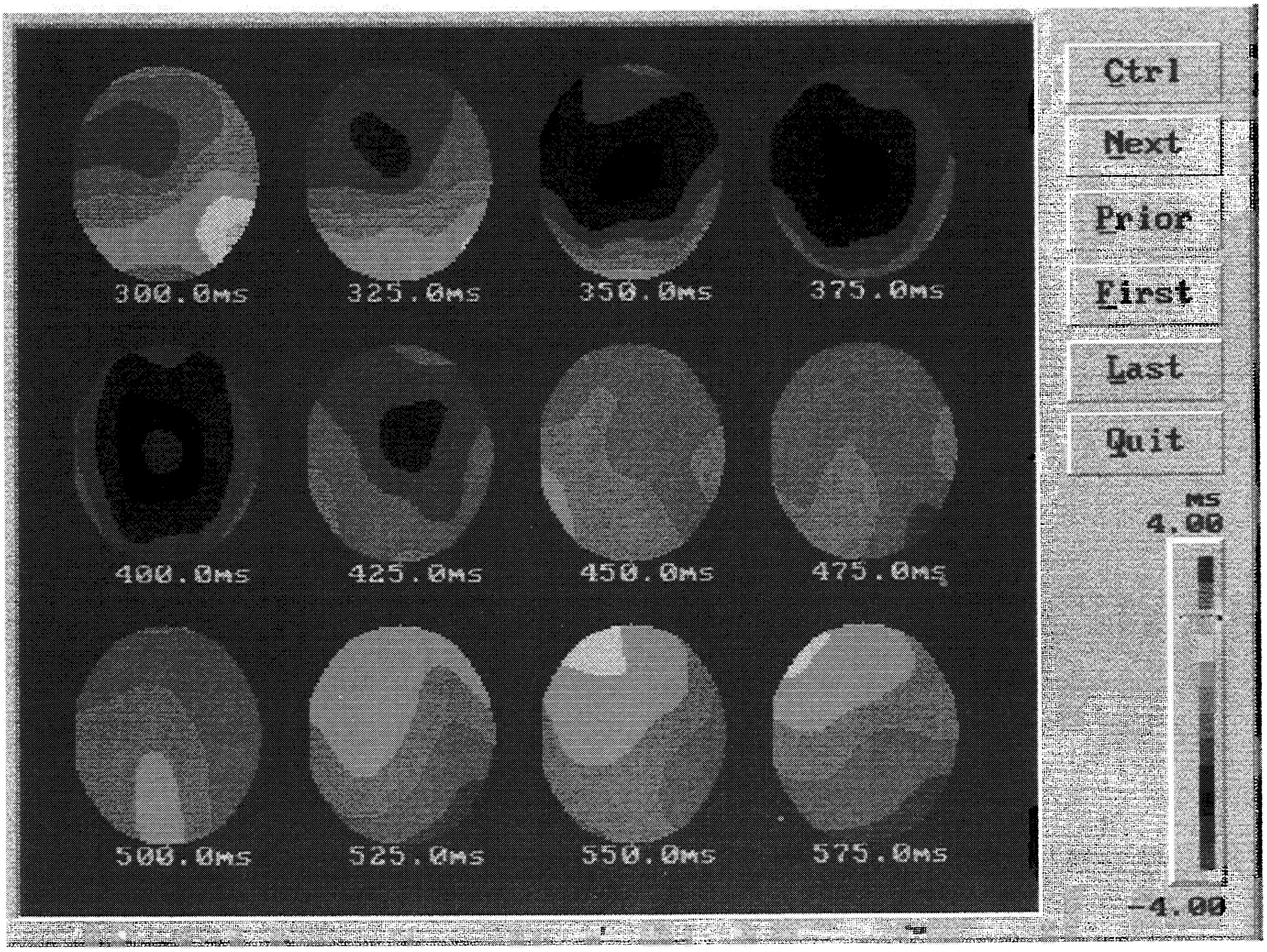
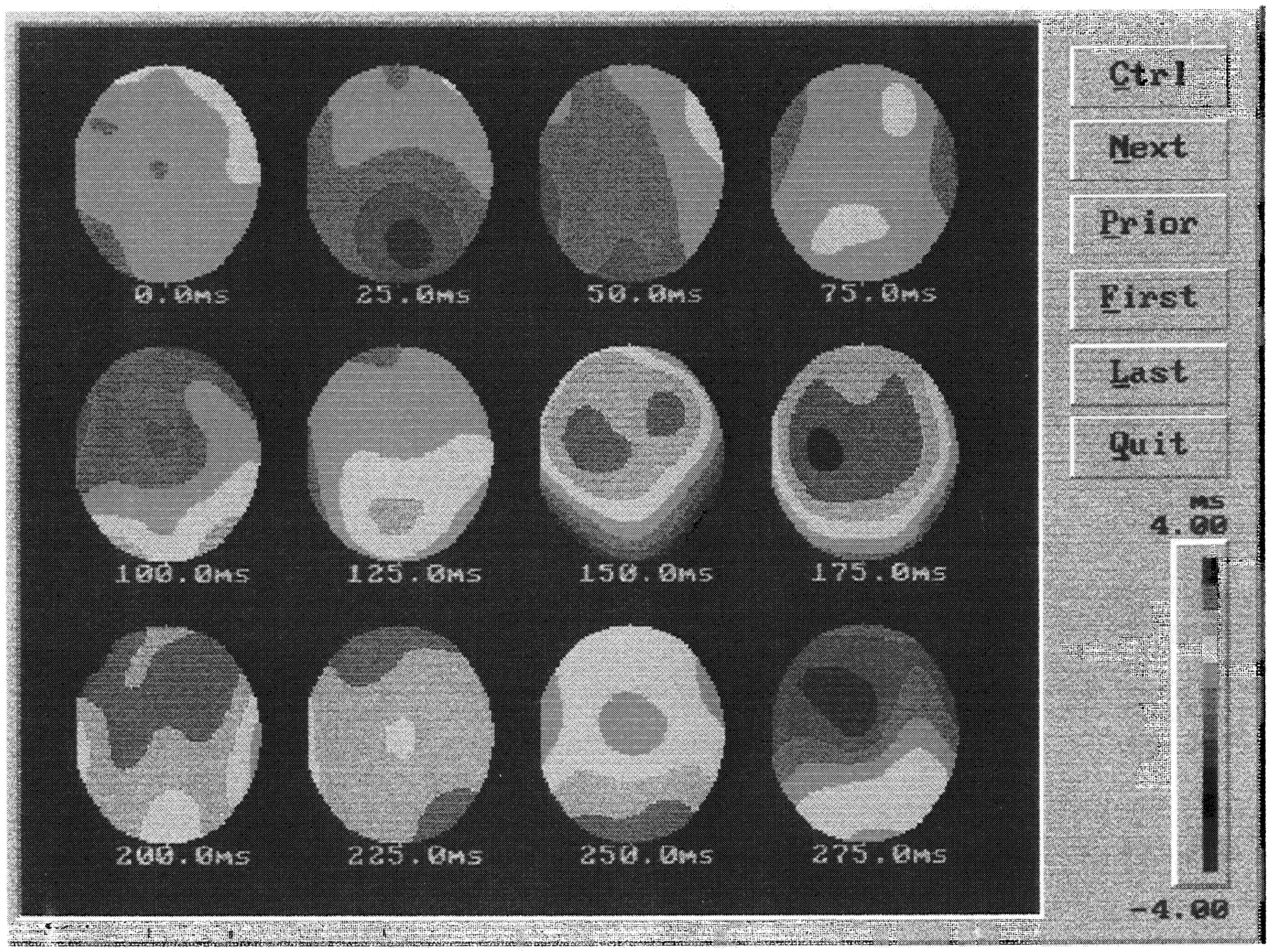
15 subjects total



Page 2 Grand average Ambiguous Words NV



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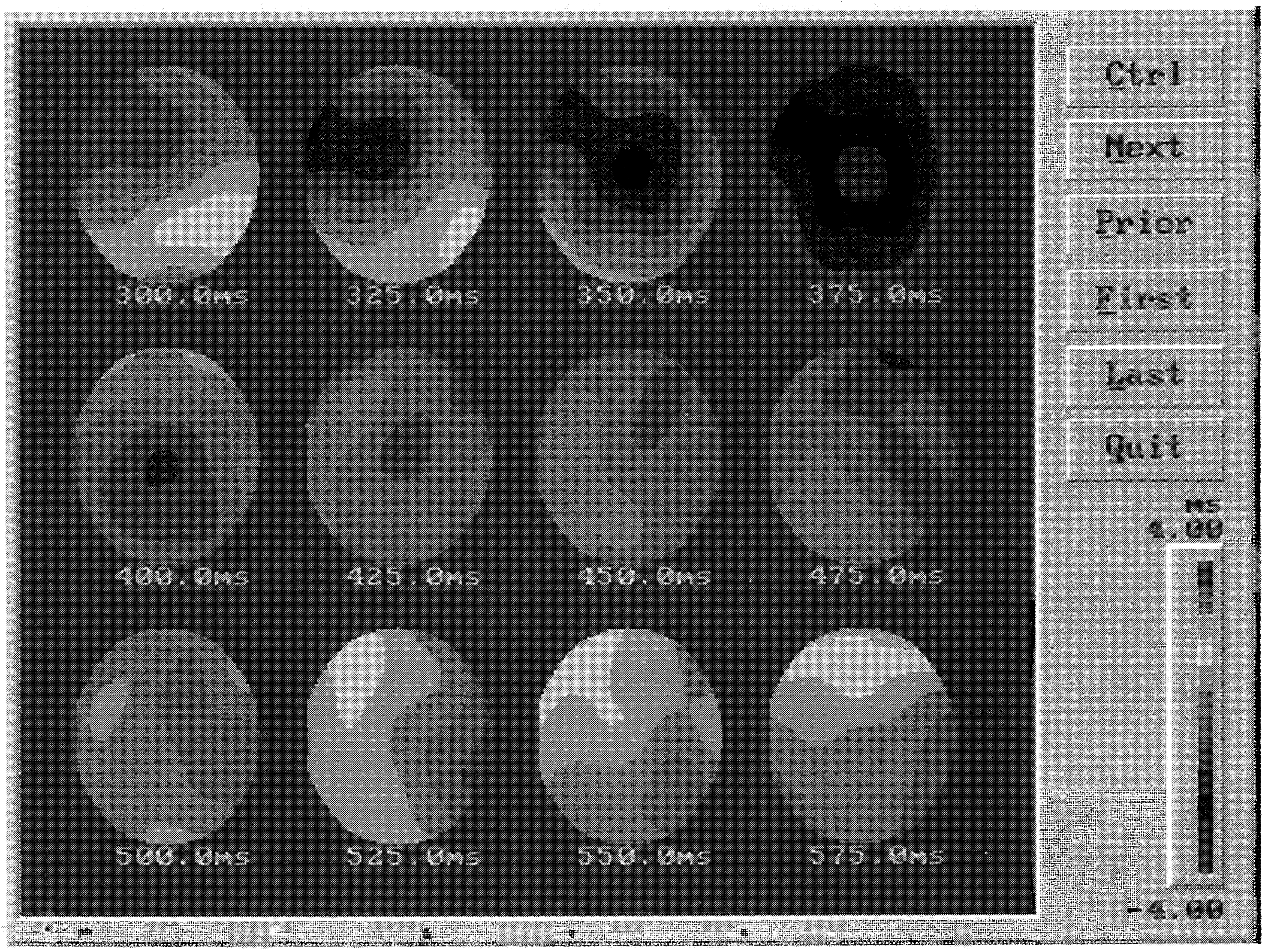
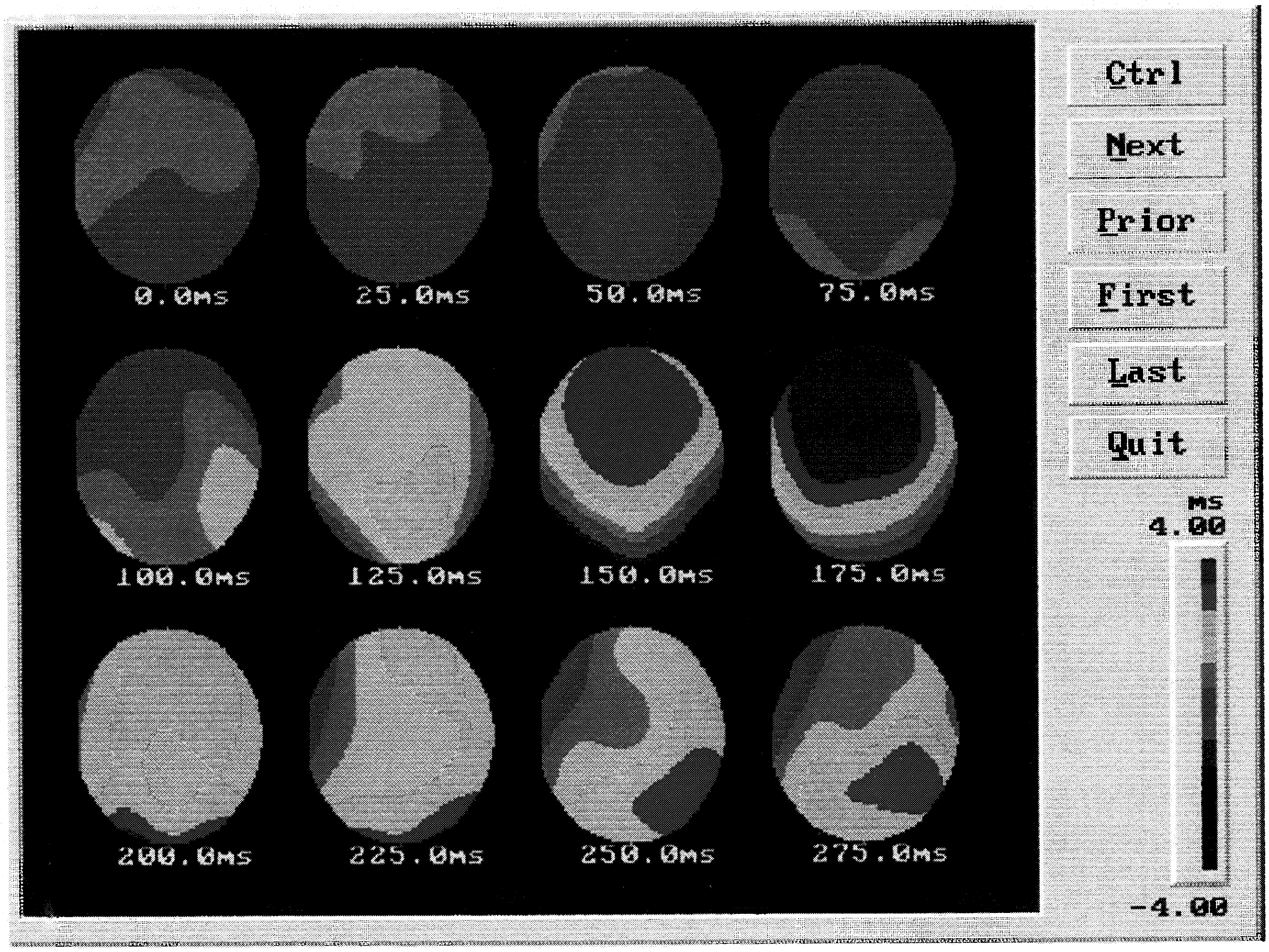
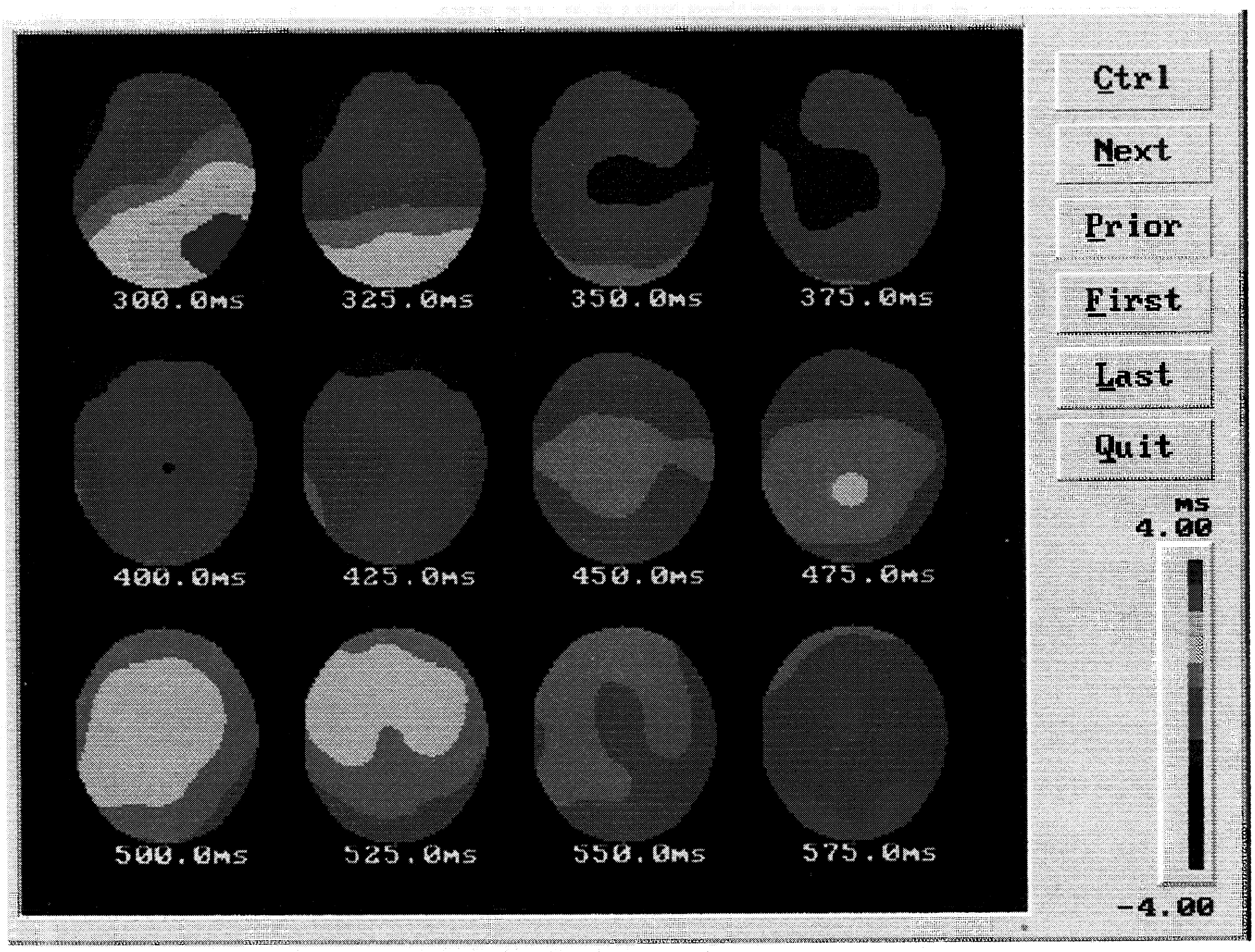


Page 2 Grand Average Nouns words NV

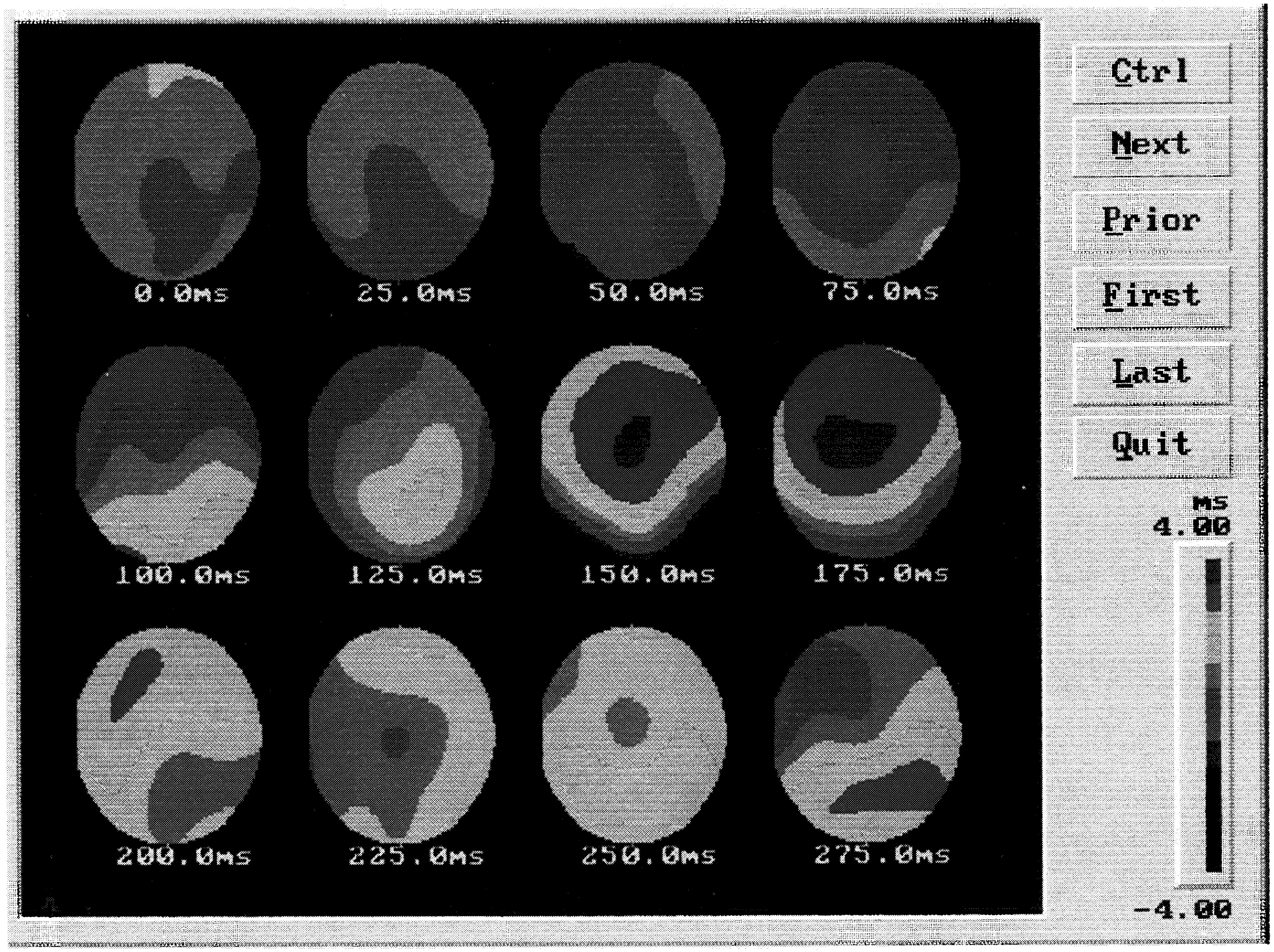


Page 1 Grand Average City

18 subjects

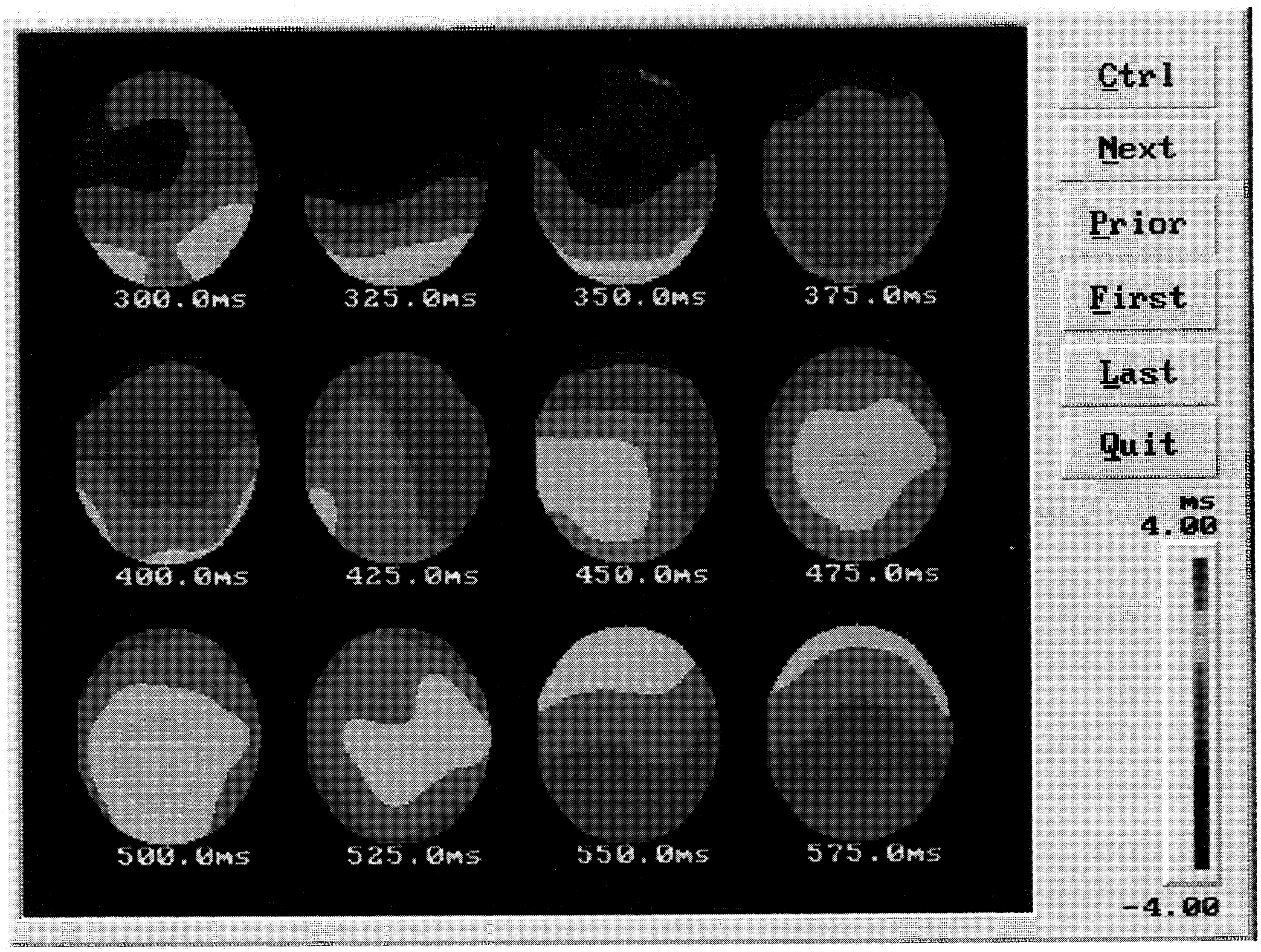


Page 2 Grand average City Words CA



Page 1 Grand Average Anim. Words CA

18 subjects



Page 2 Grand Average Animal words CA

Appendix 1. Forms for assessing participants mental states.

Thinking about experiences:
What were you thinking about (optional)?
How clear was it?
How did it make you feel? cheerful? elated? sad? depressed?
no noticeable mood change?
How were you feeling to begin with?

I was thinking about one of my friends.

It was fairly clear.

It made me feel very happy.

I was not really feeling anything (not happy or depressed)

Thinking about experiences:
What were you thinking about (optional)?
How clear was it?
How did it make you feel? cheerful? elated? sad? depressed?
no noticeable mood change?
How were you feeling to begin with?

I thought about what it would be like if my sister got hurt.

It was pretty clear.

It made me feel depressed.

I wasn't feeling anything to begin with.

Sequence prediction:
What strategy were you using to predict the sequences? guessing? remembering? some abstract relationship?
How effective was it?
How did you feel during the task? cheerful? elated? sad? depressed? attentive? complacent? focused? preoccupied? excited? bored? other?

I figured out the sequence and said it along as the letters came up.

It was very effective

I felt that I was focused on the task + concentrated mostly on what the next letter would be.

Sequence prediction:
What strategy were you using to predict the sequences? guessing? remembering? some abstract relationship?
How effective was it?
How did you feel during the task? cheerful? elated? sad? depressed? attentive? complacent? focused? preoccupied? excited? bored? other?

At first I didn't get it. Then I just guessed by which letter showed up more. Then I figured out it was the first letter shown, so I just always put that letter.

Once I figured out the last part, it was very effective.

At the beginning, I was frustrated. Once I figured out I only needed the first letter, I was a little bored.

Sequence prediction:
What strategy were you using to predict the sequences? guessing? remembering? some abstract relationship?
How effective was it?
How did you feel during the task? cheerful? elated? sad? depressed? attentive? complacent? focused? preoccupied? excited? bored? other?

I always put the most frequent letter.

It was fairly effective.

I felt focused.

Sequence prediction:
What strategy were you using to predict the sequences? guessing? remembering? some abstract relationship?
How effective was it?
How did you feel during the task? cheerful? elated? sad? depressed? attentive? complacent? focused? preoccupied? excited? bored? other?

I figured out the pattern + kept repeating it with the presentation.

It was very effective.

I felt focused during the task.

Appendix 2. Words used in categorization tasks.

NOUNS

cow	1.000	queen	1.400
cup	1.733	straw	1.000
fruit	1.000	cat	1.067
house	1.867	pie	1.000
job	1.000	pole	1.400
meal	1.133	pond	1.000
pipe	1.533	rice	1.000
pool	2.000	truth	1.000
silk	1.000	card	1.667
shirt	1.133	globe	1.200
bone	1.333	tin	1.000
dirt	1.267	truck	1.733
door	1.267	snake	1.867
aunt	1.000		
cheese	1.400		
class	1.200		
fact	1.000		
mice	1.000		
task	1.400		
blank	2.000		
chest	1.067		
day	1.000		
lake	1.000		
lip	1.400		
mouse	1.200		
pine	1.933		

VERBS

like	4.333
reach	4.000
fail	4.933
pour	4.667
dry	4.267
shoot	4.600
hide	4.000
think	4.933
burst	4.000

AMBIGIOUS

cave	2.333	march	3.133	hope	3.267
date	3.000	miss	3.733	slide	3.000
hold	3.533	move	3.600		
knot	2.714	pet	2.800		
lift	3.533	play	3.067		
log	2.200	rise	3.933		
pass	3.200	train	2.733		
pile	2.867	bank	2.200		
pitch	3.200	bend	3.800		
pound	2.800	graph	3.000		
press	3.333	leaf	2.267		
rule	3.067	roll	3.067		
sail	3.133	stream	2.467		
shell	2.267	club	2.400		
sound	2.667	deck	2.467		
store	3.000	plant	2.867		
tie	3.067	bark	3.000		
touch	3.400	call	3.200		
track	2.933	drop	3.533		
cap	2.571	knee	2.067		
chain	2.667	load	3.000		
cook	3.067	shade	2.867		
dream	3.000	aid	3.067		
duck	2.800	blow	3.733		
fix	3.800	cage	2.533		
oft	2.200	court	2.533		

Cities and Animals

1. Leopard
2. Rabbit
3. Houston
4. Tokyo
5. Champaign
6. Cat
7. Hippopotamus
8. Chicago
9. San Diego
10. Horse
11. Las Vegas
12. Mule
13. Seattle
14. Bethesda
15. Berlin
16. Kansas City
17. Zebra
18. Wolf
19. Memphis
20. Rome
21. Fox
22. Pittsburgh
23. College Park
24. Silver Springs
25. Rockville
26. Antelope
27. Decatur
28. Moose
29. Annapolis
30. Lamb
31. Monkey
32. Raccoon
33. Llama
34. Skunk
35. Milwaukee
36. Bull
37. Elephant
38. Pig
39. Bear
40. Baltimore
41. Paris
42. Philadelphia
43. Dallas
44. Cow
45. Sheep
46. Moscow
47. St. Louis
48. Beaver
49. Gazelle
50. Elk
51. Urbana
52. Boston
53. Madrid
54. Lion
55. Reno
56. Mouse
57. Peoria
58. Rat
59. Columbus
60. Deer
61. Giraffe
62. Dog
63. Tampa
64. Tiger
65. Cheetah
66. Rhinoceros
67. Denver
68. New Orleans
69. Los Angeles
70. Richmond
71. Goat
72. Washington
73. Squirrel
74. Turtle
75. Springfield
76. New York
77. Buffalo
78. Miami
79. Camel
80. San Francisco
81. Atlanta
82. Panther
83. Jaguar
84. Minneapolis
85. Fort Lauderdale
86. Detroit
87. Donkey
88. Cleveland

Appendix 3. Binary sequences for prediction tasks.

RECURSIVE STIMULI

1. OX OX OX OX O?
2. OOXX OOXX OOXX OOXX OOX?
3. OOX OOX OOX OOX OO?
4. OXX OXX OXX OXX OX?
5. XXOO XXOO XXOO XXOO XXO?
6. XOOXO XOOXO XOOXO XOOXO XOOX?
7. OXOXX OXOXX OXOXX OXOXX OXOX?
8. OOXXOX OOXXOX OOXXOX OOXXOX OOXXO?
9. OOXOXX OOXOXX OOXOXX OOXOXX OOXOX?
10. OOOXOOX OOOXOOX OOOXOOX OOOXOOX OOOXOO?
11. XXOOXO XXOOXO XXOOXO XXOOXO XXOOX?
12. XOOXXO XOOXXO XOOXXO XOOXXO XOOXX?
13. XXXOXO XXXOXO XXXOXO XXXOXO XXXOX?
14. XOOOXXO XOOOXXO XOOOXXO XOOOXXO XOOOXX?
15. OXXXOOX OXXXOOX OXXXOOX OXXXOOX OXXXOO?
16. XXXOOOXXOO XXXOOOXXOO XXXOOOXXOO XXXOOOXXO?
17. OOXXXOXXX OOXXXOXXX OOXXXOXXX OOXXXOXXX OOXXXOXX?
18. OXOXXOO OXOXXOO OXOXXOO OXOXXOO OXOXXO?
19. OXOOOXXX OXOOOXXX OXOOOXXX OXOOOXXX OXOOOXX?
20. OXXX OXXX OXXX OXXX OXX?
21. OOOX OOOX OOOX OOOX OOO?
22. XXOOO XXOOO XXOOO XXOOO XXOO?
23. XOXXOOO XOXXOOO XOXXOOO XOXXOOO XOXXOO?
24. XOOXXXOOO XOOXXXOOO XOOXXXOOO XOXXXOOO XOXXXOO?
25. OOXXX OOXXX OOXXX OOXXX OOXX?
26. XXXOOXOO XXXOOXOO XXXOOXOO XXXOOXOO XXXOOXO?
27. OOXXXOOOX OOXXXOOOX OOXXXOOOX OOXXXOOOX OOXXXOOO?
28. OXOXXX OXOXXX OXOXXX OXOXXX OXOXX?
29. XOOOXXO XOOOXXO XOOOXXO XOOOXXO XOOOXX?
30. XXXXXO XXXXXO XXXXXO XXXXXO XXXXX?
31. OOXXXOXXX OOXXXOXXX OOXXXOXXX OOXXXOXXX OOXXXOXX?
32. XXOOOXXOO XXOOOXXOO XXOOOXXOO XXOOOXXOO XXOOOXXO?
33. XOXOXXOO XOXOXXOO XOXOXXOO XOXOXXOO XOXOXXO?
34. XOXXO XOXXO XOXXO XOXXO XOXX?
35. OOOOXOXX OOOOXOXX OOOOXOXX OOOOXOXX OOOOXOX?
36. OOOXXOXX OOOXXOXX OOOXXOXX OOOXXOXX OOOXXOX?
37. OXOXOXX OXOXOXX OXOXOXX OXOXOXX OXOXOX?
38. XOOOXO XOOOXO XOOOXO XOOOXO XOOOX?
39. XOXXOO XOXXOO XOXXOO XOXXOO XOXXO?
40. OOXXX OOXXX OOXXX OOXXX OOXX?

Program XORECA displays CORRECT when subject responds correctly, or else shows NOT CORRECT.

Program XORECB does the same except for lines:
6, 10, 12, 16, 19, 21, 26, 30, 36, 40
which always show NOT CORRECT.

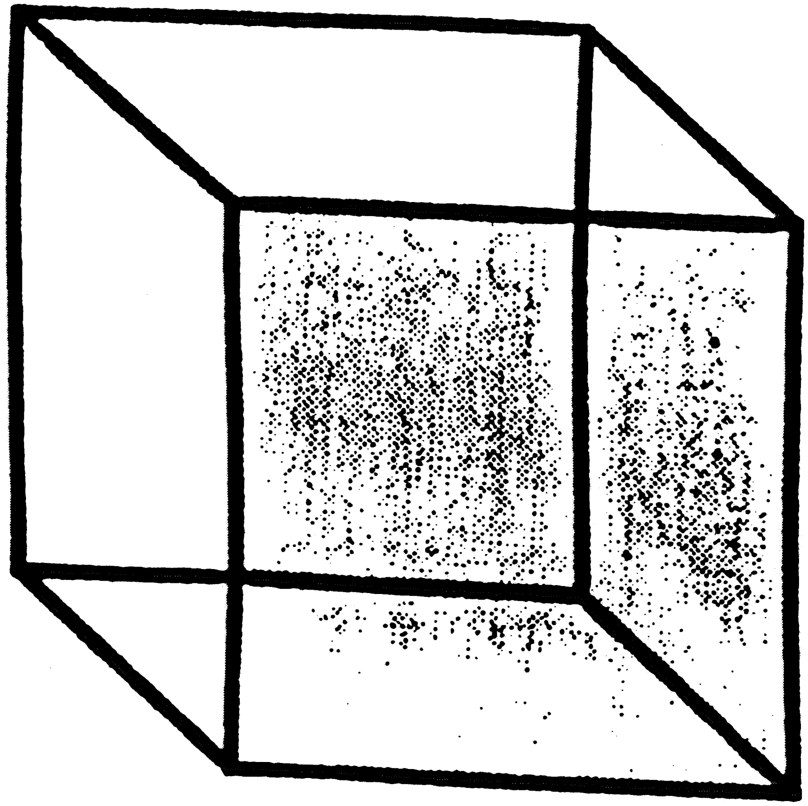
STOCHASTIC STIMULI

1.	X X O X X X X O X O X X X O O X O O X O X O X X O X X X O X X X ?
2.	O O X O O O X O X O X X O X O O X X O O O X O O O O X O O X O X ?
3.	X O X X O X X O O X X X O X X X X O X O X O O X X X O X O X X O ?
4.	O O O X O O O O X O O X O X X O X O O X O X O O X O X X O O O X ?
5.	X O X O X X O O X X X O X X X X O X O O X O X X O X X O X X X O ?
6.	X O X X O O X X X O X X X X O X O X O O X O X X O X X O X X X O ?
7.	O X O X X O O O O X O X O O O X O X O O X X O O X O O O X O O X ?
8.	X O X X X O X X O O X X X O X X X X O X O X O X O O X X O X X O ?
9.	O X O O O O X O X O O O X O O X X O O X O X O O O X O O X X O X ?
10.	X O X X X O X X O X O O X X O O X X O X O X X X O X X X X O X O ?
11.	O X X O O X O O X O X O O O X O O O O X O X O O O X X O X O O X ?
12.	X O O X O X X O X O O X X O X X X O X X X X O X O X X X O X X O ?
13.	O O O X O O X O X O X O O O X O O X O O O O X O X X O X X O O X ?
14.	X O X O O X X X O X X O X O O X X X X O X X X O X X O X X O X O ?
15.	O O X O O X O O O X O X X O O O O X O O O X O X O X X O O X O X ?
16.	X X X X O X X O X X O O X O X X O X X X O X O O X O X O X X X O ?
17.	O O X O O O O X X O O X O X O X O X X O O O X O X O O X O O O X ?
18.	X X O O X X X X O X O X X O X X X O O X X X O X X O X O X O X O ?
19.	O O O O X X O O X O X O X O X O O O X O X O O X O O X O O O X X ?
20.	X O X X O X O X X X O X X X O X O X O X X O X X X X O O X X O O ?
21.	O X O O O X O X O O X O X O O O X O O X X O O O O X X O O X O X ?
22.	X X O X O X X X O X O X X O O X O X X X O X X O X O O X X X X O ?
23.	O O O O X O X O O O X O X O O X O O O X O X X O O X O O X X O X ?
24.	X O X X O X X O O X X X X O X O O X O X X X O X X O X O X X X O ?
25.	O O X O X X O O O X O O O O X O X O O X O X X O X O O X O O O X ?
26.	X O X X O X O O X O X X X O X X O X O X X X X O X X X O O X X O ?
27.	O X O O X O X O O X X O O O X O O O O X O X O O X O O O X O X X ?
28.	X X O O X O X O X X X O X X O X O X X X X O O X X O X O X X X O ?
29.	O X O X O X O O O X O X O O X X O X X X X O O X X O X O X X X O ?
30.	X X X O X X O X X X X O O X X O O X O X O X X O X X X O X O X O ?
31.	O O X X O O X O X O O O X O X O X O O X X O O O O X O O O X O X ?
32.	X O X X X O X O X X O O X X O X X X O X X X X O O X X O X O X O ?
33.	O O O O X O O O X X O O X O O X O X O X O O X X O X O O O X O X ?
34.	X X O O X X X O X X X X O X O X X O X O X X X O X O O X X O X O ?
35.	O O X O X O O O O X O O O X O X O O O X O X O X O O X X O O X X ?
36.	X X X O X O X O X X X O X O X X O O X X O O X X O X O X X X X O ?
37.	O X X O O X O O X X O O X O O O O X O X O O O X O X O X O O O X ?
38.	X X X O X X O X X O O X O X O X O X X X O X O X X X X O X X O O ?
39.	O O X O O O X X O O X O O O O X O X O X X O O X O O O X O X O X ?
40.	X X X X O X X O X O X O X X O O X X X O O X X O X O X O X X X O ?

Program XOPRBA displays CORRECT when subject chooses most frequently displayed character, or else shows NOT CORRECT.

Program XOPRBB does the same except for lines:
11, 14, 17, 21, 23, 27, 29, 34, 36, 39
which always show NOT CORRECT.

Appendix 4. Examples of reversible figures.



Appendix 5. Typical session schedule.

William and Mary Experiment Schedule at NASA LaRC HEM Lab

Subject 7 Date: October 26, 1995

☑ 1. mental state induction tape (~20 min)

☑ 2. word categorization - Noun/Verb (105 stim)

☑ 3. XO task XORECB

- ☑ 4. Questionnaire (Sequence prediction)

☑ 5. Affective state induction instructions - Pleasant

- ☑ 6. Questionnaire (Thinking about experiences)

☑ 7. XO task XOPRBA

- ☑ 8. Questionnaire (Sequence prediction)

☐ 9. Ambiguous / alternating figure task

Lunch

☑ 10. repeat mental state induction tape (~20 min)

☑ 11. word categorization - City/Animal (88 stim)

☑ 12. XO task XOPRBB

- ☑ 13. Questionnaire (Sequence prediction)

☑ 14. Affective state induction instructions - Unpleasant

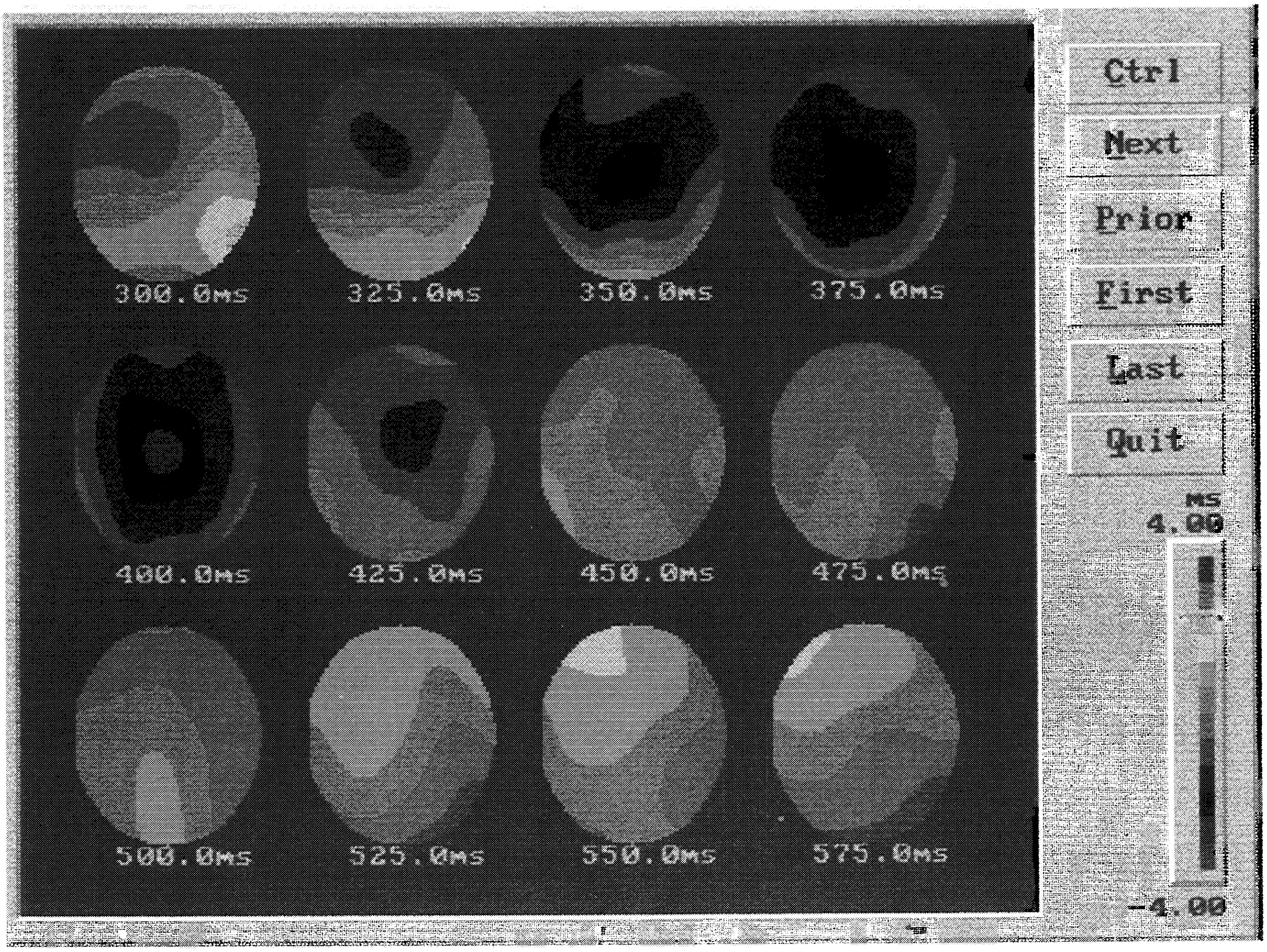
- ☑ 15. Questionnaire (Thinking about experiences)

☑ 16. XO task XORECA

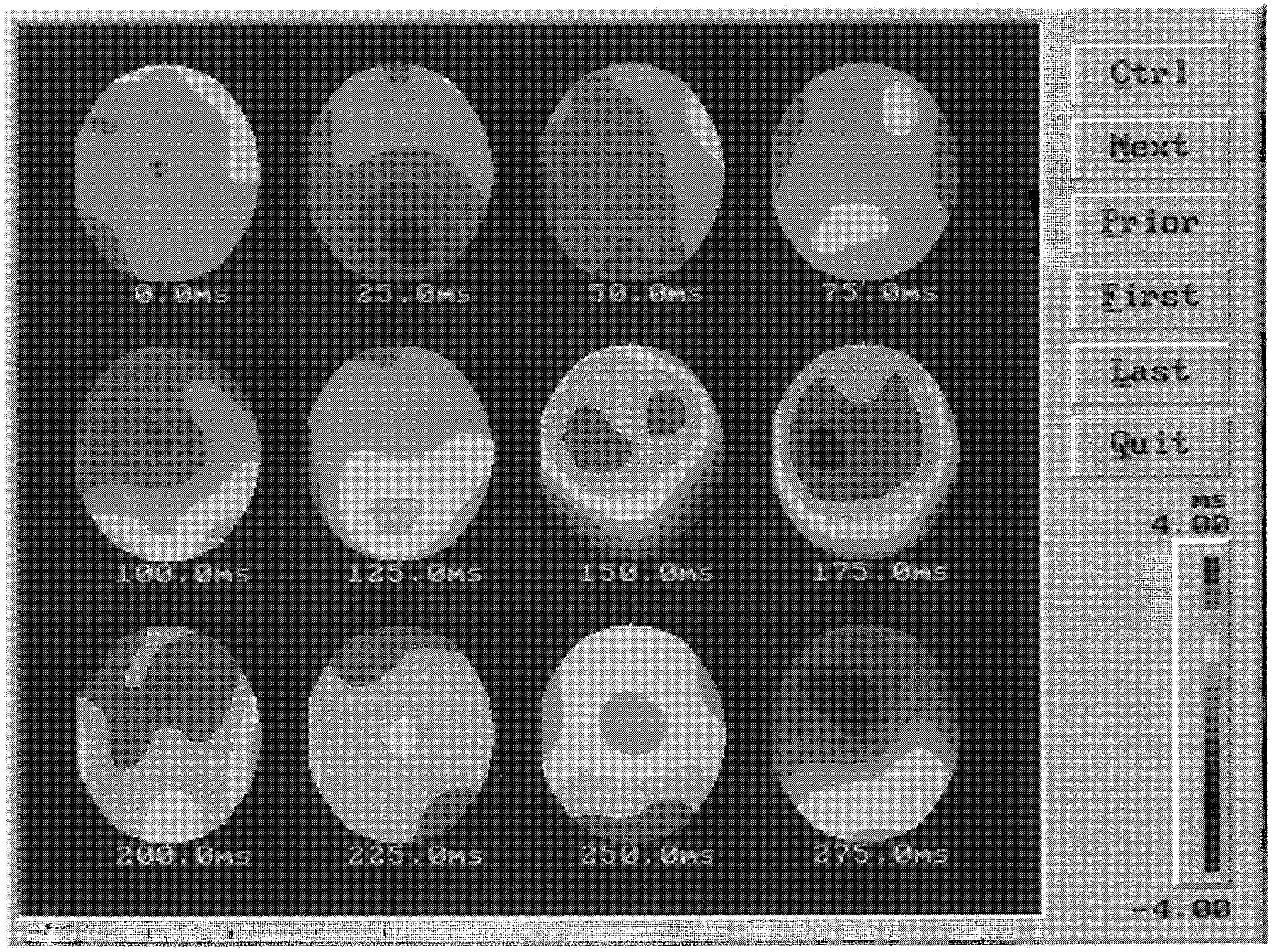
- ☑ 17. Questionnaire (Sequence prediction)

☐ 18. Clock reading task (96 stim)

Disconnect /Debrief



Page 2 Grand average Ambiguous Words NV



Page 1 Grand Average Nouns words NV

Cadwell Filetime wrds NVnoun.av 16:50

14 subjects total