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Alzheimer's Disease and Contrast Sensitivity: Implications for Everyday Functioning

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Implications for Everyday Functioning

by Sandra Neargarder

Alzheimer's disease (AD) is a progressive brain disorder that gradually destroys an individual's mental functions and social capabilities, including memory, reasoning, decision-making, communication, and the ability to carry out everyday activities. According to the Alzheimer's Association, AD affects approximately 4.5 million Americans, and by the year 2050 this number could increase to 11.3–16 million. Increasing age is the greatest risk factor for AD. Approximately 10% of individuals over the age of 65 and 50% of those over the age of 85 are affected. It is estimated that after the onset of symptoms, individuals with AD live an average of 8 years, but the duration of the disease can range anywhere from 3 to 20 years. With rising healthcare costs (the average lifetime cost of care for an individual with AD is $174,000), it is imperative that individuals with AD be able to function independently for as long as possible.

Patients, caregivers, and most health-care professionals primarily identify AD as a memory disorder. Although a memory deficit is usually the first sign of AD, impairments are evident in other domains, including visual function. These impairments are commonly overlooked because visual function is typically measured in terms of visual acuity (the standard letter chart used in an optometrist's office), which is normal in individuals with AD. Based on previous research we know that impairments exist in a variety of visual domains, including blue/yellow color vision, depth perception, motion perception, and contrast sensitivity. In fact, approximately 60% of individuals with AD show a decline in one or more of these visual abilities, which is not the result of normal aging processes.

Contrast sensitivity has been the most extensively examined visual function, and may, in fact, have the greatest influence on the ability of individuals with AD to carry out activities of daily living. Contrast sensitivity is defined as the smallest difference in intensity that a person can resolve between an object and its immediate surroundings. It is typically measured in a laboratory setting using standardized vision charts such as the Vistech or the FACT (Functional Acuity Contrast Test). These tests measure an individual's ability to detect differences in contrast (both high and low) across a range of spatial frequencies (both high and low). Thus, one's contrast sensitivity measure is based on both contrast and spatial frequency. We will consider these two terms separately, starting with contrast.

A high contrast example would be detecting a white electrical outlet against a dark-brown wall; a low contrast example would be detecting a white electrical outlet against a white wall. Healthy elderly adults would be able to detect the electrical outlet in both cases; individuals with AD would not. They would be able to detect the outlet in the high contrast example, but because of deficits in contrast, would be unable to detect the outlet in the low contrast example.

Now consider high versus low spatial frequencies. High spatial frequencies convey visual information about details such as angles and lines. Low spatial frequencies convey visual information about gross form and smooth, flat planar surfaces. Any given object in the environment contains both high and low spatial frequencies. For example, consider a picture of a human face. Extraction of high spatial frequencies would result in a cartoon-like looking face with lines detailing the eyes, mouth, and so on. Extraction of low spatial frequencies would result in a shadow-like looking face where details cannot be seen, but the overall contour and shadows of the face are observed. When high and low spatial frequencies are combined, a face with details, shadows, and contours is observed. Research suggests that healthy elderly adults exhibit impairments at high spatial frequencies, whereas individuals with AD exhibit impairments at both high and low spatial frequencies.

Assessments such as the Vistech and the FACT enable researchers to measure individual contrast thresholds at different spatial frequencies. In other words, when presented with individual spatial frequencies, ranging from high to low, researchers measure at what contrast these frequencies need to be in order for individuals with AD to detect them. These individual frequencies are typically created using sinusoidal gratings in a laboratory setting. This information can then be used to examine how specific deficits relate to real-world functioning. A perfect example of this is the AD filter, developed by our colleagues Drs. Grover C. Gilmore and Cecil Thomas at

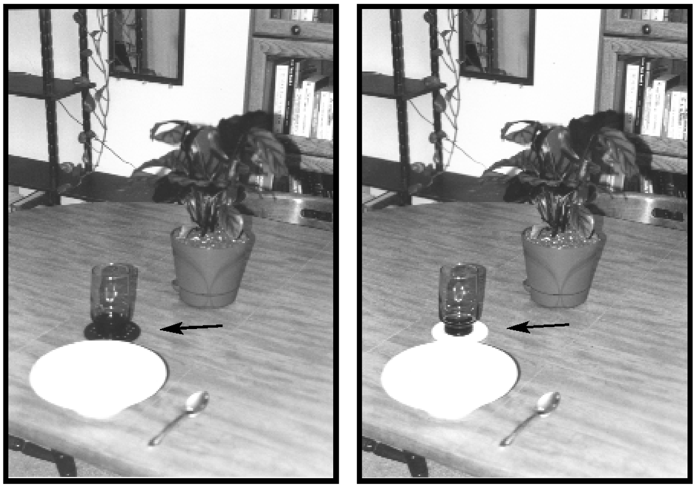
Case Western Reserve University. When provided with an image, this filter which is a computer algorithm, uses results from the Vistech to filter out spatial frequencies at specific contrasts known to be deficient in AD. The end result is a simulated image as it would appear to an individual with AD. An example of this is provided below. The image on the left is the original; the one on the right is the simulated AD image. This is an excellent example of how deficits in contrast sensitivity measured in a laboratory setting relate to the real world.

Although research has demonstrated that contrast sensitivity deficits exist in AD, one question concerns the location of the neuropathology responsible for these deficits. Researchers have shown that these deficits result from damage to the brain, rather than from damage to the retina in the eye or the optic nerve. Specifically, the neuropathological hallmarks of AD, which include the presence of senile amyloid plaques and neurofibrillary tangles, have been identified in higher order visual areas of the brain including areas within the occipital lobes (extra-striate visual cortex), parietal lobes (posterior regions), and temporal lobes (inferior regions). This neuropathological evidence combined with behavioral evidence suggests that individuals with AD most likely experience problems with everyday tasks because of visual impairments such as those noted in contrast sensitivity that are independent of any memory deficits.

Contrast sensitivity actually relates to a number of real-world abilities including reading, driving, watching television, locating objects, and even eating. The primary goal of my research is to design experiments that examine how deficits in contrast sensitivity relate to real-world functioning. The two studies I will be describing involve the ability of individuals with AD to detect changes in real scenes in the environment (the change detection study—in press in *Cognitive and Behavioral Neurology*) and how manipulation of contrast sensitivity affects the eating and drinking patterns of individuals with AD (the nutrition study—published in the international journal Clinical Nutrition). The former was conducted in collaboration with my colleague Dr. Alice Cronin-Golomb, and the latter with colleagues Drs. Tracy Dunne, P.B. Cipolloni and Alice Cronin-Golomb.

THE CHANGE DETECTION STUDY

In the change detection study, individuals with mild to moderate AD, healthy elderly adults, and young adults were presented with several pairs of 5" x 7" colored photographs taken of three rooms in a home (kitchen, dining room, and bathroom). Their task was to identify the one object or target that changed from one photograph to the next. The target could change in three different ways: color, presence/absence, or contrast. For the color target, an object changed in color (red to green or blue to yellow) from one photograph to the next. For the presence/absence target, an object appearing in one photograph disappeared from the second photograph. For the contrast target, an object changed in contrast from one photograph to the next. Both a high contrast target (black to white) and a low contrast target (black to gray) were included. An example of a high contrast target (the coaster) is shown below.



In addition to target type, we manipulated scene complexity using both simple and complex scenes. For the simple scene condition, photographs were taken at close range depicting approximately five objects per scene, including the target. For the complex scene condition, photographs were taken of the entire room, which contained many more than five items. The example shown above is a simple scene.

Participants were shown 36 pairs of photographs and were asked to identify the target as quickly as possible. They were aware of the type of target they were searching for. We measured both reaction times and accuracy rates. Results revealed that individuals with AD were much slower overall than healthy elderly adults, who were themselves slower than young adults, at identifying each of the three target types. Moreover, all three groups were slower at identifying targets in the complex scenes compared to the simple scenes. Of particular interest were the findings related to the contrast target. In the high contrast, complex scene condition, individuals with AD were unable to find the target 33% of the time compared to 5% for the healthy elderly adults and 0% for the young adults. More extreme group differences emerged in the low contrast, complex scene condition. Here, individuals with AD were unable to find the target in 62% of the trials compared to 38% for the healthy elderly adults and 7% for the young adults. This inability to find the target was minimal for the other target conditions of color and presence/absence.

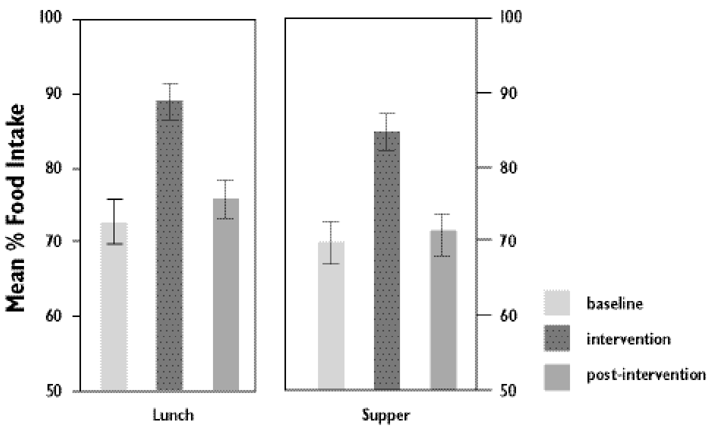
These results suggest that as a scene becomes more complex, individuals with AD have more difficulty finding the target, especially when that target relates to contrast. The smaller the contrast difference (e.g., a target that changes from black to gray) the less likely the individual with AD will be able to find it. These findings parallel what we know about contrast sensitivity deficits in AD and how basic visual impairments can impact one's ability to function in a real-world environment. For example, imagine an individual with AD pouring black coffee into a black mug. Because of the minimal contrast difference between these two items, it is highly likely that the individual with AD would not be able to perform this simple everyday task. However, if we replaced the black mug with a white one, thereby enhancing the contrast between the two items, the individual would have a greater probability of success. This idea of enhancing contrast in the everyday environment of an individual with AD is further demonstrated in the following study on nutrition and AD.

THE NUTRITION STUDY

Research suggests that significant weight loss affects approximately 40% of individuals with AD. This weight loss may arise from depression, the inability to eat independently, or the inability to attend to more than one food at a time. One additional explanation is that these individuals have deficits in contrast sensitivity. Without sufficient contrast they are unable to distinguish a plate from a table setting, food from a plate, or liquid from its container, thereby leading to an overall reduction in consumption. Realizing that a number of AD day programs, nursing homes, and other AD care facilities commonly use white table settings (tablecloths, plates, cups) and often serve food and liquid that are of the same color (chicken, rice, mashed potatoes, milk, etc.), we wondered if we could alter food and liquid intake by manipulating the contrast between the food and liquid and the table settings used.

The AD participants in this study resided in long-term care units of the Geriatric Research, Education and Clinical Center at the ENRM Veterans Affairs Medical Center in Bedford, Massachusetts. All exhibited severe levels of dementia. We collected data over three consecutive 10-day periods in order to coincide with menu changes. We measured food intake (in grams) and liquid intake (in ounces) across the three 10-day periods for both lunch and supper. For the first 10 days (the baseline condition), white plates and white cups were used. For the next 10 days (the intervention condition), bright (high contrast) red plates and red cups were used. For the last 10 days (the post-intervention condition) white plates and white cups were used again. There were no variations in staff, room setting, lighting, daily routine, or health status of the individuals with AD over the 30-day testing period.

Results revealed a significant increase in food and liquid intake for both lunch and supper when the plates and cups were changed from white (baseline) to red (intervention). See the figure below for the group results for

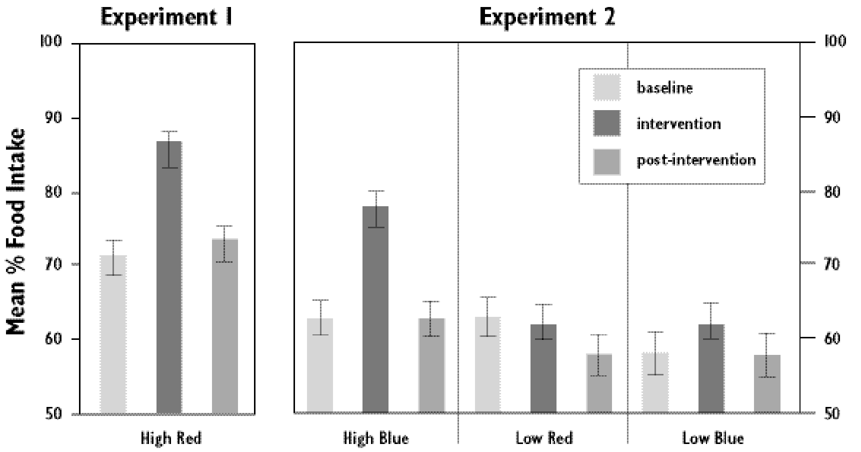


food intake. Overall, there was a 24.6% mean increase in food intake and an 87% mean increase in liquid intake. Intake values dropped back down again in the post-intervention condition when the white plates and white cups were re-introduced. In terms of individual findings, 89% of the individuals with AD exhibited at least a 10% increase in food and liquid intake at intervention relative to baseline and post-intervention for both lunch and supper. The poorer ingestors appeared to benefit the most. These findings suggest that deficits in contrast sensitivity significantly impact food and liquid intake in individuals with AD.

Following the completion of this study, we designed a second study. Questions arose concerning whether the color of the plates was an important factor or even whether our results were simply due to a novelty effect. That is, individuals may have eaten more because the red plates were new and interesting to them. One additional question concerned whether the saliency of the color of the plate mattered. For instance, would we obtain the same results if we used a pastel (or low contrast) red plate instead of a bright (high contrast) red plate?

In the second study (which consisted of some participants from the first study plus a few new ones) data were collected over seven consecutive 10-day periods, which I will refer to as the seven phases of the study. Once again food and liquid intake were measured for both lunch and supper. The colors of the plates and cups used for each of the seven phases were as follows: Phase 1: white plates and cups; Phase 2: bright (high contrast) blue plates and cups; Phase 3: white plates and cups; Phase 4: pastel (low contrast) red plates and cups; Phase 5: white plates and cups; Phase 6: pastel (low contrast) blue plates and cups; Phase 7: white plates and cups.

Group results revealed that when bright (high contrast) blue plates and cups were used, there was a significant 25.1% mean increase in food intake and a 29.8% mean increase in liquid intake. Increases were noted for both lunch and supper. Once again, intake values dropped back down again when the white plates and white cups were re-introduced. The use of the pastel (low contrast) red plates and cups and the pastel (low contrast) blue plates and cups did not reveal any significant increases in either food or liquid intake across conditions. Group results of food intake collapsed across lunch and supper, along with the collapsed group results from the first experiment for comparison, are given below.



These results suggest that high contrast tableware (in this case bright red and bright blue plates and cups) significantly increases food and liquid intake in severely demented individuals with AD. Low contrast tableware (pastel red and pastel blue plates and cups) is ineffectual. These data disprove the novelty effect and support the idea that the saliency of the color of the tableware is a crucial factor, thereby demonstrating that the enhancement of contrast is a simple yet effective intervention for increasing food and liquid intake in individuals with AD.

PRACTICAL APPLICATIONS

When we present our research findings at various conferences or even AD care facilities, the audience is often interested in knowing the more practical application of our findings. Specifically, they are interested in learning ways in which they can change contrast in the environment in order to maintain or improve functional abilities in individuals with AD. The following suggestions are adapted from a book chapter written by Dr. Tracy Dunne appearing in *Vision in Alzheimer's Disease* edited by Cronin-Golomb and Hof. Ideas for enhancing contrast in the bathroom and kitchen are briefly discussed.

One of the major challenges in caring for individuals with AD is getting them to bathe. Because of deficiencies in depth and contrast perception, individuals with AD may have difficulty transitioning into the bathtub. Placing a non-skid bath mat inside the tub that is a contrasting color to the tub should help alleviate this difficulty. Moreover, using different colored knobs for hot and cold faucets (for e.g., red for hot and blue for cold) and using grab rails that contrast to the walls should also provide some assistance. Contrast can also be used to aid with toileting behaviors, which pose a major concern for caregivers. As the disease progresses, it is not uncommon for individuals with AD to mistakenly use plants, hampers, and wastebaskets as toilets. By providing contrast around the toilet area, either by using colored toilet water and/or by placing a contrasting toilet mat around the base of the toilet, it will help to provide a cue as to where the individual should sit or stand. Moreover, placing a light inside the toilet bowl or right above the toilet using commercially made products that use a light-emitting diode may also be beneficial. Finally, installing safety rails of a contrasting color is another way to draw attention to the toilet itself.

To encourage independent functioning in the kitchen, use light switches and electrical outlets that contrast with the walls, and provide high-contrast knobs and handles on cabinets. If, however, use of switches, outlets, and cabinets poses a safety hazard, use plate covers and handles that are the same color as the walls and cabinets to discourage use. Keep in mind that caregivers can easily enhance or minimize contrast depending on whether they want to encourage or discourage particular behaviors. Other ideas for the kitchen include the use of large, multicolored buttons on appliances and the use of open shelving or glass cabinet doors to aid in finding items used on a daily basis such as bread or cereal.

In conclusion, by visually manipulating the environment we can begin to compensate for brain-based visual deficits, such as those noted in contrast sensitivity, and thereby ultimately improve the quality of life for both individuals with AD and their caregivers.

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